CH 42010: PROCESS PLANT OPERATION and SAFETY

LTP: 3-0-0, CRD: 3

Lecture 1

Introduction: Why Safety is required

PROCESS PLANT OPERATION & SAFETY

SYLLABUS :-

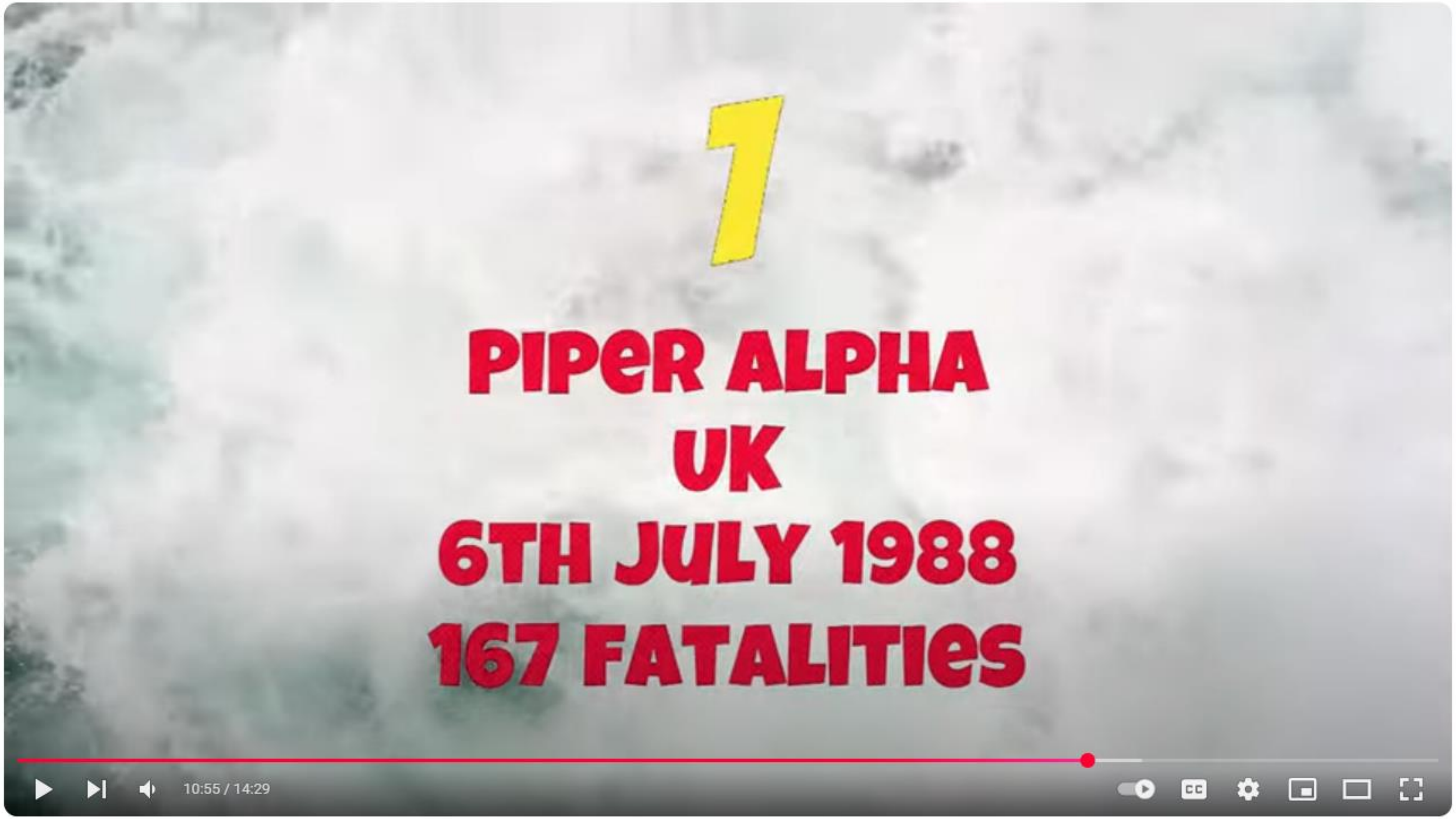
Prerequisite-CH30009Process plants-continuous and batch plants. Procedure for systematic study of plants. Plant and equipment start up and shut downs, operations at steady state. Emergency response strategy for plants and equipment. Plant test runs and rating calculations for various equipment. Plant systems for utilities and auxiliary services. Handling of plant effluent. Safe commissioning of plants.Aspects of engineering safety; Safety in relation to economic and operational aspects. General principles of industrial safety. Hazards due to fire, explosions, toxicity. Chemical hazards. Notified dangerous operation. Engineering control of chemical plant hazards. Industrial plant layout. HAZAN and HAZOP. Plant and equipment reliability analysis. Case studies plant accidents.Text Book: 1.Fault analysis and diagnosis in chemical and petrochemical processes by D. M. Himmelblau2.Health, Safety and Accident Management in the Chemical Process Industries Ed. By H. Heinmann, M. Dekker3.The Basics of FMEA by R. E. McDermott4.HAZOP and HAZAN by Trevor Kletz.5.Emergency Relief Systems for Runaway Chemical Reactions and Storage Vessels by T. Kletz.

Prof. Joydip Choudhary

Me

List of Textbooks and Reference Books

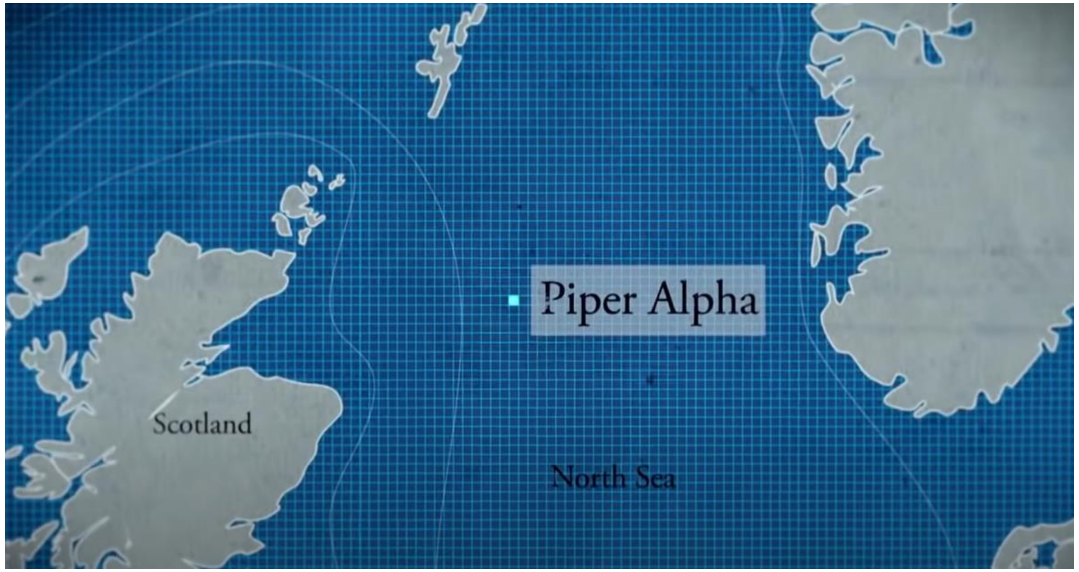
Piper Alpha Case:
One of the Deadliest Offshore Disasters



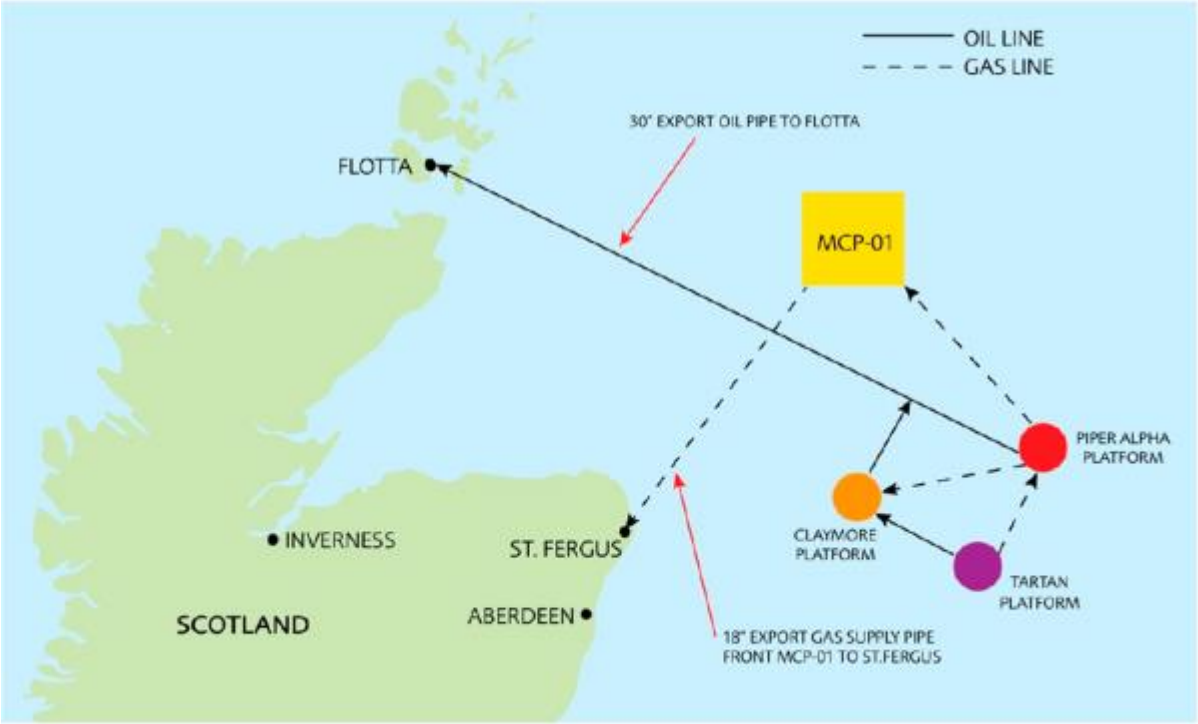
Deadliest Offshore Disasters : 10 Worst Oil Rig Accidents

https://www.youtube.com/shorts/_AEGhVt5HxY?feature=share

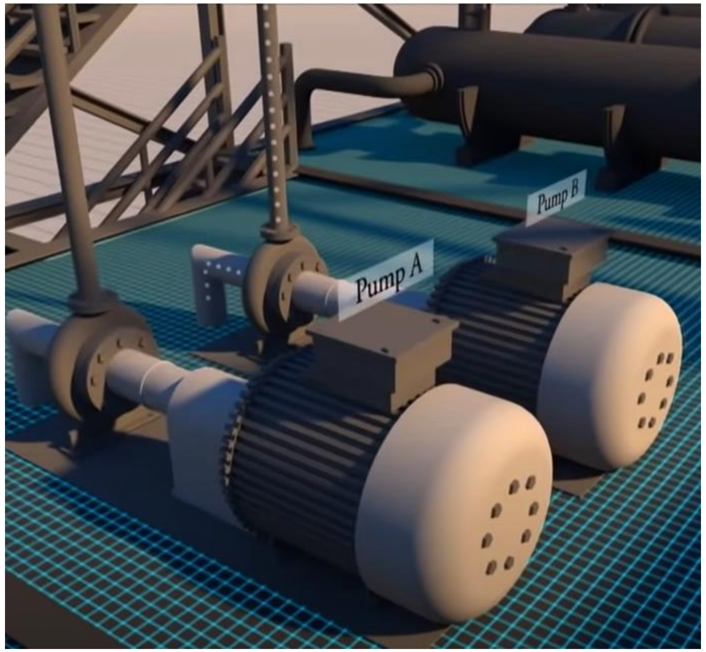
Piper Alpha



Piper Alpha
Scotland
North Sea



OIL LINE
GAS LINE
30" EXPORT OIL PIPE TO FLOTTA
FLOTTA
MCP-01
PIPER ALPHA PLATFORM
CLAYMORE PLATFORM
TARTAN PLATFORM
INVERNESS
ST. FERGUS
ABERDEEN
SCOTLAND
18" EXPORT GAS SUPPLY PIPE FRONT MCP-01 TO ST.FERGUS



12:00 PM (Day Shift):

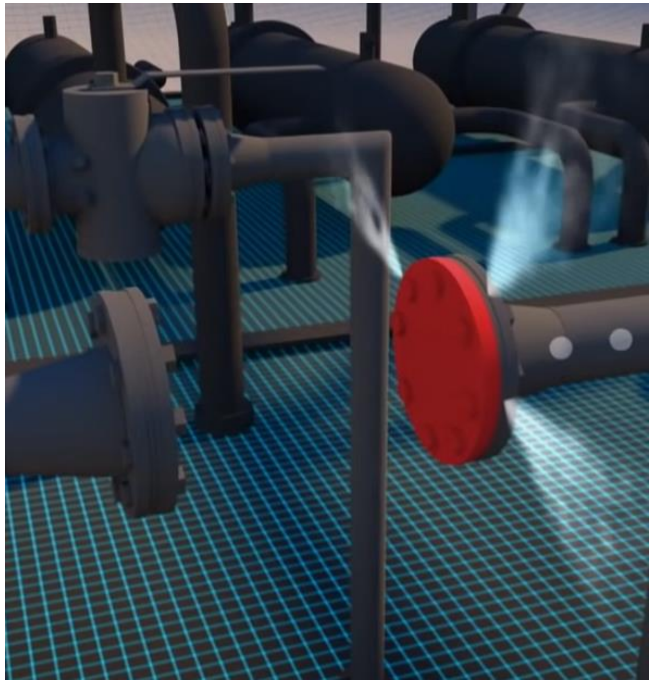
•Maintenance conducted on Condensate Pump A.

•Pressure Safety Valve (PSV) removed and pipe temporarily sealed (blind flange).

Shift Change (~6:00 PM):
No clear handover

9:45 PM:

- Problems arise with Condensate Pump B.
- Operators decide to switch to Pump A



9:52 PM:

Gas leak detected when Pump A is started.

High-pressure condensate escapes from the blanked line.

9:55 PM:

First Explosion occurs

10:04 PM – 11:50 PM:

Continuing explosions and partial structural collapses

"Safety is not an intellectual exercise to keep us in work. It is a matter of life and death. **It is the sum of our contributions to safety management** that determines whether the people we work with live or die".

- Sir Brian Appleton after Piper Alpha:

Main Reasons for the Piper Alpha Disaster

Poor Maintenance & Communication.

- A critical PSV was removed for maintenance and not replaced.
- Inadequate shift.

Safety Culture & Management Failures.

- Safety procedures were not prioritized or enforced effectively.
- Management placed production demands over rigorous safety oversight.

Inadequate Firefighting & Emergency Systems.

- The sprinkler system was on manual mode.
- Complex operational changes (oil to gas) were not fully integrated.

Faulty Platform Modifications.

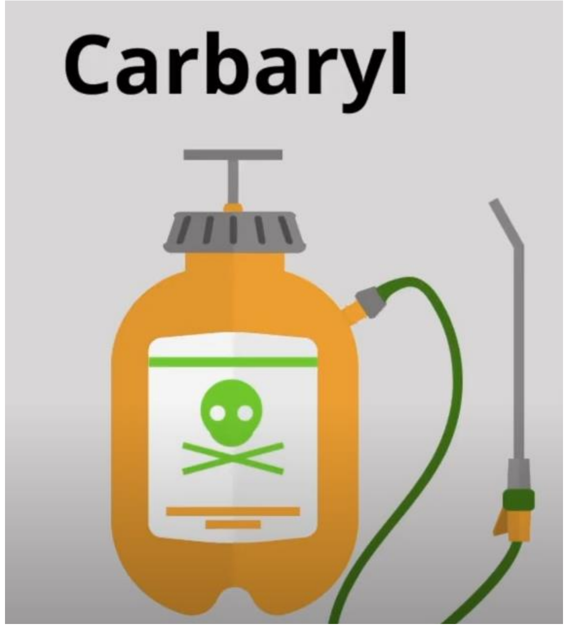
- Piper Alpha was originally designed for oil production but later converted for gas, creating design and operational complexities

Union Carbide India Ltd., Bhopal, India:

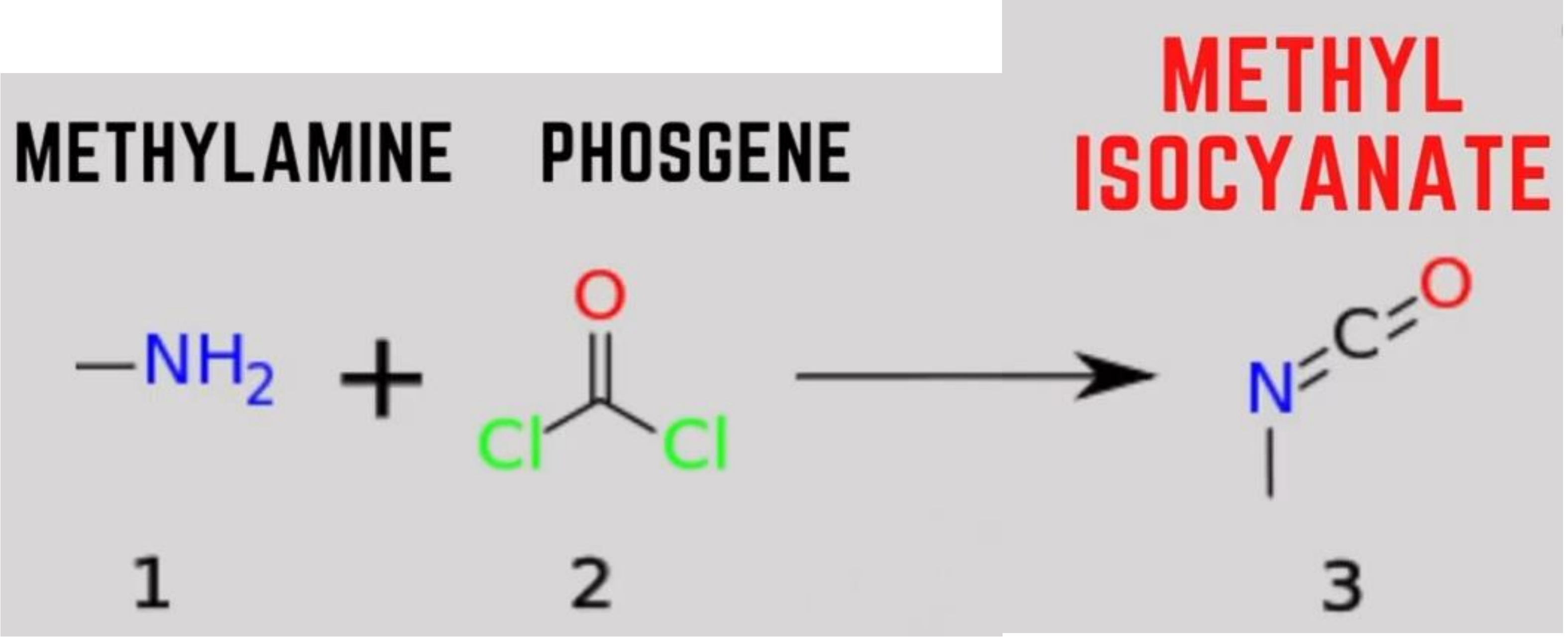
The world's deadliest gas leak in the of the chemical industry

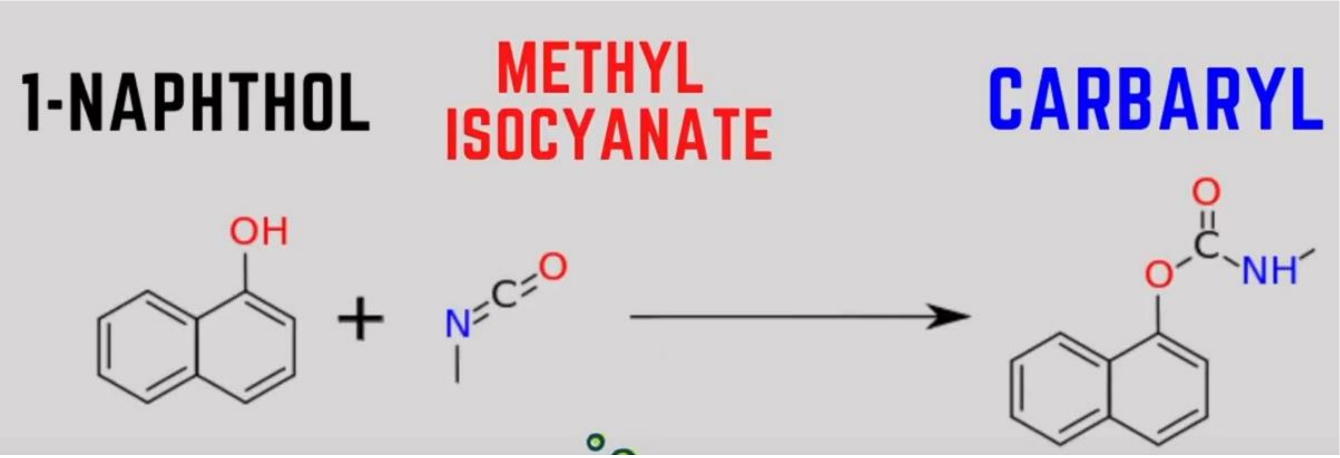
Date: 3 December, 1984

- 2500 died immediately
- 8000 more due to diseases
- 500000 injuries

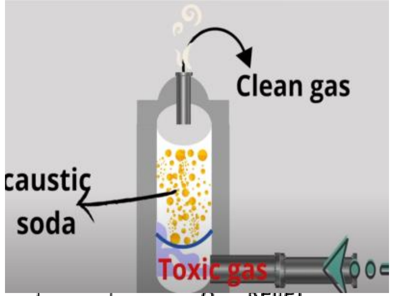

Carbaryl

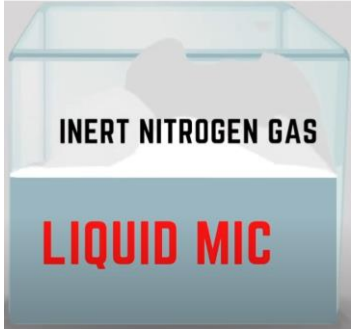

SEVIN

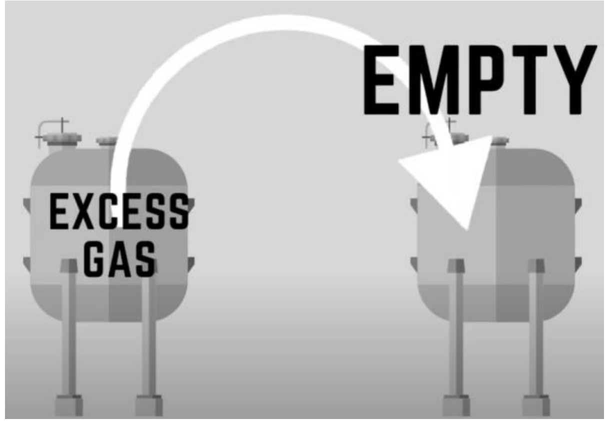

METHYLAMINE
PHOSGENE
METHYL ISOCYANATE
1
2
3

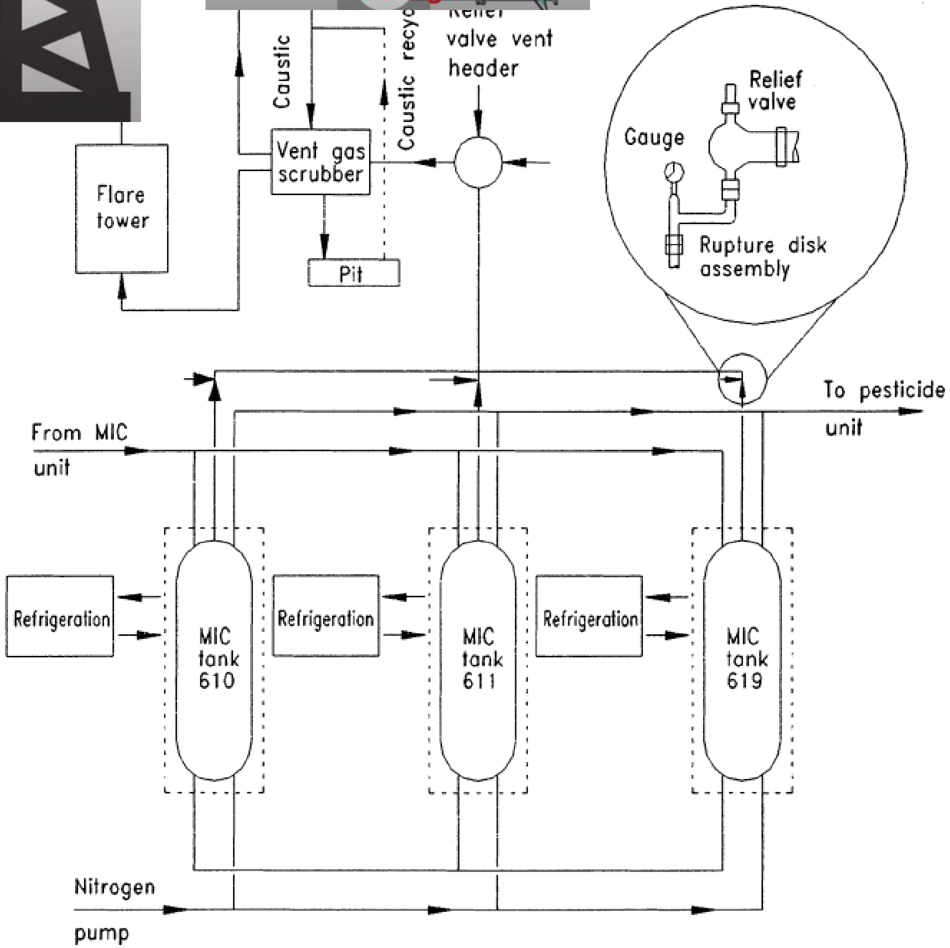

1-NAPHTHOL
METHYL ISOCYANATE
CARBARYL

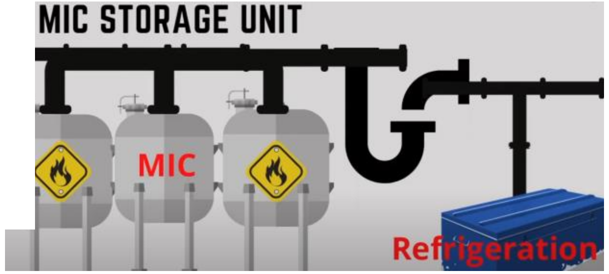
Protocols for the safe storage of MIC



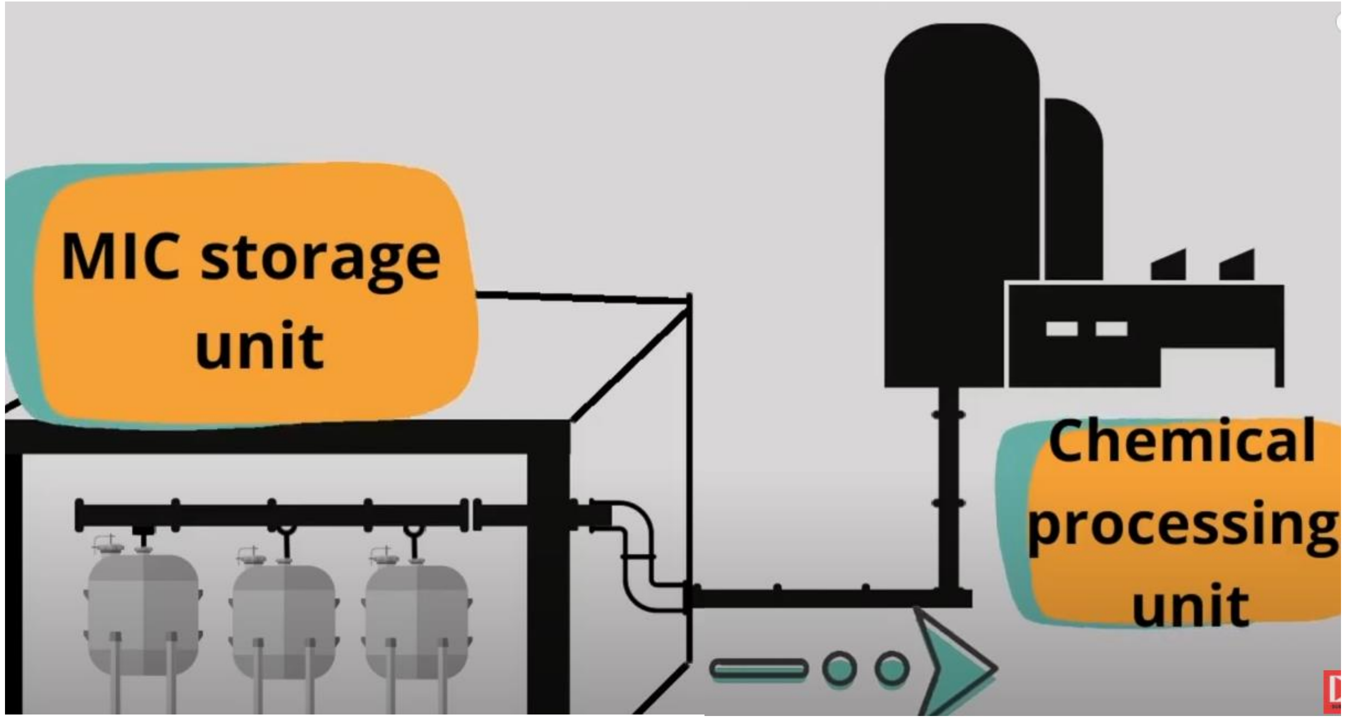


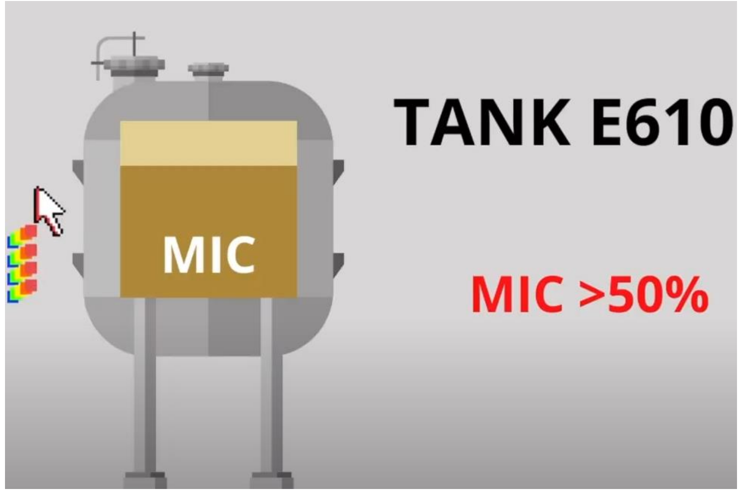




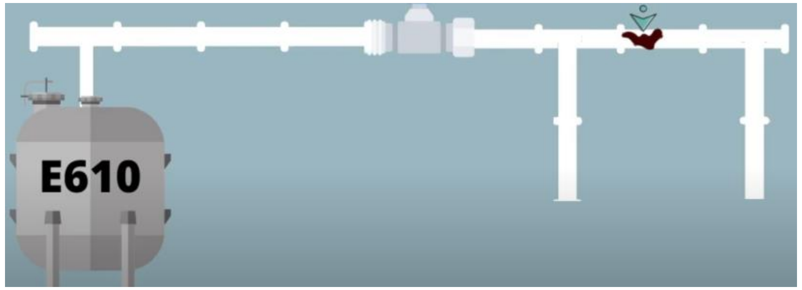


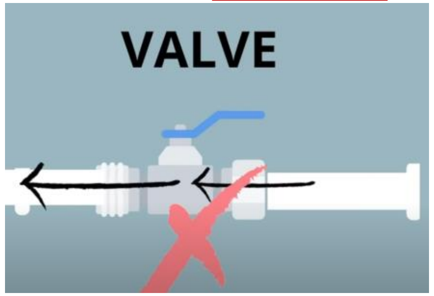
Safety Protocols Neglected

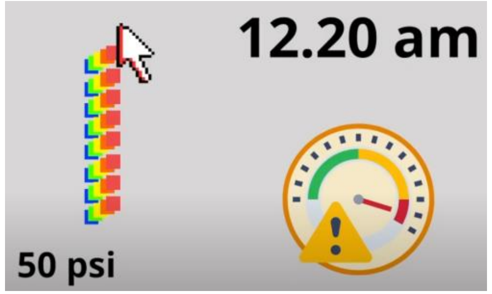




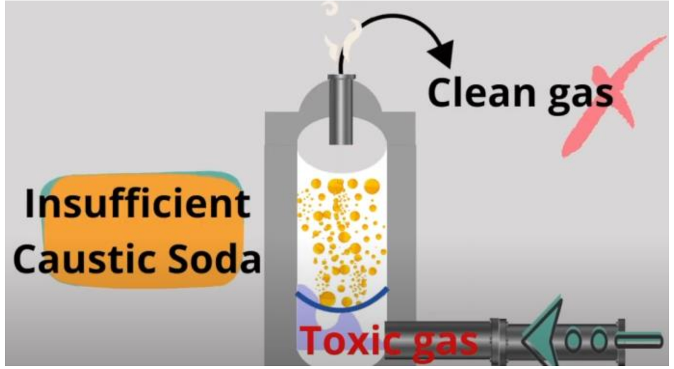
CAUSE







FAILURE



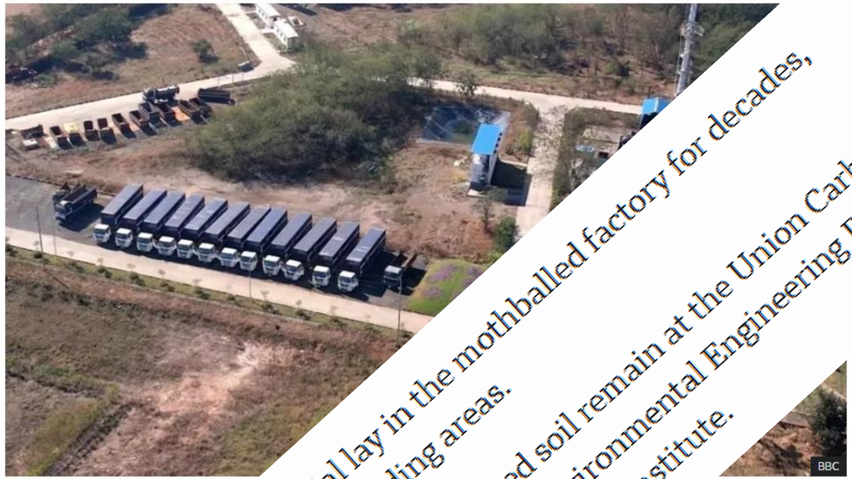
CONSEQUENCE

Toxic waste from world's deadliest gas leak fuels protests in India

1 day ago

Share Save

Vishnukant Tiwari
BBC Hindi



Protests have broken out af… …ampur

The waste, transported from the now-defunct Union Carbide factory in the city of Bhopal - site of the 1984 gas tragedy that **killed** thousands - has sparked fears among locals.

They worry that disposing of it near their homes could be harmful and even cause an …nvironmental disaster.

…sts erupted on 3 January, a day after the waste arrived in the town, escalating …to stone-throwing and attempted self-immolations.

Since the disaster, the toxic material lay in the mothballed factory for decades, polluting groundwater in the surrounding areas.

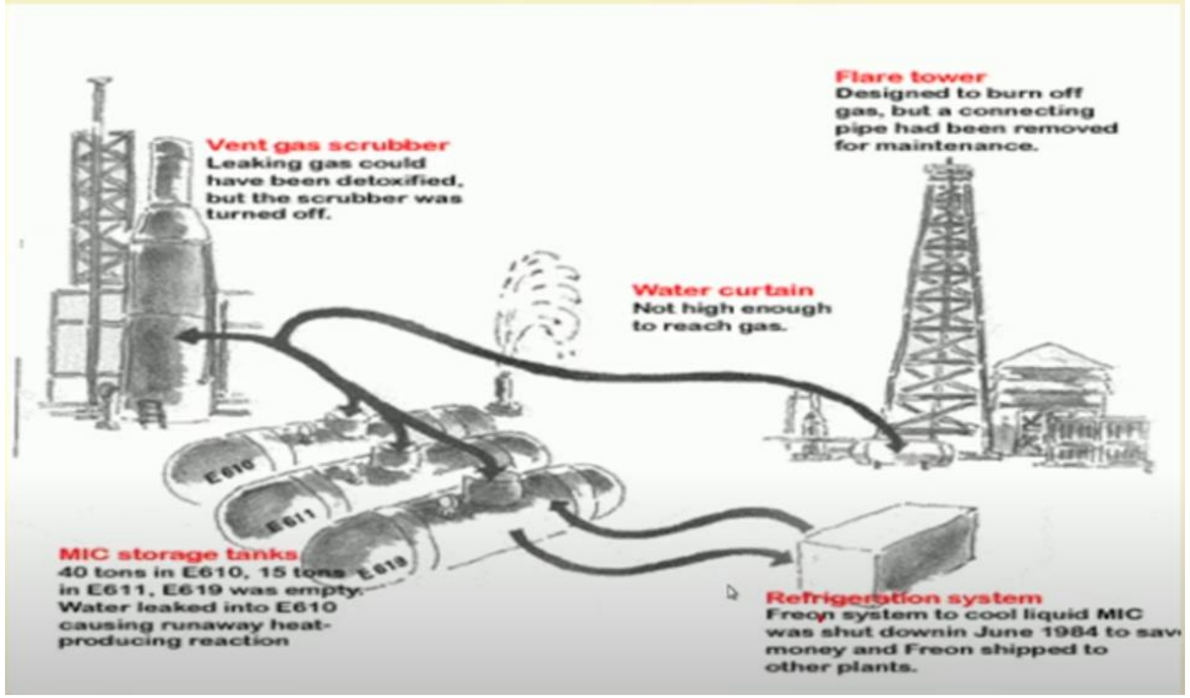
More than 1.1 million tonnes of contaminated soil remain at the Union Carbide factory site, according to a 2010 report by National Environmental Engineering Research Institute and the National Geophysical Research Institute.

The toxic waste cleared from the Bhopal factory included five types of hazardous materials - including pesticide residue and "forever chemicals" left from its manufacturing process. These chemicals are so-named because they retain their toxic properties indefinitely.

Over the decades, these chemicals have seeped into the surrounding environment, creating a health hazard for people living around the factory in Bhopal.

But officials dismiss fears of the waste disposal causing environmental issues in Pithampur.

Main Reasons for the Bhopal Gas Tragedy



1. Cost-cutting measures led to compromised safety systems.

2. Negligent maintenance allowed critical equipment to deteriorate.

3. Large quantities of hazardous MIC were stored without adequate safeguards.

4. Multiple safety mechanisms failed or were shut down to reduce expenses.

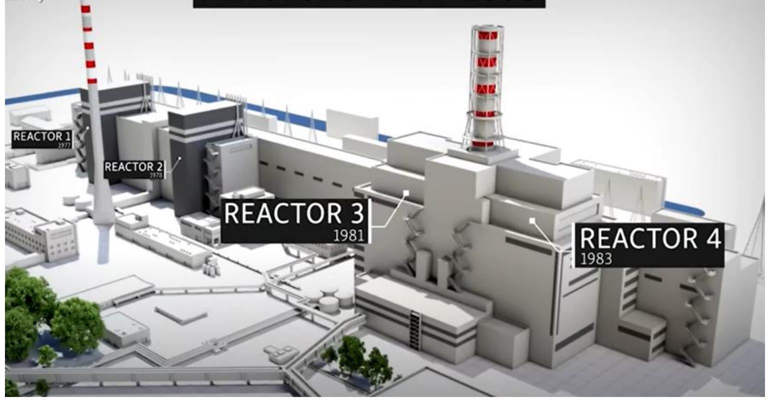
5. Poor training and oversight worsened the response to the emergency.

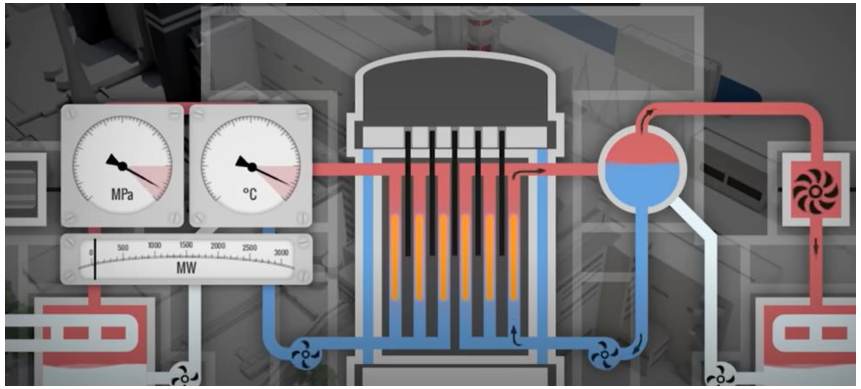
Chernobyl disaster, Pripyat in northern Ukraine:

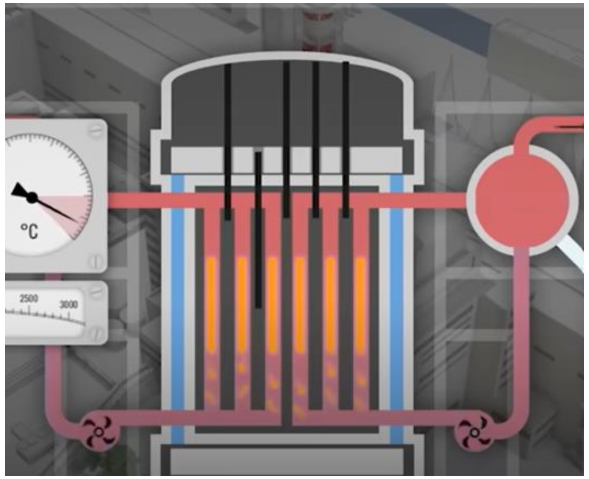
The world worst civilian nuclear disaster

Date: 26 April 1986

- 31 died immediately
- 900000 died between 1986-2004







Safety Test: *The reactor design had known safety flaws, and the test was conducted with the power level set dangerously low.*

- **In an RBMK reactor, when coolant (water) in the core turns to steam (a "void"), it reduces neutron absorption and can *increase* reactor power.**

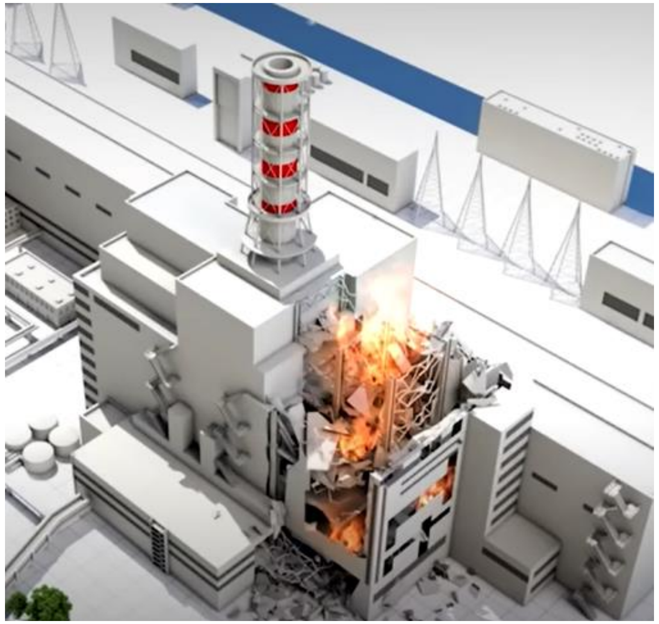
- **Control rods, designed with graphite tips, are meant to reduce reactivity by absorbing neutrons.**

- **When the control rods were inserted, the initial effect was an *increase* in reactivity before the neutron-absorbing portion of the rod entered the core**

- **Operators turned off key safety systems (e.g., emergency cooling) to carry out a low-power test, believing they could manage the reactor without automated backups.**

- **This left the reactor vulnerable to uncontrolled conditions and leads to catastrophe.**

Main Reasons for the Disaster



1. **Faulty Reactor Design (RBMK)**: A positive void coefficient made the reactor dangerously reactive under low-power conditions, while graphite-tipped control rods initially increased reactivity instead of reducing it.

2. **Safety Systems Disabled**: Operators deliberately shut off key emergency measures.

3. **Low-Power Operation**: The test required the reactor to run at a level below safe operating limits, making it unstable.

4. **Inadequate Training and Communication**: Personnel lacked thorough understanding of the reactor's vulnerabilities and did not fully grasp the risks of the test procedure.

5. **Poor Safety Culture**: Pressure to complete the experiment and a culture of secrecy led to rushed decisions and delayed emergency responses.

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Lecture 2

Aspects of engineering Safety

VARIOUS ASPECTS OF ENGINEERING SAFETY

- **Inherent Safety Principles**
- **Toxicology and Exposure Control**
- **Hazard Identification and Risk Analysis**
- **Chemical Reactivity Hazards**
- **Fires and Explosions**
- **Relief and Vent Systems Design**
- **Safety Instrumented Systems (SIS) and Controls**
- **Accident and Incident Analysis**
- **Risk Management and Regulatory Compliance**
- **Operational Safety Practices**
- **Design for Safety**

Inherent Safety Principles:**TERMS**

- **SAFETY**, in general, is defined as "a strategy for accident prevention."
- **PROCESS SAFETY** is safety applied to processes, including chemical processes

Loss Prevention: defined as the prevention of incidents that cause losses due to death, injury, damage to the environment, or even loss of production or inventory

Inherent Safety Principles :TERMS

American Institute for Chemical Engineers (AICHE) Center for Chemical Process Safety (CCPS)

https://www.aiche.org/ccps/resources/glossary

TERM	Definition	Example
Hazard	An inherent chemical or physical characteristic that has the potential for causing damage to people, the environment, or property	A pressurized tank containing MIC.
Accident	An unplanned event or sequence of events that results in an undesirable consequence. The scope of the accident description is arbitrary	A leak in a pressurized vessel containing MIC.
Consequence	A measure of the expected effects of a specific incident outcome case.	A MIC leak results in a toxic cloud downwind.

Inherent Safety Principles :TERMS

American Institute for Chemical Engineers (AICHE) Center for Chemical Process

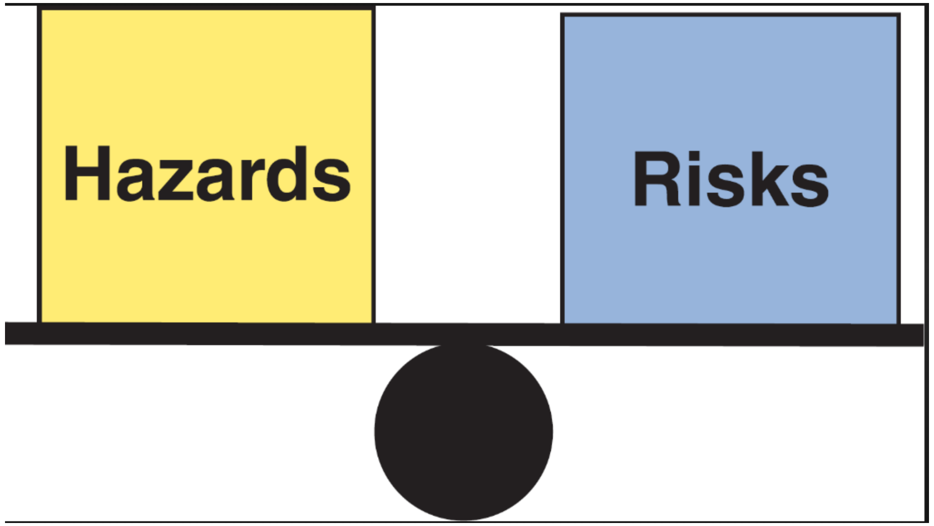
TERM	Definition	Example
Hazard evaluation/analysis	Determination of the mechanisms causing a potential incident and evaluation of the incident outcomes or consequences.	A Hazard and Operability (HAZOP) study was completed on the distillation column.
Hazard identification	Identification of material, process, and plant characteristics that can produce undesirable consequences through the occurrence of an incident.	The chemicals in the process are toxic and flammable hazards
Impact	A measure of the ultimate loss and harm of an incident.	A MIC leak produces a downwind toxic vapor cloud resulting in death, an emergency response, plant downtime, and loss of community support.

Inherent Safety Principles :TERMS

American Institute for Chemical Engineers (AICHE) Center for Chemical Process Safety (CCPS)

TERM	Definition	Example
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	The major risk in the process was a chemical spill into the adjacent river with environmental damage.
Risk analysis	Quantitatively combining risk estimates from a variety of scenarios using engineering evaluation and mathematical techniques to arrive at an overall risk estimate	A detailed fault tree and event tree analysis of the process resulted in an overall risk estimate.
Safety culture	The common set of values, behaviors, and norms at all levels in a facility or in the wider organization that affect process safety.	After the incident, the company decided to improve the corporate safety culture.

Inherent Safety Principles :TERMS



Inherent Safety Principles :HAZARD

- **A hazard, in general, is anything that can cause an accident.**
- **Hazards can arise due to materials, energy, physical situations, equipment design, and even procedures**

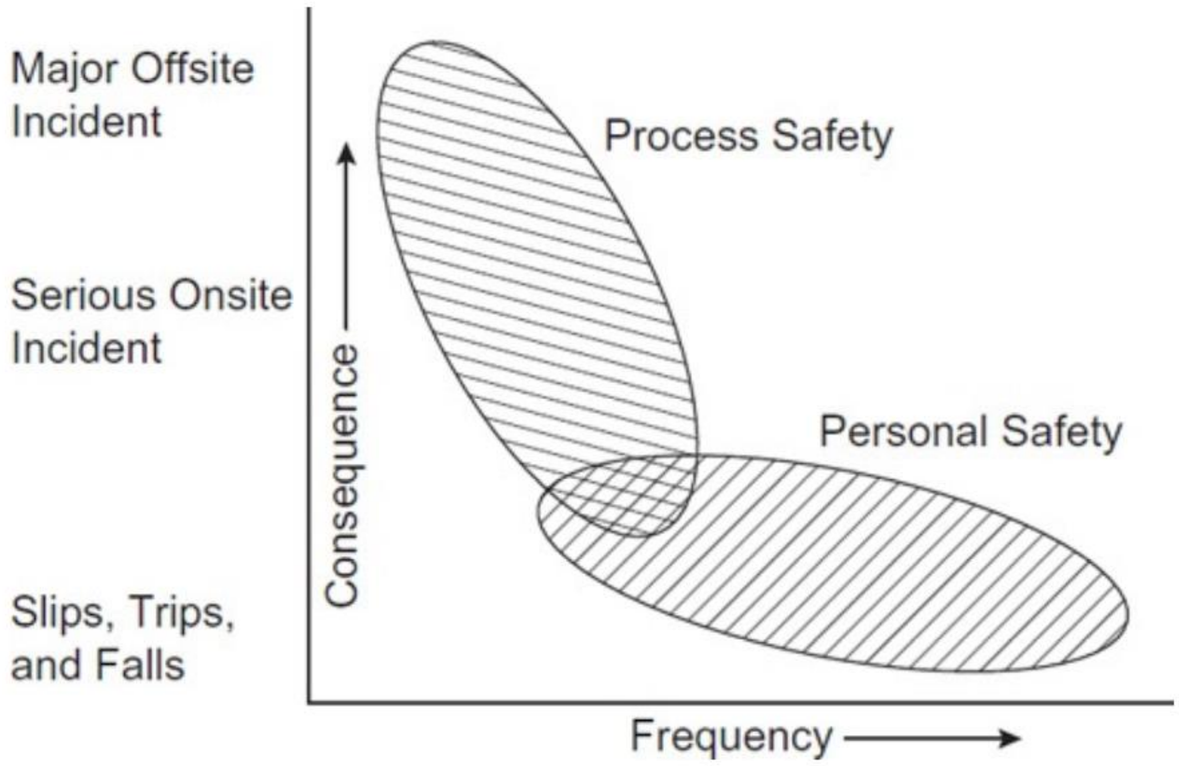
Key process information required for chemical plant hazard analysis/evaluation includes:

- **Chemical-related properties:** hazardous properties, physical properties, and more
- **Process conditions:** temperature and pressure, flow rates, concentrations, and other factors
- **Equipment design parameters:** equipment capacity, operating limits for temperature and pressure, materials of construction, and pipe wall thicknesses, among others
- **Site and plant layout:** equipment spacing, control room location, and other considerations
- **Procedures and policies:** startup, operating, shutdown, maintenance procedures, and others
- **Location** and nature of adjacent communities and sensitive locations, such as schools

Inherent Safety Principles :MYTHS

Process safety costs a lot of money and has a negative impact on the company's bottom line: safety programs do cost money and there may be startup costs, the reduction in costly accidents, and the improvements in all business aspects results in even greater cost savings

Process safety is the same as personal or even laboratory safety.



Source: Dow Chemical Faculty Workshop, June 2017, AICHE.

Inherent Safety Principles :MYTHS

Process safety is no more than following rules and regulations:
The safety program must work its way through the levels from the bottom to the top: No levels can be skipped

Levels	Action Plan
Level 0	• Consists of No safety program and maybe even disdain for safety. • Such a program is destined to have continuous accidents, may be even accidents that are repeated. • No improvement is ever achieved.
Level 1	• Safety program that reacts to accidents as they occur. • Accidents do result in changes, but only on a reactive basis, rather than the organization taking a proactive stance. • Accidents continue to occur, although specific accidents are not likely to be repeated.
Level 2	• Safety program that consists of complying with rules and regulations. • Rules and regulations can never be complete, however, and can never handle all situations. • Regulations have legal authority and generally set a minimum standard for industrial operations

Inherent Safety Principles :MYTHS

Levels	Action Plan
Level 3	• Introduces management systems to assess hazards and provide procedures to manage hazards. • A variety of management systems can be used to achieve this level, including job safety assessment, management of change (MOC), and other means to control hazards during operations. Written management systems provide documentation to train operators and others and to ensure consistency in operating practices.
Level 4	• Uses monitoring to obtain statistics on how well the safety program is performing. • The performance monitoring identifies problems and corrects them.
Level 5	• The highest level, at which the safety program is dynamic and adapting. • Safety is a core value for everything that is done and the primary driving force for a successful enterprise.

Question: Classify the following from 0 to 5 based on the hierarchy of safety programs. Explain why.

a) The company and plant executive teams are very receptive to any safety suggestions and the suggestions are reviewed and implemented on a timely basis.

b) A change is made in a laboratory apparatus after a valve has leaked.

c) The faculty member in charge of a laboratory has very little knowledge about safety.

d) The faculty member in charge of a laboratory states that "Safety is very important!" but does nothing after a small accident.

e) The company uses several leading safety metrics to assess its safety program.

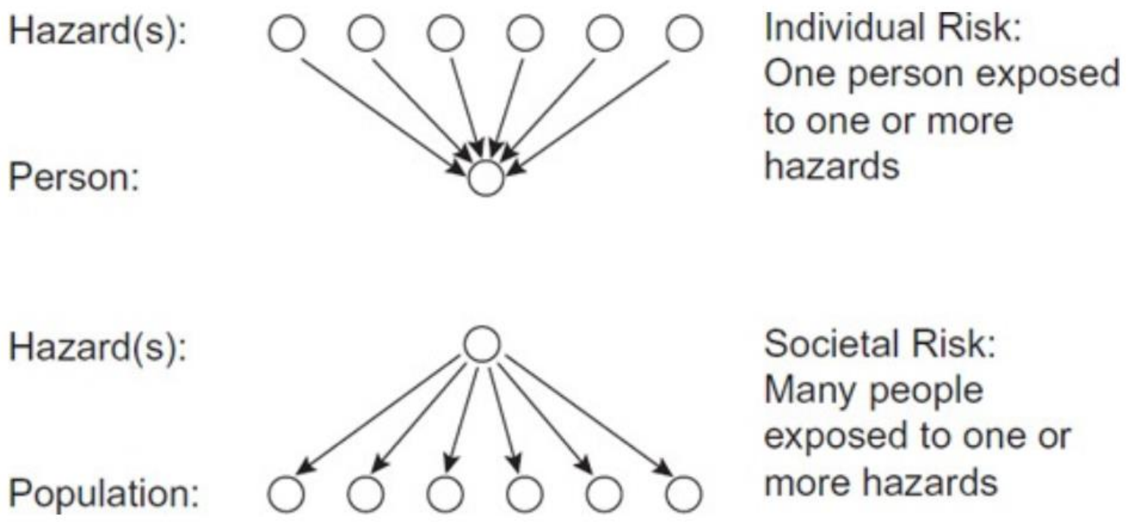
f) The laboratory meets all the rules in the safety manual.

g) The faculty member in charge of a laboratory states that the safety program is interfering with the research efforts.

h) The laboratory is a mess.

Individual Risk, Societal Risk, and Risk Populations

Individual risk: one person is exposed to one or more hazards.
normally performed when considering a plant employee exposed to plant hazards.



Societal risk: a group of people is exposed to one or more hazards.
normally performed when considering the risks to a community surrounding a chemical plant and exposed to multiple plant hazards.

Voluntary and Involuntary Risk

- 1. Voluntary Vs In voluntary Risk
  - If a person knowingly takes any risks, then he feels it safe
  - voluntary Risks are consider as safe (even if risks are really Unsafe)
  - Involuntary Risks are consider as unsafe (even if risks are really Safe)

- **Chemical plant employees are aware of and trained to handle the risks that are found in their work environment.**
- **People in the surrounding community may not be fully aware of these risks or may not understand the risks and the associated probabilities and consequences.**

A community outreach program is a very important part of any process safety program for a company and plant site.

The plant officials must carefully explain the risks—including both the probabilities and the consequences—to any community that may be impacted by these risks.

Question:

For the following cases, identify the primary risk population, classify the case as involving individual risk and/or societal risk, and identify the risk as voluntary or involuntary.

a. A worker does not wear the required personal protective equipment for the chemicals being used.

b. A large butane storage facility is built next to a congested neighborhood.

c. A person drives a car from Kharagpur to Kolkata.

d. A person drives a car without wearing the seat belt.

e. A person drives a car while intoxicated.

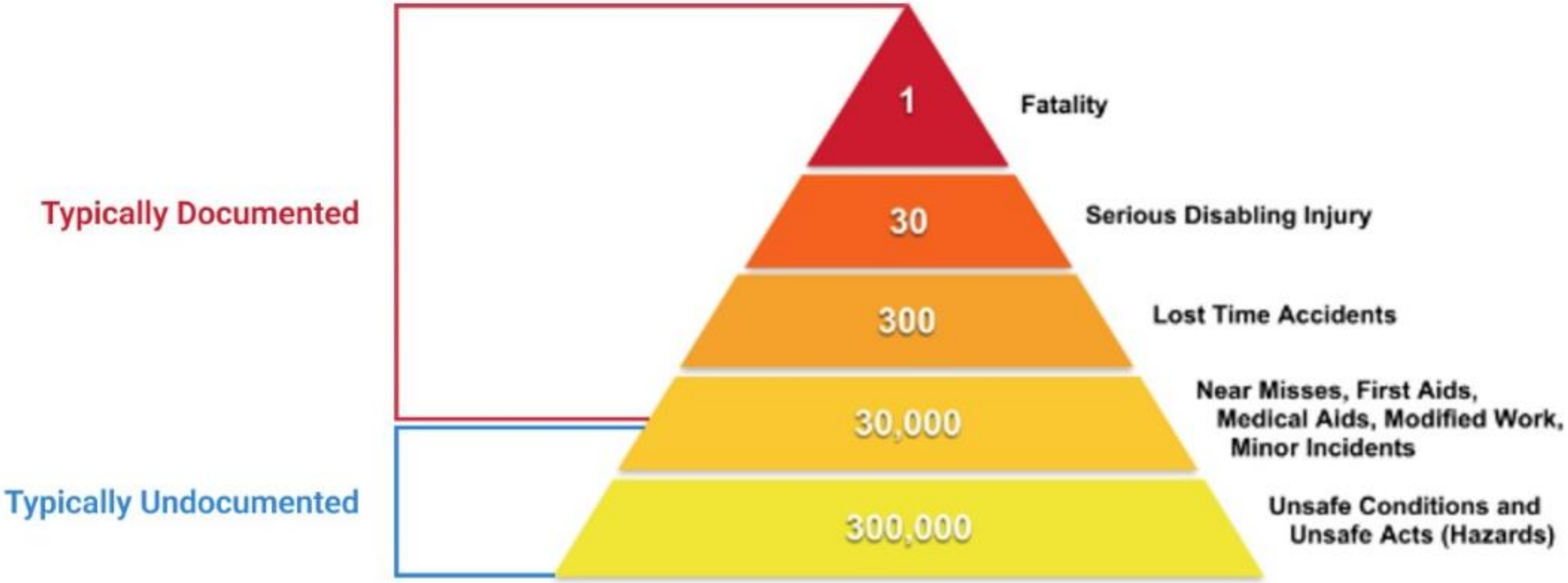
f. An airplane is produced with a manufacturing defect.

g. A tank truck containing gasoline is driven from the refinery to the gas station for unloading.

h. An underground pipeline is routed through a residential area.

Safety Metrics

- Measurement of the safety program effectiveness.
- Company must identify metrics that are effective for its operations.
- Not universal, will change between companies and even plant sites, and will change with time



Accident and Loss Statistics

❖ **Accident statistics are one metric to determine the effectiveness of any safety program.**

❖ **More indicative of personal safety rather than process safety.**

❖ **U.S. Occupational Safety and Health Administration (OSHA)**

❖ **The Ministry of Labour and Employment**

Accident and Loss Statistics

Most commonly used methods to measure accident statistics :

- ❖ **Total number of fatalities or injuries/illnesses.**
- ❖ **Fatality rate, or deaths per person per year**
- ❖ **Fatal injury rate based on total hours or total workers**
- ❖ **Incidence rate**

Note:

Each method has strengths and weaknesses and no single method is capable of measuring all of the required aspects.

These measures are lagging indicators.

Leading vs. Lagging indicators

Leading Indicator:

- An indicator of performance that might predict future success.

Examples:

- User guide usage
- Calories per day
- Using safety equipment

Lagging Indicator:

- An indicator of *past* performance that measures how we performed.

Examples:

- Customer satisfaction
- Weight
- Number of deaths

Leading and *Lagging* indicators are time-based

Question:

Safety metrics: Classify the following as either leading or lagging safety metrics. Explain why.

a. Number of reports of unsafe activities in a plant

b. Number of near-miss incidents

c. Money spent on insurance claims

d. Number of visits to the plant first aid facility

e. Number of process alarms that were managed without incident

f. Time duration to complete maintenance.

Accident and Loss Statistics

Name	Definition
Fatality	Injuries or illnesses that result in death, regardless of the time between the injury and death or the length of the illness.
Injury	Any injury, such as a cut, fracture, sprain, amputation, and so forth, that results from a work-related event or from a single instantaneous exposure in the work environment.
Illness	Any abnormal condition or disorder caused by exposure to factors associated with employment, other than those resulting from an instantaneous event or exposure. This includes acute and chronic illnesses or diseases.

Accident and Loss Statistics

$$\text{Fatality rate} = \frac{\text{Number of fatalities per year}}{\text{Total number of people in applicable population}}$$

The fatality rate, or deaths per person per year, is independent of the number of hours exposed to the hazard and reports only the fatalities expected per person per year

$$\text{Worker-based fatal injury rate} = \frac{\text{Total number of fatalites during period}}{\text{Total number of employees}} \times 100{,}000 \text{ workers}$$

Accident and Loss Statistics

It can also be defined in hours: Total hours worked by 100,000 full-time equivalent workers

For 100,000 workers working 40 hours per week and 50 weeks per year

$$\text{Hours-based fatal injury rate} = \frac{\text{Total number of fatalites during period}}{\text{Total hours worked by all employees}} \times 200{,}000{,}000 \text{ hours}$$

- Hours-based fatal injury rates are generally considered more applicable than worker-based fatal injury rates.

Why?

If there are high percentage of part-time workers

Accident and Loss Statistics

The incidence rate is based on the cases per 100 workers

A worker year is assumed to contain 2000 hours (50 work weeks/year × 40 hours/week)
100 worker years × 2000 hours/year = 200,000 hours

$$\text{Incidence rate} = \frac{\text{Number of incidents during period}}{\text{Total hours worked by all employees}} \times 200{,}000 \text{ hours}$$

- The incidence rate is typically used for accidents involving injuries or illnesses

Accident and Loss Statistics

Industry	Total fatalities	Hours-based fatal injury rate[a]	Total recordable incidence rate[b]
All Industries	**4836**	**3.4**	**3.3**
Construction (overall)	937	10.1	3.5
Transportation and warehousing	765	13.8	4.5
Agriculture, forestry, fishing, and hunting	570	22.8	5.7
Truck transportation	546	25.2	4.3
Professional and business services	477	3.0	1.4
Manufacturing	353	2.3	3.8
Government (state and local)	338	2.2	5.1
Retail trade	269	1.8	3.5
Leisure and hospitality	225	2.0	3.5
Wholesale trade	175	4.7	3.1
Government, federal	118	1.3	
Restaurants and other food services	100	1.4	3.0
Police and sheriff's patrol officers	85	11.7	5.8
Financial activities	83	0.9	1.1
Carpenters	83	6.7	
Electricians	83	10.7	2.8
Professional, scientific, and technical services	76	0.8	0.9
Roofers	75	39.7	5.6
Taxi drivers and chauffeurs	54	13.4	2.4
Information	42	1.5	1.3
Fire fighters	29	4.3	9.2
Mining (except oil and gas)	28	12.4	2.6
Chemical manufacturing	28	2.0	2.1
Fishing, hunting, and trapping	23	54.8	4.4
Utilities	22	2.2	2.2
Hospitals	21	0.4	8.1
Colleges, universities, and professional schools	17		1.8
Plastics and rubber products manufacturing	17	3.3	4.3
Oil and gas extraction	6		0.7
Chemical and allied products merchant wholesalers	3		2.2

[a] Rate per 100,000 full-time equivalent workers based on exposure hours.

[b] Rate per 100 worker years = 200,000 hours.

Source: U.S. Bureau of Labor Statistics, www.bls.gov/iif/.

Accident and Loss Statistics

2015 Fatal Occupational Injuries Related to the U.S. Chemical Industry

Chemical industry	Fatalities
Gasoline Stations (Retail)	39
Chemical Manufacturing	28
Fertilizer manufacturing	6
Basic chemical manufacturing	5
Soap, cleaning compound, and toilet prep manufacturing	4
Pharmaceutical and medicine manufacturing	3
Paint, coating, and adhesive manufacturing	2
Industrial gas manufacturing	1
All other chemical manufacturing	7
Plastics Manufacturing	13
Petroleum and Coal Products Manufacturing	12
Asphalt paving mixture and block manufacturing	5
Petroleum refineries	4
Asphalt shingle and coating materials manufacturing	3
Petroleum and Petroleum Products Merchant Wholesalers	9
Crude Petroleum and Natural Gas Extraction	6
Rubber Product Manufacturing	4
Chemical and Allied Products Merchant Wholesalers	3

Source: U.S. Bureau of Labor Statistics, www.bls.gov/iif/.

Question:

A company employs 1000 full-time employees. If the company has one fatality over a one-year time period, calculate (a) the worker-based fatal injury rate and (b) the hours-based fatal injury rate. If the company has one recordable injury rate in that same year, calculate (c) the total recordable incidence rate.

Risk Perception

The actual risk associated with the chemical industry is generally much less than that perceived by the public.

The chemical industry is held to a higher safety standard than other industries

Risk Tolerance

Risk tolerance or acceptance: the maximum level of risk of a particular technical process or activity that an individual or organization accepts to acquire the benefits of the process or activity.

A risk matrix is a semi-quantitative method to represent risk and to help companies make risk acceptance decisions

Risk Matrix: Risk Matrix for Semi-Quantitative Classification of Incidents

Risk Matrix 1. Select the severity from the highest box in either of columns 1, 2, or 3. Read the Category and Safety Severity Level from the same row. 2. Select the likelihood from columns 4 through 7. 3. Read the Risk Level from the intersection of the severity row and the likelihood column. TMEF: Target mitigated event frequency (yr^{-1}). TQ: Threshold quantity—see Table 1-15.						Likelihood			
						4 **LIKELY** **Expected to happen several times over the life of the plant**	**5** **UNLIKELY** **Expected to happen possibly once over the life of the plant**	**6** **IMPROBABLE** **Expected to happen possibly once in the division over the life of the plant**	**7** **IMPROBABLE, BUT NOT IMPOSSIBLE** **Not expected to happen anywhere in the division over the life of the plant**
Severity	**1** **Human health impact**	**2** **Fire, explosion direct cost ($)**	**3** **Chemical impact**	**Severity category**	**Safety severity level**	0–9 years	10–99 years	≥ 100 years	> 1000 years
	Public fatality possible, employee fatalities likely	Greater than $10 million	≥ 20 × TQ	Catastrophic	**4** TMEF = 1×10^{-6}	Risk level A	Risk level A	Risk level B	Risk level C
	Employee fatality possible, major injury likely	$1 million to < $10 million	9 × to < 20 × TQ	Very serious	**3** TMEF = 1×10^{-5}	Risk level A	Risk level B	Risk level C	Risk level D
	Lost time injury (LTI) likely[a]	$100,000 to < $1 million	3 × to < 9 × TQ	Serious	**2** TMEF = 1×10^{-4}	Risk level B	Risk level C	Risk level D	Negligible risk
	Recordable injury[b]	$25,000 to < $100,000	1 × to < 3 × TQ	Minor	**1** TMEF = 1×10^{-3}	Risk level C	Risk level D	Negligible risk	Negligible risk

Risk level A: Unacceptable risk; additional safeguards must be implemented immediately.
Risk level B: Undesirable risk; additional safeguards must be implemented within 3 months.
Risk level C: Acceptable risk, but only if existing safeguards reduces the risk to as low as reasonably practicable (ALARP) levels.
Risk level D: Acceptable risk, no additional safeguards required.

[a]Lost time injury (LTI): The injured worker is unable to perform regular job duties, takes time off for recovery, or is assigned modified work duties while recovering.
[b]Recordable injury: Death, days away from work (DAW), restricted work or transfer to another job, medical treatment beyond first aid, or loss of consciousness.

Risk Matrix

The chemical impact is based on a chemical release quantity called a threshold quantity (TQ).

1. Select the severity levels from columns 1, 2, and 3 and select the highest level from any of these columns.

2. Read the Risk Category and Safety Severity Level from the highest row.

3. Select the likelihood from columns 4 through 7.

4. Read the risk level from the intersection of the Safety Severity Level row and the Likelihood column

2000 kg = 4400 lb_m

Acrylamide
Ammonium nitrate fertilizer
Amyl acetate
Amyl nitrate
Bromobenzene
Calcium oxide
Carbon dioxide
Carbon, activated
Chloroform
Copper chloride
Kerosene
Maleic anhydride
n-Decane
Nitroethane
Nitrogen, compressed
Nitrous oxide
Nonanes
Oxygen, compressed
Paraldehyde
Phosphoric acid
Potassium fluoride
Potassium nitrate
Sulfur
Tetrachloroethylene
Undecane

200 kg = 440 lb_m

Ammonia, anhydrous
Carbon monoxide

5 kg = 11 lb_m

Acrolein
Arsine
Diborane
Dinitrogen tetroxide
Methyl isocyanate
Nitric oxide, compressed
Nitrogen trioxide
Phosgene
Phosphine
Stibine

1000 kg = 2200 lb_m

Acetic anhydride
Acetone
Acetonitrile
Aldol
Ammonium perchlorate
Aniline
Arsenic
Barium
Benzene
Benzidine
Butyraldehyde
Carbon tetrachloride
Copper chlorate
Copper cyanide
Cycloheptane
Cycloheptene
Cyclohexene
Dioxane
Epichlorohydrin
Ethyl acetate
Ethyl benzene
Ethylenediamine
Formic acid
Heptane
Hexane
Methacrylic acid
Methyl acetate
n-Heptene
Nitrobenzene
Nitromethane
Octanes
Phenol, molten or solid
Propylamine
Pyridine
Silver nitrate
Sodium permanganate Tetrahydrofuran
Tetrahydrofuran
Toluene
Triethylamine
Vinyl acetate
Zinc peroxide

500 kg = 1100 lb_m

Acetaldehyde
Acrylonitrile
Calcium cyanide
Carbon disulfide
Cyclobutane
Diethyl ether or ethyl ether
Ethane
Ethylamine
Ethylene
Furan
Hydrazine, anhydrous
Hydrogen, compressed
Lithium
Methylamine, anhydrous
Potassium
Potassium cyanide
Propylene oxide
Silane
Sodium
Sodium cyanide
Sodium peroxide
Trichlorosilane

100 kg = 220 lb_m

Hydrogen bromide, anhydrous
Hydrogen chloride, anhydrous
Hydrogen fluoride, anhydrous
Methyl bromide
Methyl mercaptan
Sulfur dioxide

25 kg = 55 lb_m

Chlorine
Cyanogen
Germane
Hydrogen sulfide
Nitric acid, red fuming
Sulfuric acid, fuming

Source: AICHE/CCPS. Details on how to compute the TQ are available from *AICHE/CCPS Process Safety Metrics: Guide for Selecting Leading and Lagging Indicators* (New York, NY: American Institute of Chemical Engineers, 2018).

Question:

A risk analysis is performed on an incident involving a hole in a storage vessel containing a specific chemical.

The chemical has a TQ of 5 lb_m. Calculations for this hole release estimate a total release of 50 lb_m of chemical. An employee fatality is possible with such a release, and the fire and explosion direct cost is estimated at $150,000. This incident is expected to occur once over the life of the plant. Use the risk matrix in Table(shown in previous slide) to determine the risk category, safety severity level, TMEF, and risk level.

Codes, Standards, and Regulations

A code: set of recommendations developed by a team of knowledgeable people, who are most likely to be associated with an industrial professional organization.

Codes do not have legal authority, but governments might adopt one by turning it into law.

A standard : more elaborate, explaining in a lot more detail how to meet the code. That is, codes tell you what you need to do, and standards tell you how to do it.

Standards do not carry the weight of legal authority, but governments might adopt them by turning them into laws.

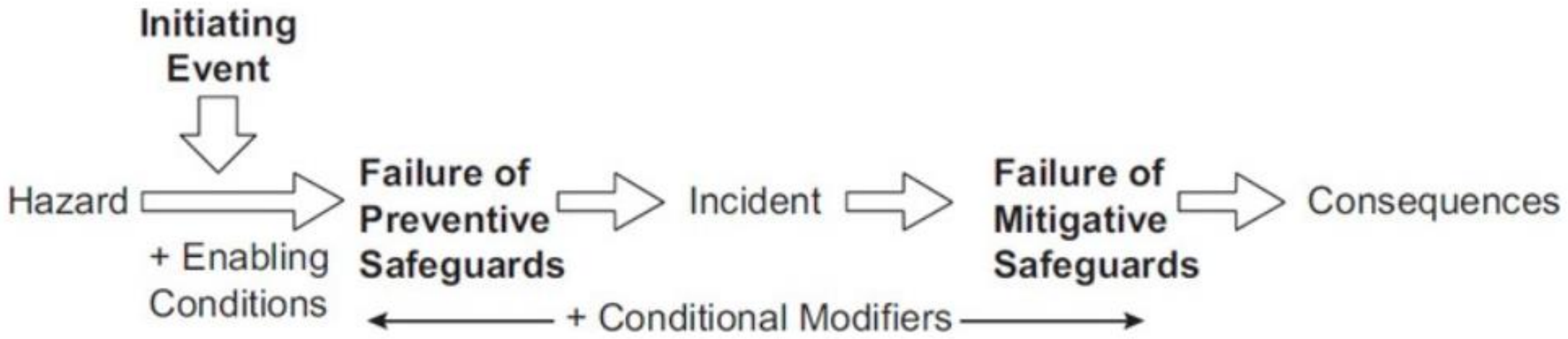
A regulation: Developed by a government and has legal authority.

It may be based on a code or standard.

Violations of regulations could result in fines and/or jail time.

Safeguards

The sequence of events in an incident:



The initiating event, or cause: a device failure, system failure, external event, or improper human inaction that begins a sequence of events leading to one or more undesirable outcomes. Caused by internal plant events such as operational problems, equipment failures, human error, and design deficiencies

The enabling conditions : operating conditions necessary for an initiating cause to propagate into a hazardous event. Enabling conditions do not independently cause the incident, but must be present or active for it to proceed. Such conditions are represented as probabilities.

Conditional modifiers: conditions that occur after initiation and impact a step in the sequence either before or after the incident has occurred.
Could include weather conditions (wind direction and speed), presence of people, and probability of ignition, among other factors.

Safeguards

A safeguard is a design feature, equipment, procedure, or even software that is in place to prevent or mitigate the consequences of an initiating event.

Two types of safeguards:

1. Preventive

2. Mitigative

A preventive safeguard (also called a protection layer) intervenes after the initiating event to stop the event from developing further into an incident.

A mitigative safeguard is a safeguard that reduces the consequences after an incident has occurred.

Safeguards

Preventive Safeguards: Prevents an initiating event from proceeding to a defined, undesirable incident; also called a protection layer.

- Basic process control system (BPCS)
- Safety instrumented functions (SIF)
- Safety instrumented systems (SIS)
- Alarm systems
- Operator response to an alarm or process conditions
- Pressure relief system with containment (may also be considered mitigative)
- Procedures
- Maintenance
- Interlocks
- Emergency shutoff valves
- Flame/detonation arresters
- Inhibitor addition to reactor
- Emergency cooling systems
- Vapor inerting and purging to prevent flammable mixtures
- Grounding and bonding to prevent static accumulation
- Normal testing and inspection

Mitigative Safeguards: Reduce the consequences after an incident has occurred.

- Active fire protection, including sprinklers, sprays, foams, and deluges
- Emergency fire water system
- Passive fire protection including insulation
- Flammable vapor detectors
- Emergency response, including on-site and off-site
- Plant and equipment layout and spacing
- Diking around storage areas/processes
- Emergency power
- Blast walls
- Water curtains to disperse vapors
- Blast resistant control rooms
- Explosion blow-out panels on process vessels

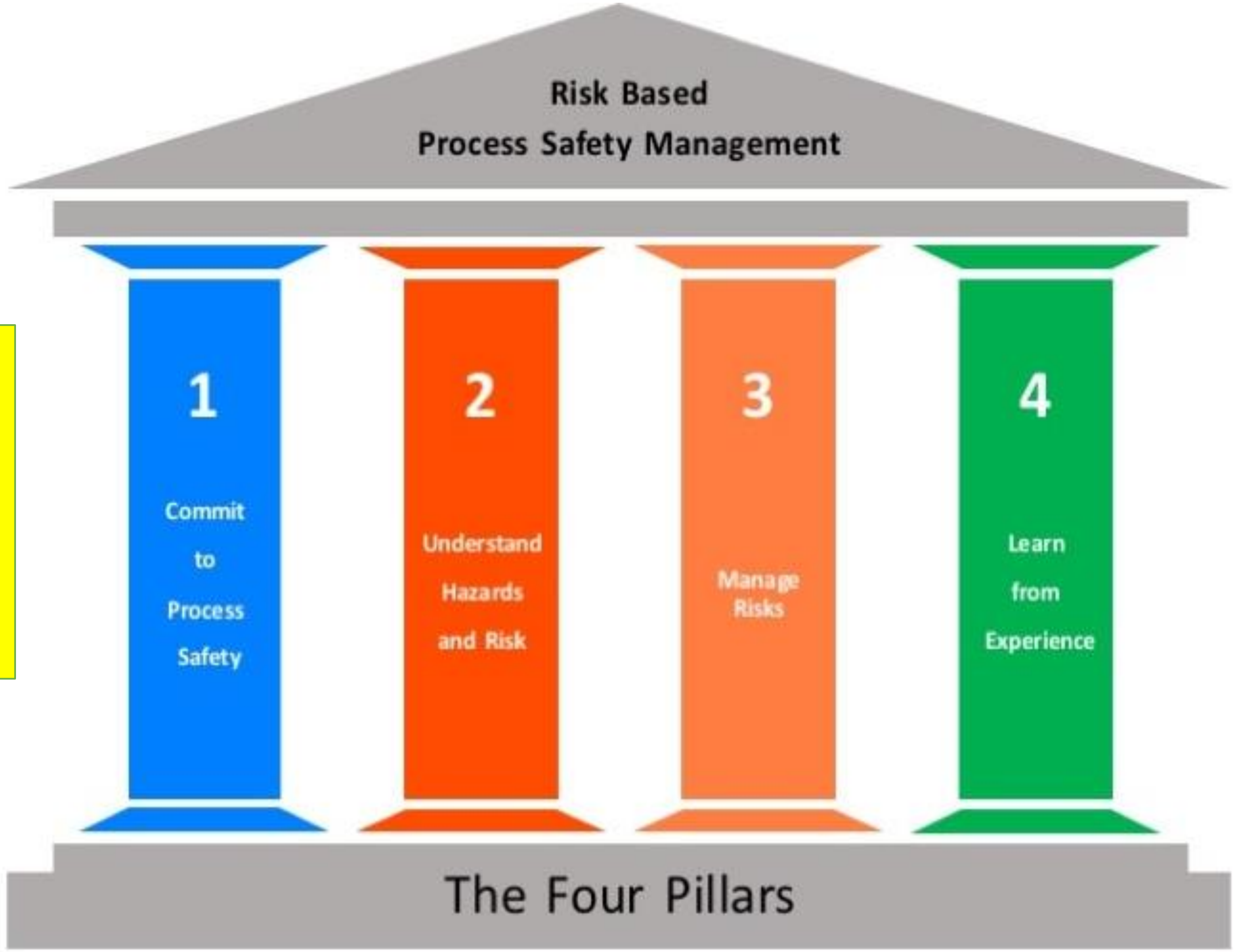
Question:

Safeguards: Classify the following safeguards as either preventive or mitigative.

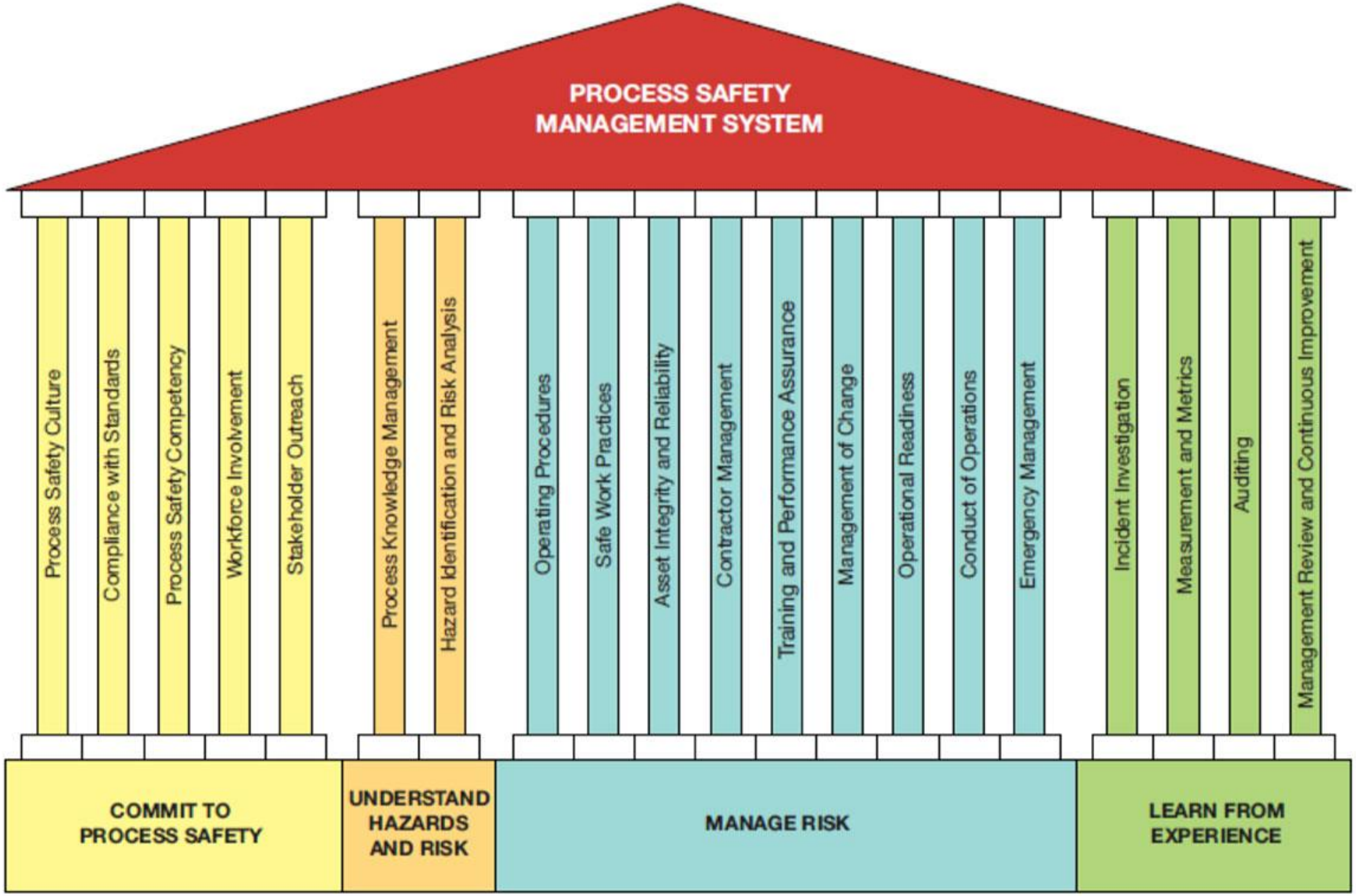
a. A safety instrumented system to shut down a process if an unsafe operating condition occurs.
b. A foam system to reduce evaporation from a pool of leaked hydrocarbon.
c. A dike around a storage vessel.
d. A flow limiter is installed on a feed line to a chemical reactor to ensure that the reaction rate does not exceed a maximum value.
e. Covers are placed over pipe flanges to prevent liquid spraying.
f. A containment pond is built to collect any liquid runoff from a plant.
g. A relief device is installed on a chemical reactor to protect the reactor vessel from the damaging effects of high pressure.
h. A containment system is installed to collect the effluent from a relief device.
i. The basic process control system.
j. An emergency alarm system.
k. An alarm system to notify the operator of out-of-limits process conditions.
l. A gas chromatograph is installed to confirm chemical concentrations in a process.
m. All plant operations personnel are given yearly emergency response training.

The CCPS 20 Elements of Risk-Based Process Safety

In 2007, the AICHE
Center for Chemical Process Safety
published *Guidelines for Risk Based Process Safety*



The CCPS 20 Elements of Risk-Based Process Safety



The CCPS 20: Commit to Process Safety

Process Safety Culture: A positive environment in which employees at all levels are committed to process safety.

Typical Activities Associated

Develop or deploy corporate process safety culture programs.

Identify process safety culture issues and influence corporate changes.

Maintain a strong process safety culture among team members.

Conduct formal assessments to identify gaps and recommend improvements in the process safety culture.

Compliance with Standards: Applicable regulations, standards, codes, and other requirements issued by national, state/provincial, and local governments; consensus standards organizations; and the company itself.

Typical Activities Associated

Interpret or apply standards for internal use.

Participate in standards development.

Develop a system to identify standards and uniformly administer and maintain the information.

The CCPS 20: Commit to Process Safety

Process Safety Competency: **Skills and resources that the company needs to have in the right places to manage its process hazards. Verification that the company collectively has these skills and resources.**

Develop a training program to increase workers' level of competency.

Typical Activities Associated

Develop competency profiles for critical process safety positions.

Evaluate a unit to determine gaps in competency.

Workforce Involvement: **Broad involvement of operating and maintenance personnel in process safety activities, to make sure that lessons learned by the people closest to the process are considered and addressed.**

Develop, lead, or participate in organizing workforce involvement efforts at the corporate, business, plant, or unit level.

As a supervisor, regularly lead discussions around process safety concerns or issues with operating personnel.

As a worker, provide constructive feedback aimed at improving process safety and track feedback to resolution.

Typical Activities Associated

The CCPS 20: Commit to Process Safety

Stakeholder Outreach: A process for identifying, engaging, and maintaining good relationships with appropriate external stakeholder groups.

Lead community action panel (CAP) meetings.

Work with the local community to create an area CAP and facilitate meetings.

Develop site or corporate practices or standards to coordinate and manage major off-site accident risks, to include communications with stakeholders.

Coordinate an emergency response simulation or drill in the community.

Typical Activities Associated

Thank You

Think Safe !

Be Safe!

Thanks Google : For the images used in slides