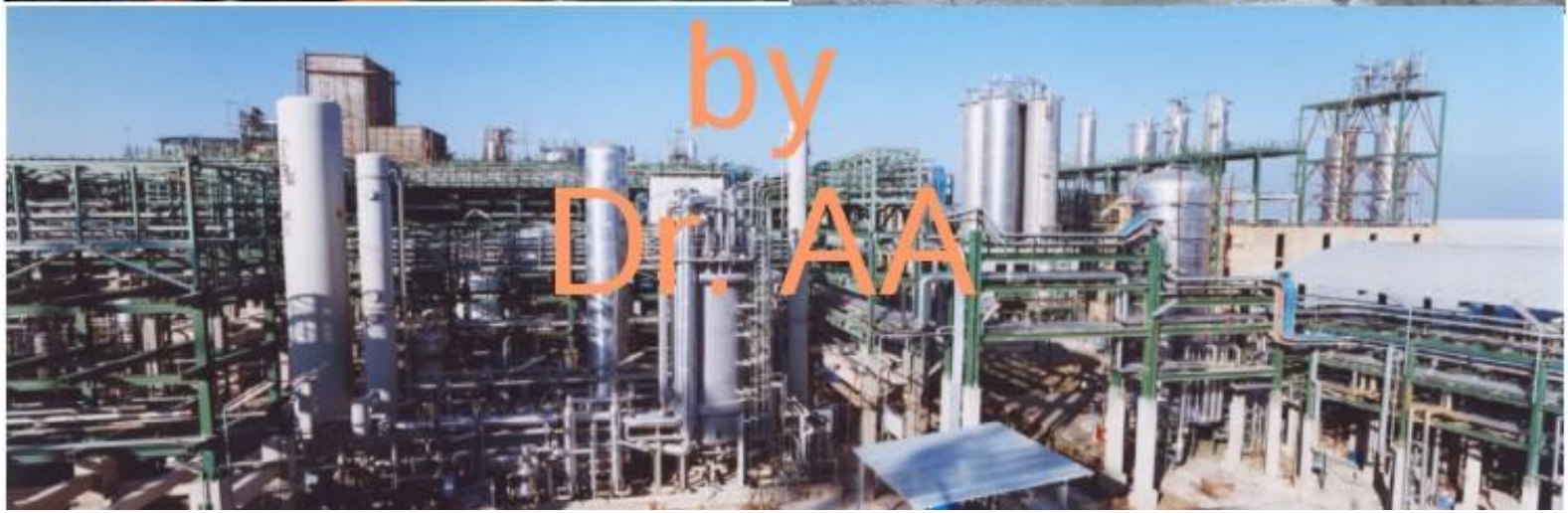




Process Safety

by

Dr. AA

Introduction to Process Safety

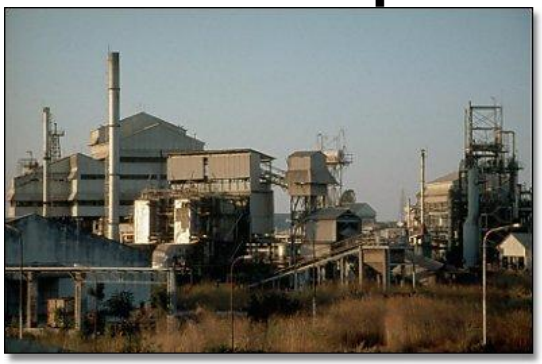
Introduction to Process Safety

Topic 1.

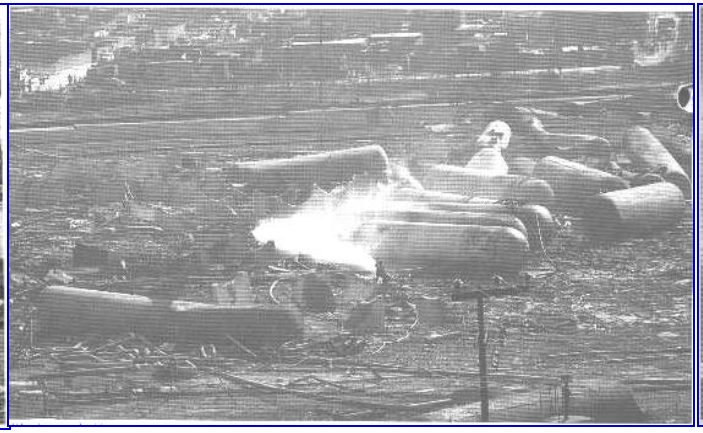
In Memories…

In Memories: Bhopal, 1984

- **Release of Toxic Gas**
  - **40 tons Methyl Isocynate escape from Union Carbide Plant**
  - **Immediate cause : 500L seepage**
  - **Erupts and release fumes**
- **Aftermath**
  - **3000 died : respiratory failure**
  - **Thousands more died in weeks that followed**
  - **500,000 suffer**
  - **USD470mil spent**

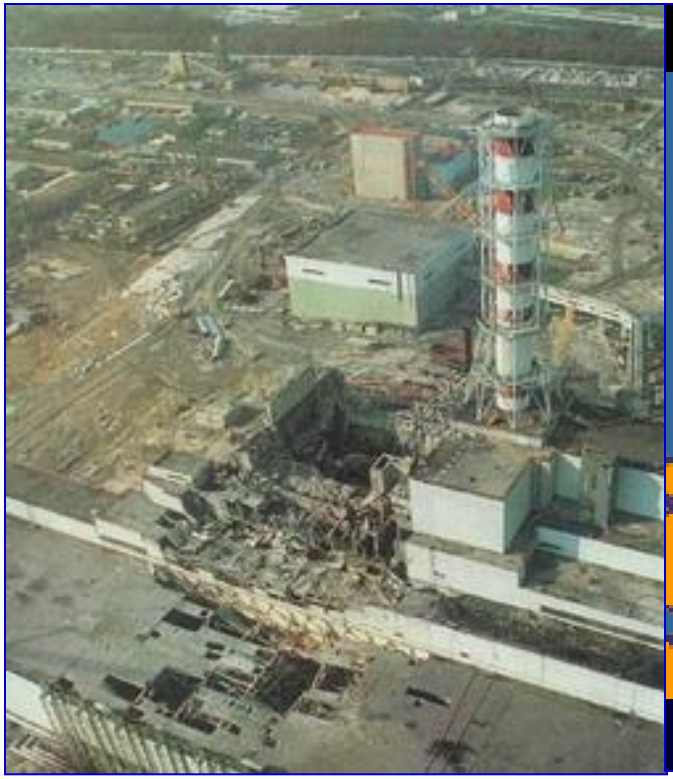


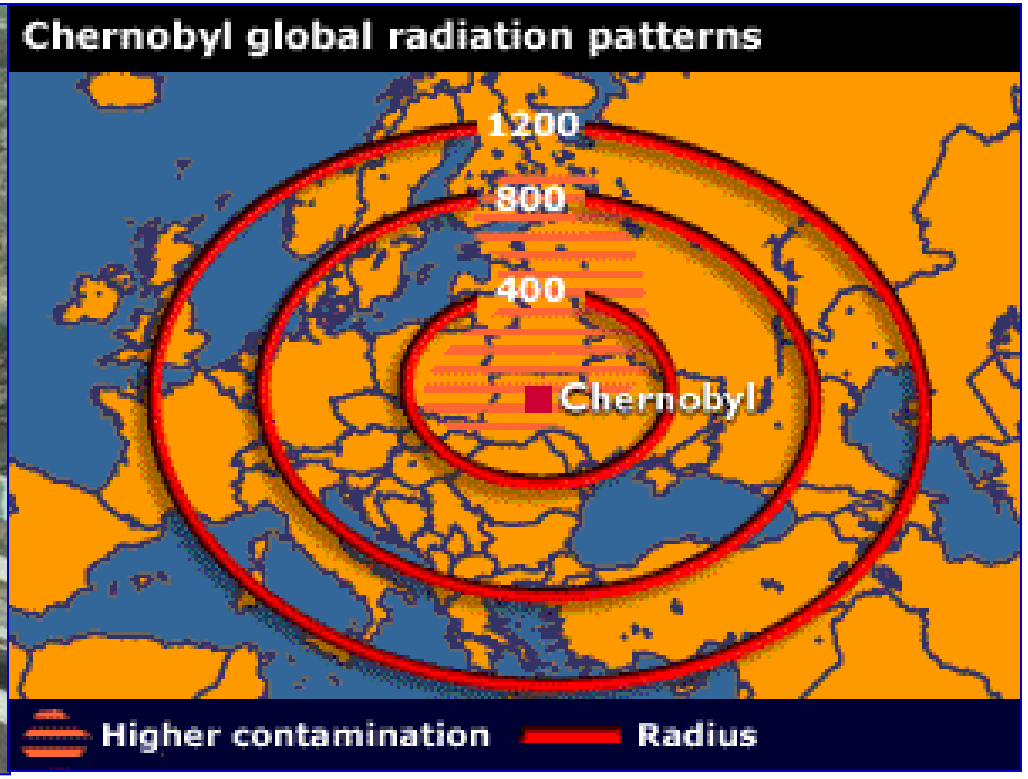
In Memories : PEMEX, 1984



- **Pemex is a liquid petroleum gas (LPG) distribution plant.**
- **Pemex is located a few km. north of Mexico City (Pop = 16MM).**
- **Plant was 25 years old and built to 1950 API standards of the U.S.**
- **15 of 48 Vessels BLEVE In Domino Fashion**
- **550 people killed., 2,000 people receive severe burns, 7,231 people classed as injured.**

In Memories: Chernobyl, 1986





- 26 April 1986 at the Chernobyl Nuclear Reactor, Ukrain
- 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

In Memories: Piper Alpha, 1988

- World's most famous oil rig disaster in North Sea 1988
- 167 out of 229 people died
- initial explosion followed by a fierce fire which, in turn, triggered off a further series of explosions
- "Jump and try or fry and die."
- Flames could be seen 100km away
- Cause of death 109 out of 137 recovered bodies inhalation of smoke & fire. Few died of burns.

PEMBAWA MAUT...Antara mercun yang ditemui di sekitar tempat kejadian.


Sekitar pemandangan kawasan tragedi kilang mercun Bright Sparkler yang meletup dan


Anggota-anggota pasukan penyelamat menggeledah kawasan sekitar kilang membuat mercun dan bunga api untuk mencari mayat-mayat yang terperangkap di hadapan sebuah kereta yang musnah akibat letupan di kilang itu.

In our backyards: Bright Sparklers, 1991

- On 7 May 1991 at about 3.45 p.m. fire ignited from product testing activities.
- Fire spread, causing an explosion, which caused the rockets to fly everywhere, spreading the fire to other places and buildings
- The fire and explosion destroyed the entire factory.
- 23 people lost their lives and 103 others sustained injuries

Some Recent Incidents

T2 Laboratories Inc – Jacksonville, FL
December 19, 2007
4 Killed and 13 Wounded in reactor explosion in manufacture of gasoline additive.

BP America Refinery – Texas City, TX
March 23, 2005
15 Killed and 180 Wounded in isomerization unit explosion and fire.

West Pharmaceutical Services – Kinston, NC
January 29, 2003
6 Killed and Dozens Wounded in dust cloud explosion and fire from release of fine plastic powder.

Source: U.S. Chemical Safety Board, www.chemsafety.gov

Introduction to Process Safety

Topic 2.

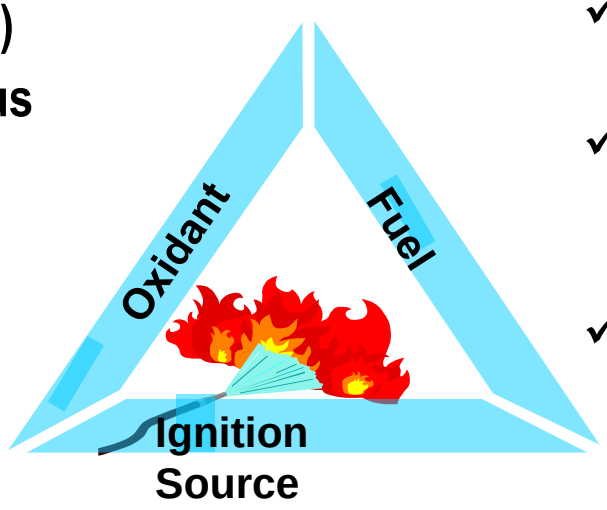
Hazard in Process Industries

Hazards in Process Industries

- **There are Three Major Hazards: Fire, Explosion, Toxic Release**
- **Fire**
  - **Impacts on plant, people and environment**
  - **May also followed by toxic release**
- **Explosion**
  - **Same as fire but more severe**
- **Toxic Release**
  - **Impacts of people and environment. e.g. Bhopal**

The Fire Triangle

2. Oxidizers* (the molecule contain oxygen atoms)
- ✓ Gases - oxygen, nitrous oxide (N2O)
- ✓ Liquids - hydrogen peroxide (H_2O_2), nitric acid (HNO3)
- ✓ Solids - ammonium nitrate (NH4NO3).



1. Fuels
- ✓ Liquids - gasoline, acetone, ether, pentane;
- ✓ Solids - plastics, wood dusts, fibers, metal particles, flour;
- ✓ Gases - acetylene, propane, carbon monoxide, H_2

3. Ignition Sources
- ✓ Sparks, flames, static electricity, heat.

Distance of Effect Comparison

INVENTORY (tons)	UVCE	BLEVE	FIRE
1	120	18	
2	150	36	
5	200	60	
10	250	90	20
20	310	130	30
50	420	200	36
100	530	280	50
200	670	400	60
500	900	600	100
1000	1150	820	130

Distance in Meters

Pool Fire

- Liquid spilled onto the ground spreads out to form a pool.
- Volatile liquid (e.g. petrol) evaporate to atmosphere and soon form flammable mixture with air.
- Upon ignition, a fire will burn over the pool.
- The heat vaporizes more fuel and air is drawn in round to the side to support combustion.
- Danger to people is by direct thermal radiation and burn.

Jet Fire

- High pressure release of gas from a vessel or pipeline ignites almost immediately.
- This give rises to a giant burner of flame length tens of meters.
- Danger from thermal radiation and also impingement on adjacent pressurized vessel, such as LPG vessel, heating the content followed by pressure build up causing 'boiling liquid expanding vapor explosion' (BLEVE).
- Sometimes called Torch Fire

Flash Fire

- ✓ If spilled material relatively volatile (e.g. propane, butane, LPG) it would still form a pool but evaporation would be much more rapid.
- ✓ If ignition did not take place immediately to form pool fire, then sizeable vapor cloud would form, drifted away by wind, to form cloud within flammable range.
- ✓ If found source of ignition, flash fire will occur. People at risk from thermal radiation effects.
- ✓ Usually unexpected event and short duration

Vapor Cloud Explosion

- **Cloud will spread from too rich, through flammable range to too lean.**
- **Edges start to burn through deflagration (steady state combustion).**
- **Cloud will disperse through natural convection.**
- **Flame velocity will increase with containment and turbulence.**
- **If velocity is high enough cloud will detonate.**
- **If cloud is small enough with little confinement it cannot explode.**

Factors Favoring Overpressures of Vapor Cloud

1. **Confinement**
   - Prevents combustion products escaping, giving higher local pressures even with deflagration.
   - Creates turbulence, a precursor for detonation.
2. **Cloud composition**
   - Highly unsaturated molecules are bad due to high flammable range, low ignition energy, high flame speed etc.
3. **Weather**
   - Stable atmospheres lead to large clouds.
   - Low wind speed encourages large clouds.

Factors Favoring Overpressures of Vapor Cloud

4. **Vapor Cloud Size impacts on:**
   - **probability of finding ignition source**
   - **likelihood of generating any overpressure**
   - **magnitude of overpressure**
5. **Source**
   - **flashing liquids seem to give high overpressure**
   - **vapor systems need very large failures to cause UVCE**
   - **slow leaks give time for cloud to disperse naturally without finding an ignition source**
   - **high pressure gives premixing required for large combustion**
   - **equipment failures where leak is not vertically upwards increases likelihood of large cloud**

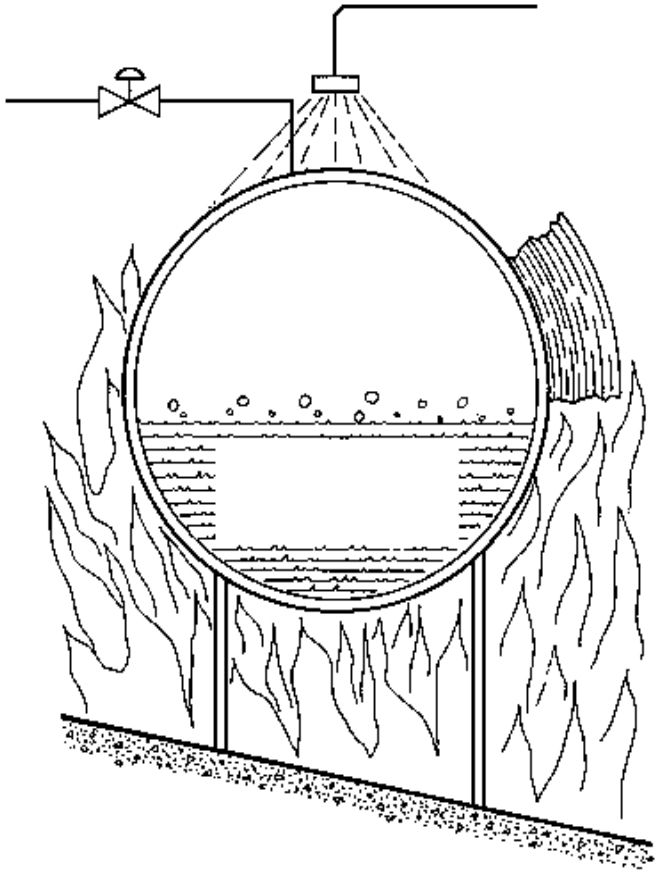
Flixborough, England

- Company: Flixborough Works of Nypro Limited.
- June 1974.
- Product: cyclohexane – highly flammable
- 6 reactors in series, total capacity 120 tons.
- Fire and explosion – over than 10 days
- 28 people died & 36 others were injured.
- 53 civilians were reported injury
- Damage: entire plant, 1821 nearby houses & 167 shops and factories.

Phillips Pasadena, USA

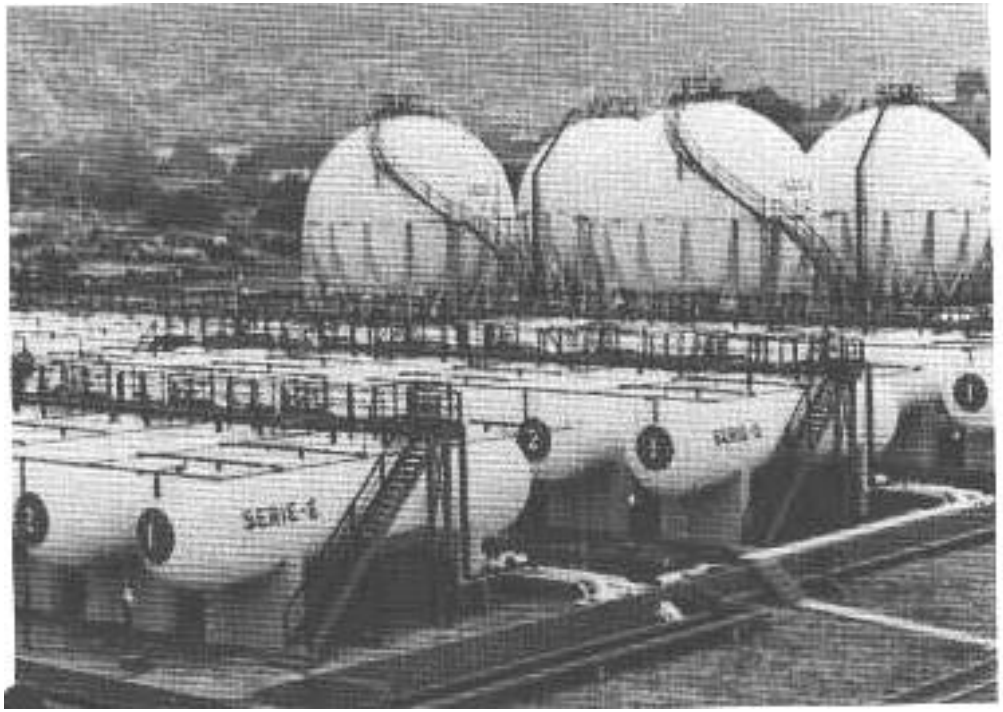
- **23rd Oct. 1989, Vapour Cloud explosion**
- **23 Deaths 130 Injuries, Loss US$ 500 Millions**

BLEVE (Boiling Liquid Expanding Vapour Explosion)



- When BLEVE is initiated, the liquid boils off rapidly producing a reaction which turns parts of the ruptured vessel into rockets which can travel 2500 ft or more.
- The liquid can take fire if it is flammable and burning material can spread over a large area. If the gas or liquid mixes with air a vapour cloud explosion can occur.

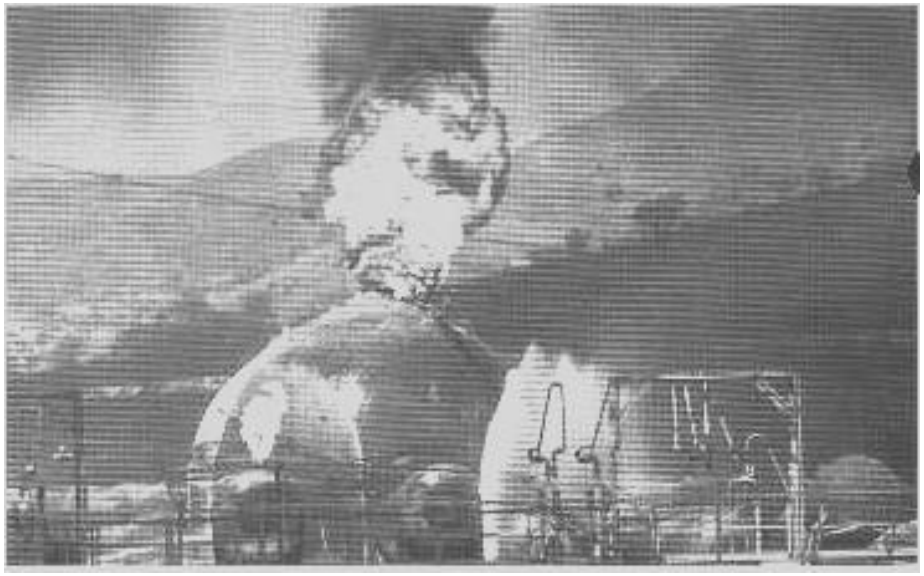
The Tragedy Of San Juanico, PEMEX, Mexico City, 19 Nov 84



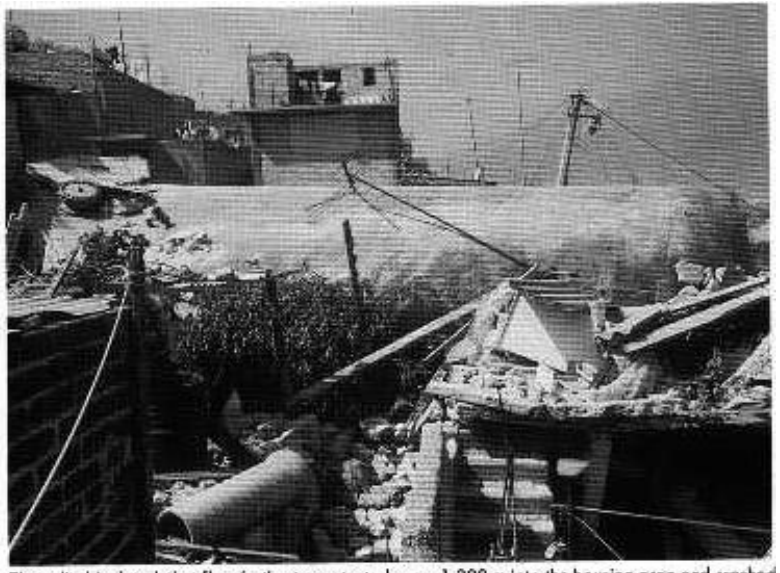
- Pemex is a liquid petroleum gas (LPG) distribution plant.
- Pemex is located a few km. north of Mexico City (Pop = 16MM).
- Plant was 25 years old and built to 1950 API standards of the U.S.
- LPG gas is used for heating and cooking in almost every household.

15 of 48 Vessels BLEVE In domino fashion
550 people killed.
2,000 people receive severe burns.
7,231 people classed as injured.

Impact



Spherical Tank Failure (F4)



The cylindrical tank that flew furthest penetrated some 1,200 m into the housing area and crashed into a 2 storey house vacated one hour before.

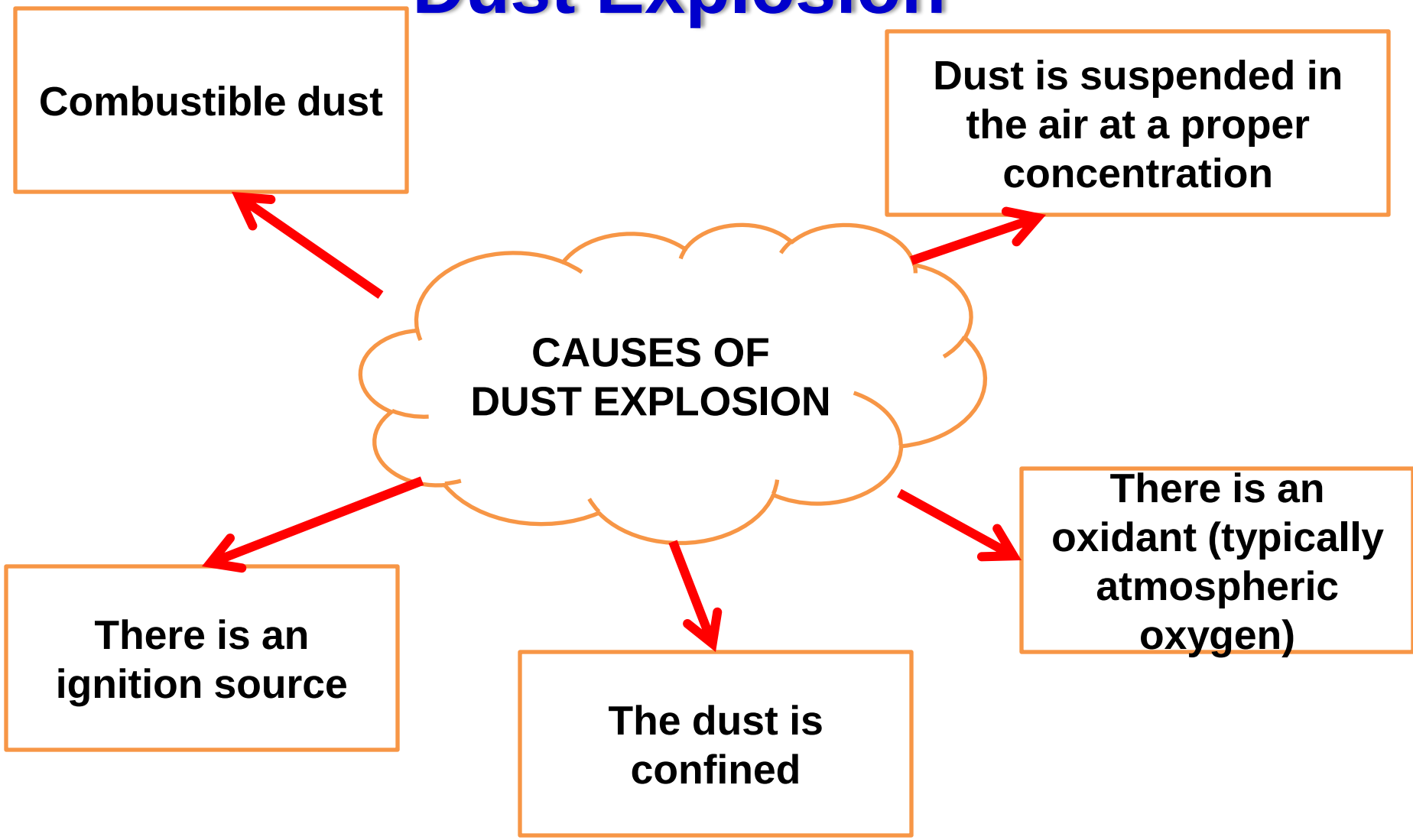
Cylindrical tank flew as missiles

Bullet Tank Area

The desolation of the burnt-out houses recalled a war scene.

Nearby Houses

Dust Explosion



*If any of these five conditions is missing there can be no dust explosion

Imperial Sugar Explosion

Figure 1. Aerial photograph of Imperial Sugar Port Wentworth facility after explosion.

February 7, 2008 in Port Wenworth, Georgia, USA. 13 people killed and 42 injured

Hazard from Toxic Substances

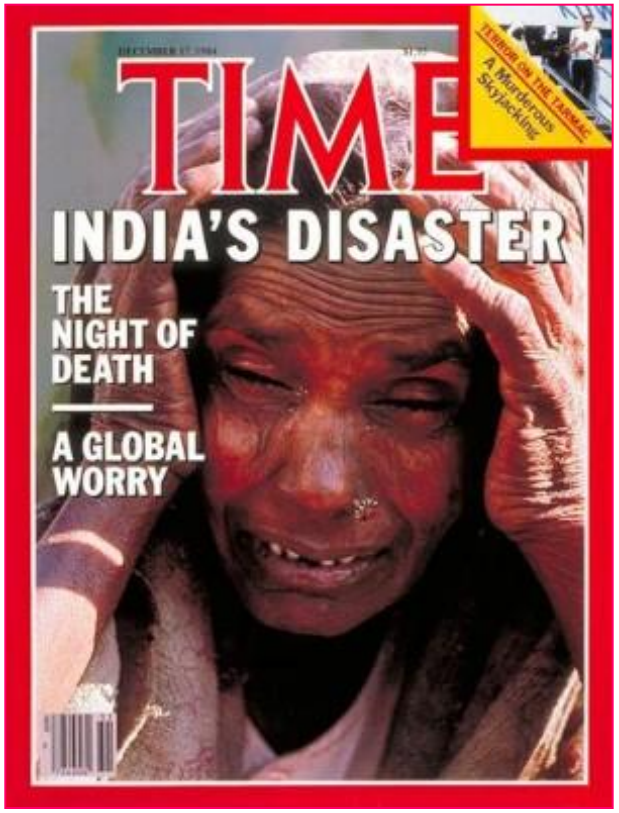
- **Source of Toxicants**
  - **Toxic Release**
  - **Fire and Explosion leading to release of toxicants**
- **Route of Entry**
  - **Injection: through cuts or hypodermic needles into the skin, usually cause highest blood level concentration.**
  - **Inhalation: through mouth/nose into the lungs**
  - **Ingestion: through mouth into stomach and gastrointestinal tract,**
  - **Dermal (Skin) absorption: through skin membrane**

Toxicants

- **Agents**
  - **Chemicals: organic solvent, pesticides, lead etc**
  - **Physical (dusts, fibers, noise, and radiation) agents, e.g. Asbestos**
  - **Carcinogenic, terratogenic, mutagenic**
- **Toxicity is a property of toxicant that describe its effect on biological organism.**
  - **Very Toxic > Toxic > Harmful**
- **Toxic Effect**
  - **Reversible vs irreversible**
  - **Acute Vs Chronic**
  - **Local Vs Systemic**

Bhopal

- 40 tons Methyl Isocynate escape
- Immediate cause : 500L seepage
- Erupts and release fumes
- 3000 died : respiratory failure
- 500,000 suffer aftermath
- USD470mil spent



Introduction to Process Safety

Topic 3.

RISK ASSESSMENT & RISK RANKING

Definition of Risk

Risk = Severity x Likelihood

Severity

- Probability of Fatality
- Monetory Losses
- Environmental Impact

Likelihood

- Chance of failure
- Probability

Risk Assessment is a procedure of estimating risks based on historical data, mathematical modeling and scenario evaluation. The outcome is useful in

- deciding whether or not risk is tolerable
- providing clear guidance to establish mitigating measure

Risk is expressed in as Rating

- **Rating is typically**
  - **simple to use and understand**
  - **Not require extensive knowledge to use**
  - **Have consistent likelihood ranges that cover the full spectrum of potential scenarios**

- **In applying risk assessment**
  - **Clear guidance on applicability is provided**
  - **Detailed descriptions of the consequences of concern for each consequence range should be described**
  - **Have clearly defined tolerable and intolerable risk levels**

Example of a Severity Range

Description	Category	Environmental, Safety and Health Result Criteria
Catastrophic	I	• Death, permanent total disability • Loss of exceeding $1M • Irreversible severe environmental damage that violates law or regulation
Critical	II	• Permanent partial disability, injuries or occupational illness that may result in hospitalization of at least 3 personnel •Loss exceeding $200K but less than $1M •Reversible environmental damage causing a violation of law or regulation
Marginal	III	•Injury or occupational illness resulting in one or more loss of workdays •Loss exceeding $10K but less than $200K •Mitigatible environmental damage without violation of law or regulation where restoration activities can be accomplished
Negligible	IV	Injury or illness not resulting in a lost work day Loss exceeding $2K but less than $10K Minimal environmental damage not violating law or regulation

Example of Likelihood Ranges

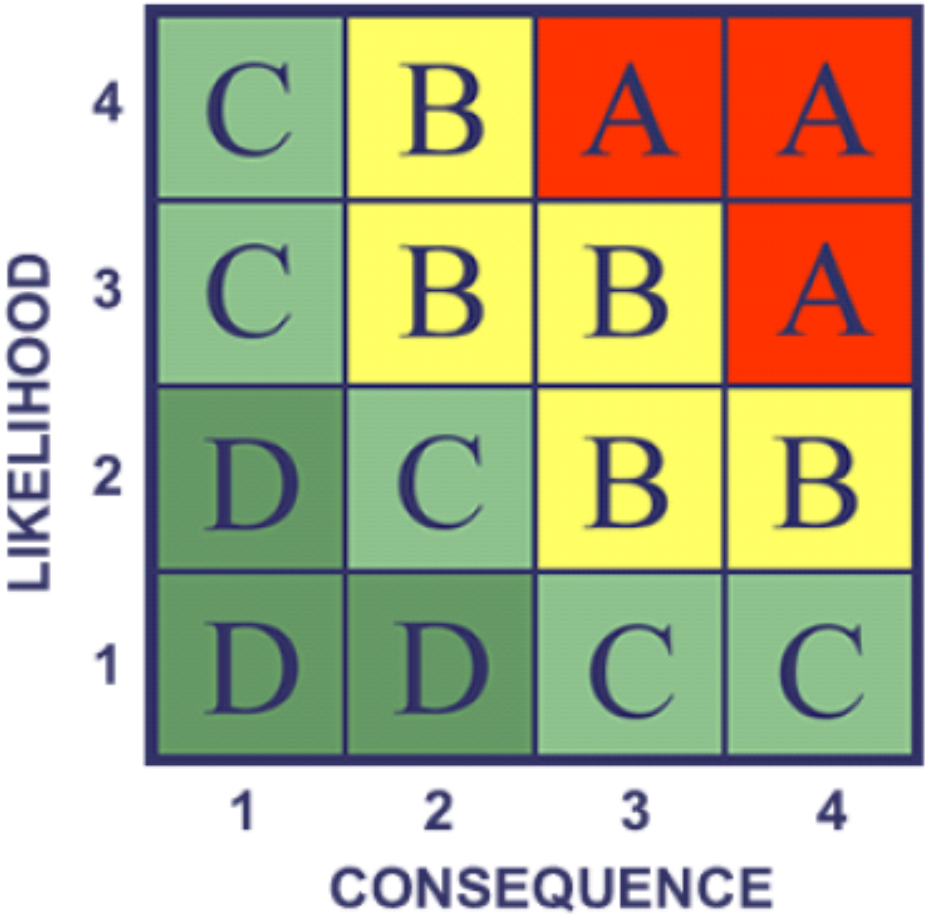
Description	Level	Specific Individual Item	Fleet or Inventory
Frequent	A	Likely to occur than 10^{-1} in that life	Continuously experienced
Probable	B	Will occur several times in the life on an item, with probability of occurrence less than 10^{-2} but greater than 10^{-3} in that life	Will occur frequently
Occasional	C	Likely to occur some time in the life of an item, with a probability of occurrence less than 10^{-2} but greater than 10^{-3} in that life	Will occur several times
Remote	D	Unlikely but possible to occur in the life of an item with a probability of occurrence less than 10^{-3} but greater than 10^{-6} in that life	Unlikely but can be reasonably expected to occur
Improbable		So unlikely, it can be assumed occurrence may not be experienced, with a probability of occurrence less than 10^{-6}	Unlikely but possible

Example Risk Ranking Categories

Risk Rank	Category	Description
I	Unacceptable	Should be mitigated with engineering and/or administrative controls to a risk ranking of III or less within a specified period such as 6 months
II	Undesirable	Should be mitigated with engineering and/or administrative controls to a risk ranking of III or less within a specified period such as 12 months
III	Acceptable with Controls	Should be verified that procedures or controls are in place
IV	Acceptable as is	No mitigation required

Sometimes presented as Risk Matrix

Risk = Probability of occurrence x Consequence of occurrence



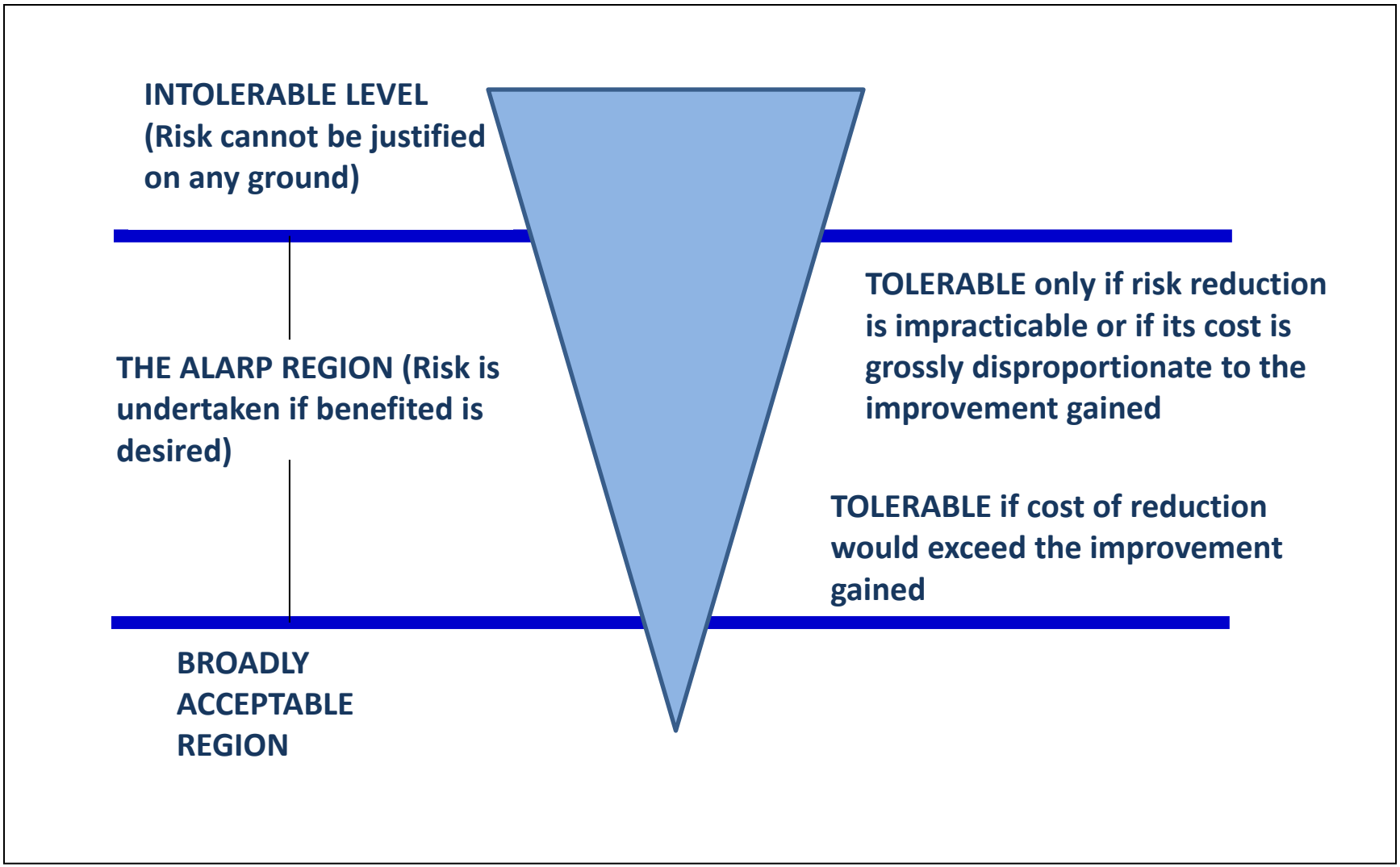
Guidelines for Risk Mitigation

Risk Level	Action Required
A	Risk Mitigation required to risk level C or D
B	Risk Mitigation required to risk level C or D
C	Risk Mitigation to risk level D is optional
D	No further Risk Mitigation required

Tolerable Risk

- **Risk cannot be eliminated entirely.**
- **Every chemical process has a certain amount of risk associated with it.**
- **At some point in the design stage someone needs to decide if the risks are “tolerable".**
- **Each country has it owns tolerability criteria.**
- **One tolerability criteria in the UK is "as low as reasonable practicable" (ALARP) concept formalized in 1974 by United Kingdom Health and Safety at Work Act.**

ALARP Criteria



The issue is… How to make the plant safe and benign?????