Introduction
Fire and Explosion in Chemical Industries

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Juwari, S.T., M.Eng PhD

Several fire and or explosion incidents in Malaysia

https://www.hazardexonthenet.net/article/189577/Explosion-at-petrochemical-plant-injures-three-in-Malaysia.aspx

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Explosion at petrochemical plant injures three in Malaysia

28 FEBRUARY 2022

An explosion and fire at a petrochemical plant injured three workers on February 24. The incident happened at a rubber plant in the Tanjung Langsat industrial complex in Malaysia's Johor state and left three people with serious injuries.

Representative image: Shutterstock

According to reports, the incident occurred at Lotte Ube Synthetic Rubbers' (LUSR) butadiene rubber plant. LUSR is a joint venture between South Korea's Lotte Chemical, its Malaysian subsidiary Lotte Chemical Titan, and Japan's Ube Industries. Local news sites said an explosion occurred at around 15:15 local time, causing damage to storage tanks and a pipeline.

The Johor Fire and Rescue Department managed to extinguish a fire caused by the explosion while emergency services took three workers to hospital where they were treated for burn injuries and a broken leg after one of them jumped from a building to escape the flames. The cause of the blast remains unknown, and the plant has been shut while an investigation is carried out at the site.

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Dust Explosion Incidents in Malaysia for Powder Manufacturing Industries

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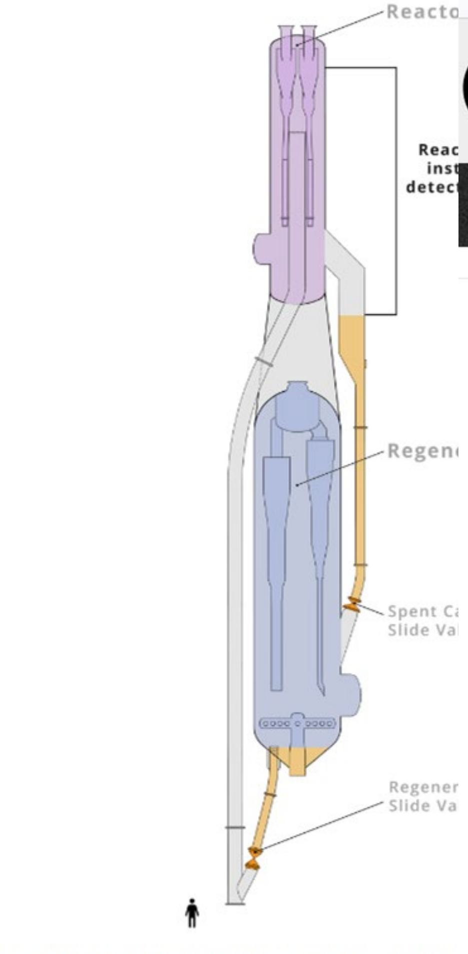
Year	Case	Process Safety management (PSM) Elements		
		Process hazard Analysis	Training of Manpower	Emergency Preparedness & Response
2008	Perak	✔	✔	✔
2010	Pulau Pinang	✔	✔	✔
2013	Pulau Pinang	✔	✔	✔
2014	Pahang	✔	✔	

Table 1: PSM analysis for Malaysia Dust Explosion Incident

Lesson learn
CSB.GOV



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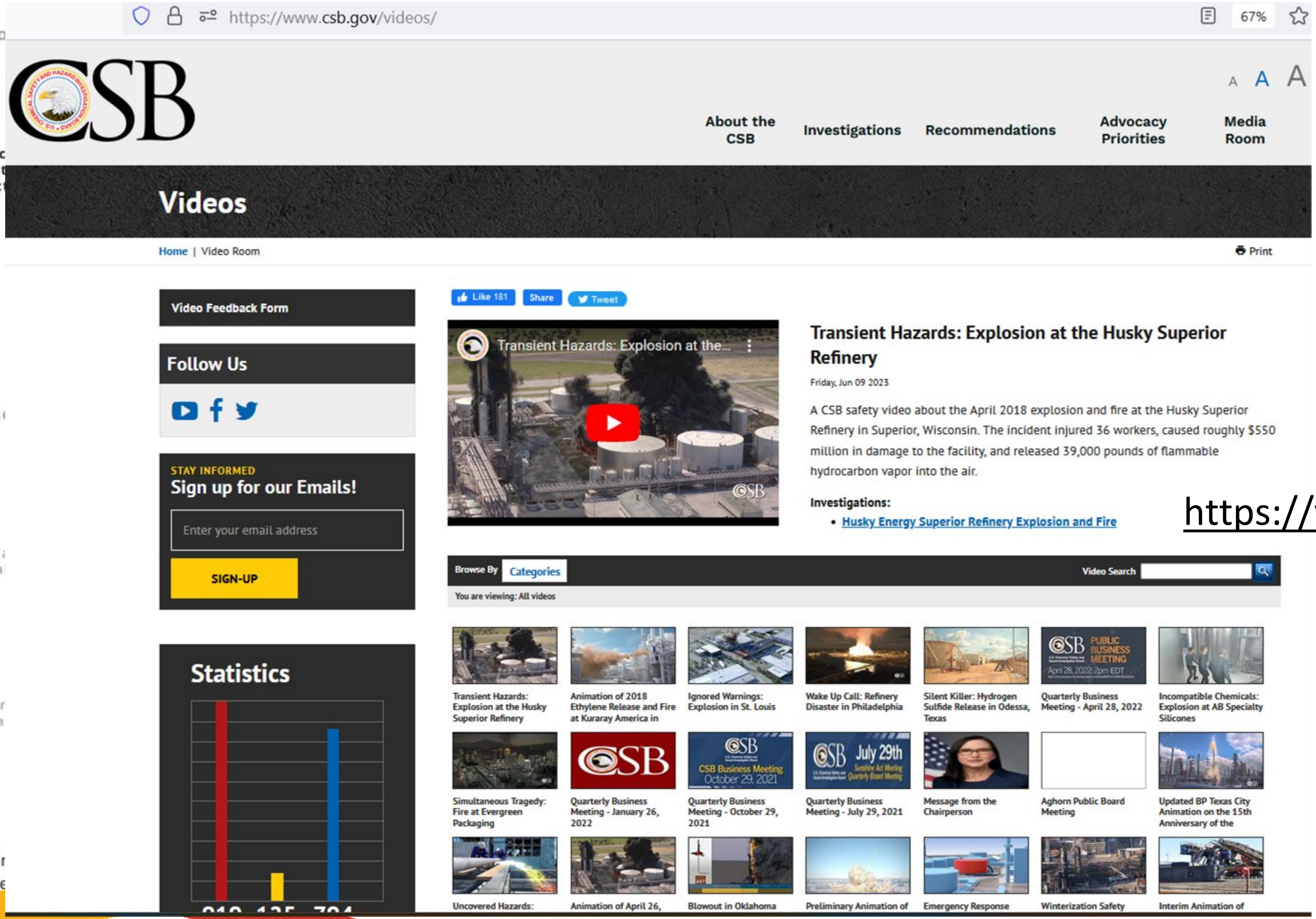
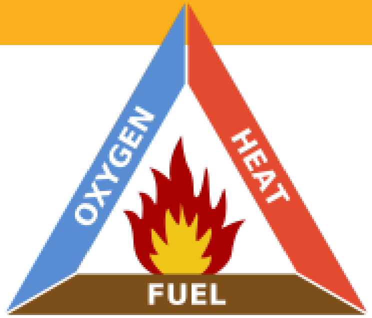
generator during a shutdown (person for scale). (Cre



https://youtu.be/sFhkzK7jkKg

Fire Triangle



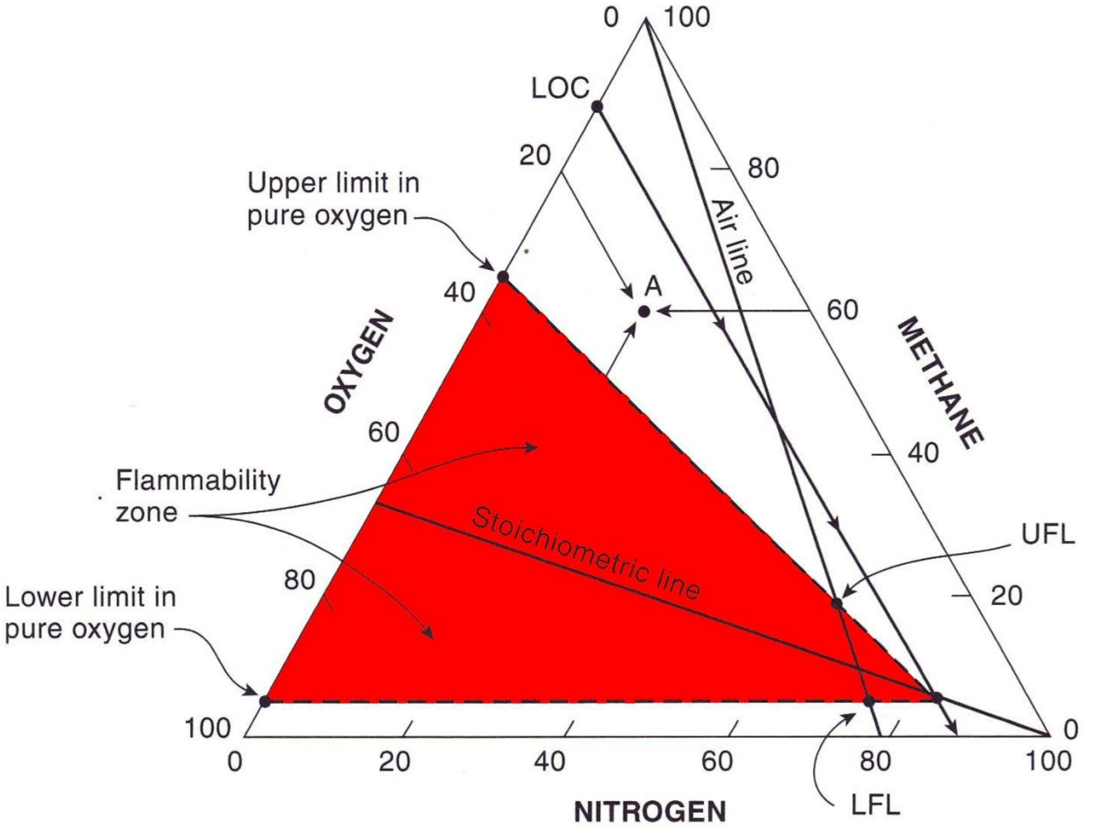
When fuel, oxidizer, and an ignition source are present at the necessary levels, burning will occur

A fire will not occur if

Fuel is not present or is not present in sufficient quantities	An oxidizer is not present or is not present in sufficient quantities	the ignition source is not energetic enough to initiate the fire

Flammability Diagram

Flammability diagrams show the regimes of flammability in mixtures of fuel, oxygen and an inert gas, typically nitrogen.



- Useful for
  - Determining if a mixture is flammable
  - Required for control and prevention of flammable mixtures
  - Red zone – flammable zone

- The air line represent all possible combination of fuel plus air.
- The stoichiometric line represent all stoichiometric combination of fuel plus oxygen
- The LOC any gas mixture containing oxygen below the LOC is not flammable.

Stoichiometric is the calculation of quantities relationship of the reactants and products in a balanced chemical reaction. It can be used to calculate quantities such as the amount of products that can be produced with given reactants and percent yield.

Flammability limits for mixtures

- The flash point temperature is one of the major quantities used to characterize the fire and explosion hazard of liquids. (The flash point of liquid is the lowest temperature at which it gives off enough vapor to form an ignitable mixture with air).
- Vapor mixtures

  frequently Lower Flammability Limit (LFL) and Upper Flammability Limit (UFL) for mixture are needed. These mixture limits are computed using the following formulae;

Flammability limits

$$LFL_{mix} = \frac{1}{\sum_{i=1}^{n} \frac{y_i}{LFL_i}} \qquad UFL_{mix} = \frac{1}{\sum_{i=1}^{n} \frac{y_i}{UFL_i}}$$

Ignition sources

Known ignition sources for vapour mixes

- Electric sparks and arcs (from electrical circuits, motors, switches etc.);
- Mechanical sparks (from friction and falling objects);
- Static electrical sparks;
- Lightning;
- Flame (including flaring, boilers, smoking);
- Hot surfaces (including hot work, hot processing equipment, electrical equipment);
- Heat of compression;
- Chemical reactions (eg auto-ignition of oil-soaked lagging on hot piping); and
- High energy radiation, microwaves, etc.

- Strategies
  - Inerting
    - To reduce the oxygen or fuel concentration to below a target value using an inert gas
    - Nitrogen is the most common
  - Use flammability diagram

Fire fighting system filled with inert gas

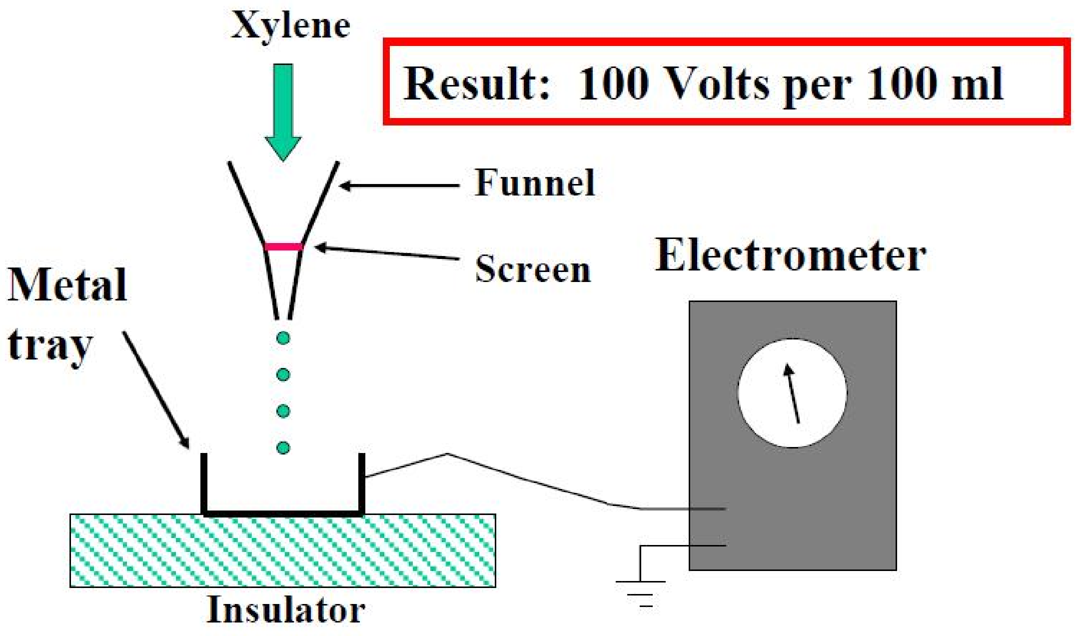
Prevention

- Strategies
  - Controlling static electricity
    - How did it happen?

- By separation of two materials
- As materials are separated, electrons must redistribute themselves
- If materials are both conductors, electrons move rapidly
- If one or more materials are non-conductors, the electrons cannot move very fast and final result is a difference in charge
- Examples: **Rubbing, Falling, Moving, Flowing**

Prevention

- Strategies
  - Controlling static electricity
    - Grounding and Bonding
    - Be careful of
      - Glass containers /vessels/pipes
      - Plastic containers /vessels/pipes/pumps
      - Low conductive liquids: benzene, toluene, xylene, heptane, hexane
    - Avoid free fall of liquids into vessels



Prevention

- Strategies
  - Ventilation
    - For inside storage areas, use 1 $ft^3/min/ft^2$ of floor area
    - For inside process areas, use 1 $ft^3/min/ft^2$ or more of floor area
  - Sprinkler system
    - 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 gpm/ft^2 protected
  - Fire extinguisher
  - Foam

Prevention

ventilation

sprinkle

Fire extinguisher

foam

Implementation of PSM (Process Safety Management) to make our plant safer

- The ***proactive*** and ***systematic*** **identification**, **evaluation**, and mitigation or **prevention** of chemical releases that could occur as a result of failures in process, procedures, or equipment.

PSM Process Safety Management should be implemented well

- Process safety information
- Standard operating procedure
- Process hazard analysis
- Mechanical integrity

Process Safety Information

Employer must complete a compilation of written process safety

Identify & understand the hazards

PSI must include;

Info on hazards of chemicals used or produced

Technology of the process

Equipments used in the process

Info on hazards of chemicals;

- Toxicity
- Permissible exposure limit
- Physical data
- Reactivity data
- Corrosivity data
- Thermal & chemical stability data
- Effect of mixing with other chemicals

Process Safety Information

Info on technology of the process;

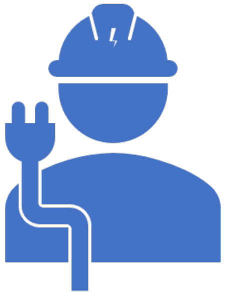
Block flow diagram or simplified PFD

Process chemistry

Maximum intended inventory

Safe upper & lower limits of T, P, x

Evaluation of consequences of deviation



Info on the equipments;

Material of construction

P&IDs

Electrical classification

Relief system design & design basis

Ventilation system design

Design codes & standard employed

Safety system (interlocks, detection or suppression system)

Sources and Process safety information

Two common examples of the three components of the fire triangle are

- wood, air, and a match
- gasoline, air, and a spark

Various fuels, oxidizers, and ignition sources common in the chemical industry are

- Fuels
  - Liquids: gasoline, acetone, ether, pentane
  - Solids: plastics, wood dust fibers, metal particles
  - Gases: acetylene, propane, carbon monoxide, hydrogen
- Oxidizers
  - Gases: oxygen, fluorine, chlorine
  - Liquids: hydrogen peroxide, nitric acid, perchloric acid
  - Solids: metal peroxides, ammonium nitrite
- Ignition sources
  - Sparks, flames, static electricity, heat

Standard operating procedure

Employer must develop & implement written procedures ≈ PSI

Appropriate, clear, consistent & well-communicated

SOP cover:-

- Initial startup and startup after (normal or emergency) shutdown – hourly.
- Normal and emergency operation
- Normal and emergency shutdown
- Operating limits and consequences of deviations
- SHE consideration – safe work practices, safety control systems and functions, hazards
- Quality control specification for all chemicals (raw material & product)
- Safety systems (interlocks, detection or suppression systems)
- Troubleshooting procedure.

Standard operating procedure

Must be ready & up-to-date for reference

Safe work practice for control of hazards during activities;

Lockout/tagout

Confined space entry

Opening process equipment or piping

Control over entrance into a facility

Process Hazard Analysis

Examples of PHA methods;

- Hazard & operability study (HAZOP) – for more complex processes
- What-if scenarios
- Checklist
- What-if/Checklist
- Failure mode & effect analysis (FMEA)
- Fault tree analysis

PHA must address the following;

- Hazard of the process
- Identification of previous incidents
- Engineering & administrative control & consequences of its failure
- Facility siting
- Human factors
- Qualitative evaluation of possible safety & health effects on employees

Mechanical Integrity

To ensure that the equipment, piping, relief systems, controls and alarms are mechanically sounds and operational.

Applicable equipments;

- Pressure vessels & storage tanks
- Piping system (including valves)
- Relief & vent. systems & devices
- Emergency shutdown systems
- Controls (alarms, locks etc)
- Pumps

Inspection & testing must be performed

Record must be kept;

- Date
- Name of person responsible
- Identifier of equipment (eg – serial no)
- Description of test
- Results of test

Frequency – recommendation or more based on prior experience

Make Sure all elements in PSM implemented

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- TERIMA KASIH -

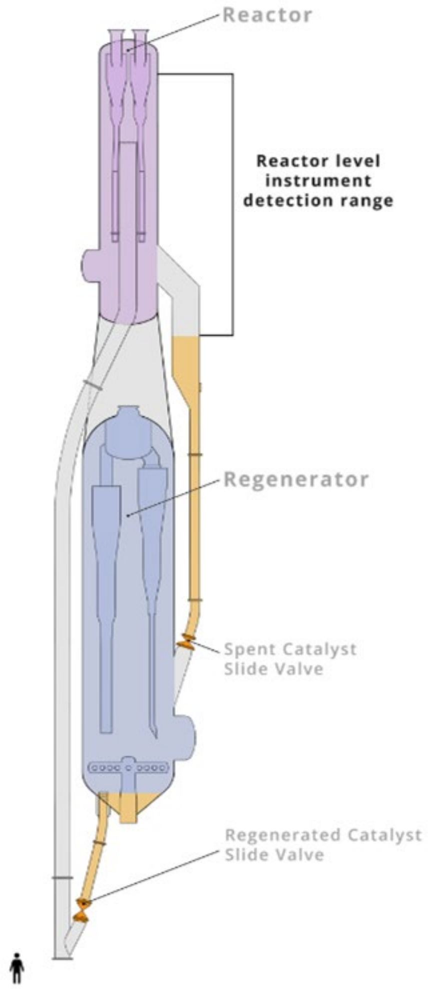

Figure 37. Potential undetectable catalyst levels within the reactor and regenerator during a shutdown (person for scale). (Credit: CSB)