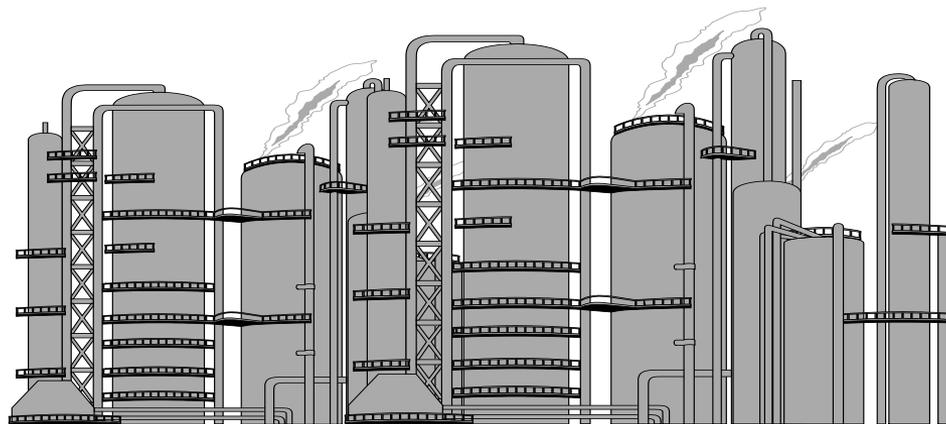


# The Bhopal gas Tragedy: A safety case study

Omar Basha

Jawaher Alajmy

Tahira Newaz

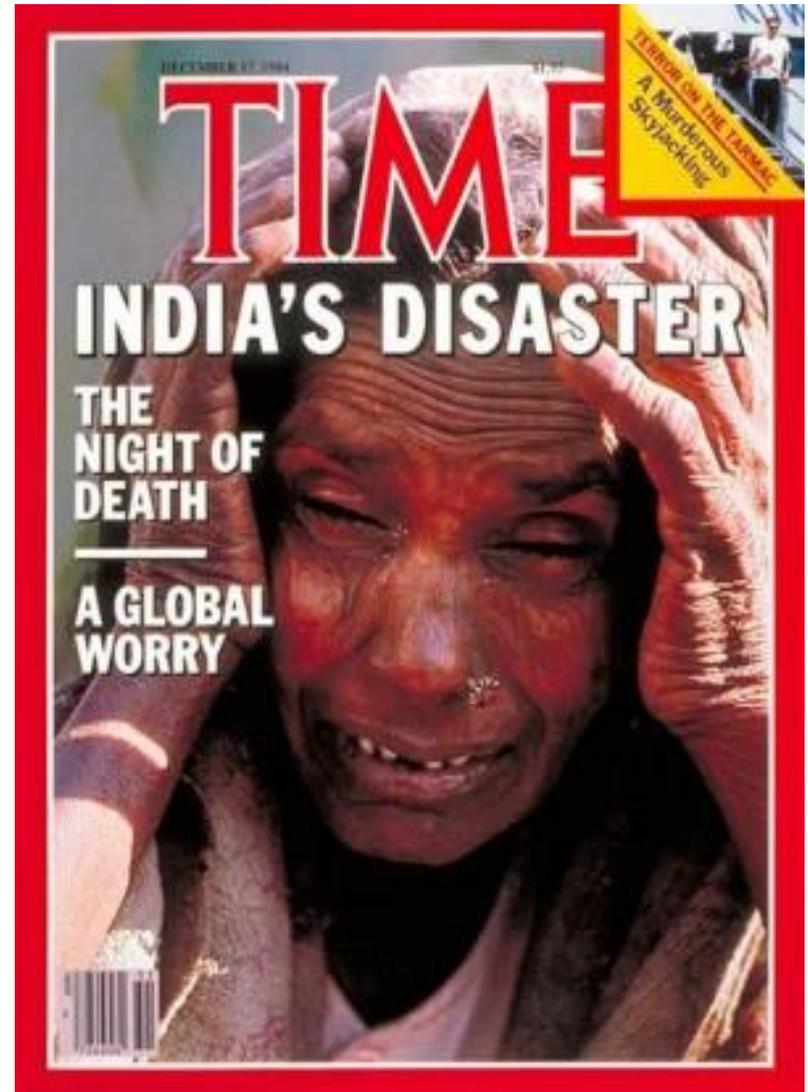


# Outline

- Introduction
- Background
- The leak
- Bhopal: Investigations and Lessons
- Observations from Bhopal
- Conclusion
- References

# The Tragedy

- On December 3 1984, Bhopal: MIC, a major component for the production of the pesticide Sevin escaped from Union Carbide's plant
- 2000 died immediately
- 50,000 permanent disabilities
- 300,000 injured
- History's worst industrial accident
- Revolutionized process safety



# Union Carbide comes to India : 1972

- Part of the Green Revolution
- UCIL: 50.9% subsidiary of the Union Carbide Corporation
- Fully Operated by Indian Labor
- Located in Bhopal



## Science helps build a new India

Oxen working the fields . . . the eternal river Ganges . . . jeweled elephants on parade. Today these symbols of ancient India exist side by side with a new sight—modern industry. India has developed bold new plans to build its economy and bring the promise of a bright future to its more than 400,000,000 people. ▶ But India needs the technical knowledge of the western world. For example, working with Indian engineers and technicians, Union Carbide recently made available its vast scientific resources to help build a major chemicals and plastics plant near Bombay. ▶ Throughout the free world, Union Carbide has been actively engaged in building plants for the manufacture of chemicals, plastics, carbons, gases, and metals. The people of Union Carbide welcome the opportunity to use their knowledge and skills in partnership with the citizens of so many great countries.

A HAND IN THINGS TO COME

WRITE for booklet B-3 "The Existing Universe of Union Carbide," which will show research in the fields of carbons, chemicals, gases, metals, plastics and nuclear energy being brought new wonders into your life.

Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y.

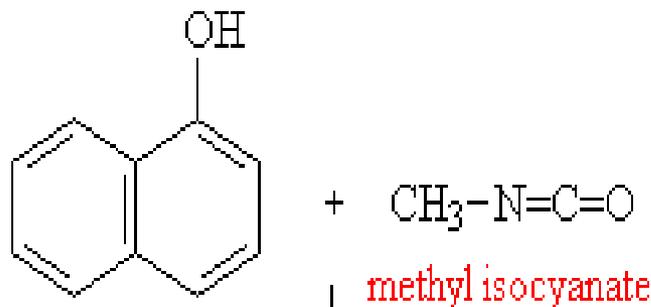
UNION  
CARBIDE

# Location



# The Sevin Process

Ingredients:



Carbon Monoxide (CO)

Monomethylamine (MMA)

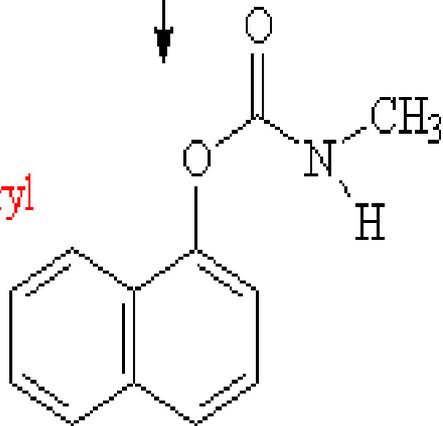
} imported by truck

Chlorine (Cl<sub>2</sub>)

Alpha-Naphthol (AN)

} made on site

Carbaryl



→ Process route

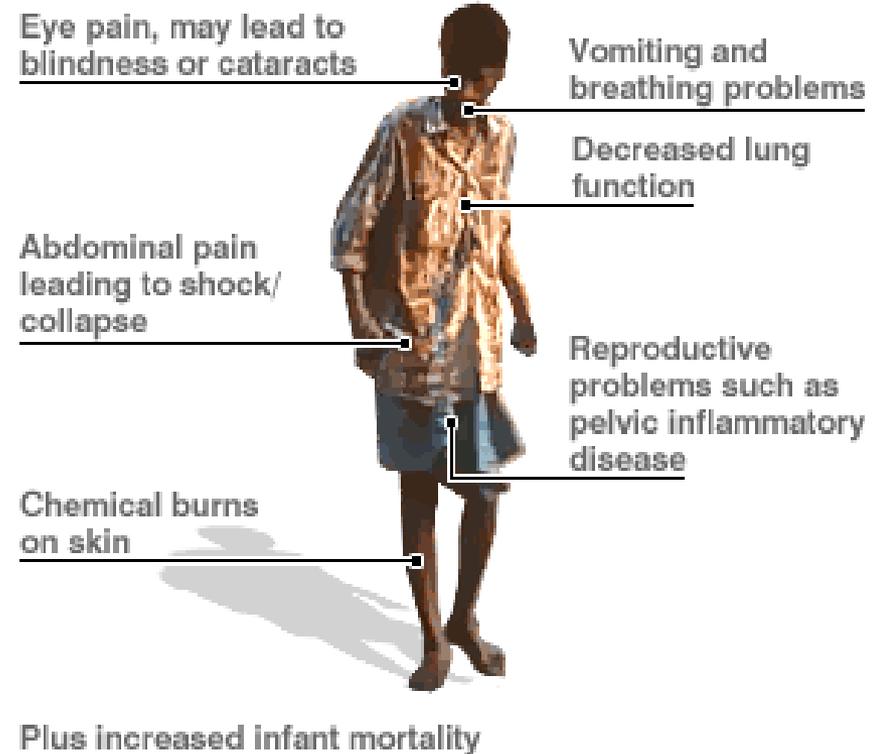


MIC stored in three 15,000 gal tanks

# MIC Toxicity

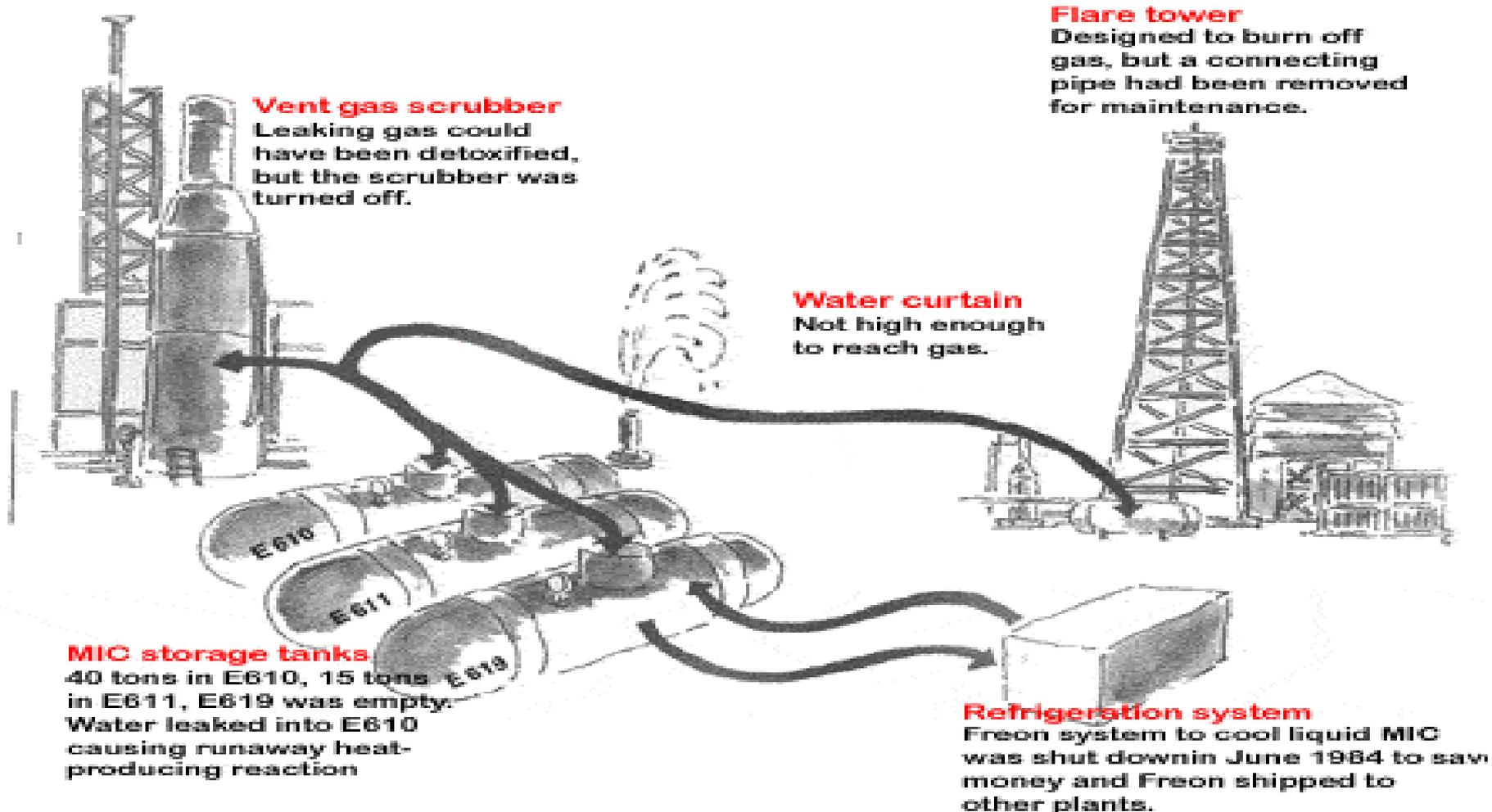
MIC is one of the most toxic and lethal substances known to humans:

- Adverse to health when inhaled than ingested
- Vaporizes at room temperature, exists as odorless, colorless, resulting in watering of the eyes and irritation of the throat
- OSHA exposure limit = 0.02ppm (8 hour period)
- Reacts with water exothermically in a violent runaway reaction



SOURCE : US Environmental Protection Agency

# Available Safety Systems



# Previous Warnings & Accidents

- 6 accidents occurred before the catastrophe
- 1981: One worker died after being exposed to phosgene gas
- 1982: 24 workers exposed to phosgene
- 1982: engineer burned by MIC
- October 1982: Operator trying to fix leak in valve received severe burns

# Leak Timeline

*December 2, 1984:*

8-9 pm: The MIC plant supervisor was ordered to wash out several pipes running from the phosgene system to the scrubber through the MIC storage tanks.

9:30 pm: The water washing begins. One of the bleeder valves (overflow device) was blocked.

11 pm: The operator in the control room noticed pressure gauge connected to Tank E610 had risen from 2 psi to 10 psi.

11.30 pm: The unit workers in the area noticed MIC's smell and saw an MIC leak near the scrubber.

# Leak Timeline (Cont.)

- 12.15-12:30 am: The control room operator noticed that control room pressure indicator for Tank E610 reads 25-30 psi.
- 12.40 am: The plant supervisor turned on the in-plant and external toxic gas sirens. The operators also turned on the fire water sprayer.
- 1 am: Plant supervisor realized that the spare tank, E619, was also not empty, so workers failed to reduce the pressure in E610 by transferring any MIC to E619.
- 1.30 am: Bhopal police chief was informed of the leak; no significant police mobilization was followed.
- 8 am: Madhya Pradesh governor ordered closure of the plant and arrest of the plant manager and 4 other employees.

# The Release

- Water entered V-610 at a high enough level to start a polymerization reaction.
- The tank contents were initially at ambient temperatures and the runaway progressed unchecked because there was no cooling on V-610.
- The heat of reaction boiled the MIC monomer and 54,000 lbs of MIC was released.

# The Disaster: Contributing Factors

## Human Error

- Critical isolation valve not closed before pipes were flushed with water, causing the fatal pressurization of tank containing MIC.
- Flare for flame neutralization of escaping gas was shut down

## Inadequate Safety Equipment

- Reach of sprayer for water neutralization of escaping gas was inadequate. Plant managers were aware of deficiency.
- Flare system lacked capacity for major gas leak.

## Failure of Safety Equipment

- Stack scrubber, activated by operator during leak, failed.

## Poor Maintenance

- Tank refrigerators inoperable; had been drained of freon
- Blockage in pipes meant to drain water that pressurized tank

# The Disaster: Contributing Factors (cont.)

## Inadequate Staffing

- Union-Carbide-trained supervisors had left Bhopal by 1984
- Staffing in MIC unit had been cut below half of recommended level
- Second-shift maintenance supervisor position eliminated weeks before disaster

## Lack of Evacuation Plans

- Visiting Union Carbide engineers repeatedly stressed need for a plan to alert and evacuate population in the event of a gas leak
- UCIL claimed to have developed such plans
- City and state officials claimed no knowledge of such plans

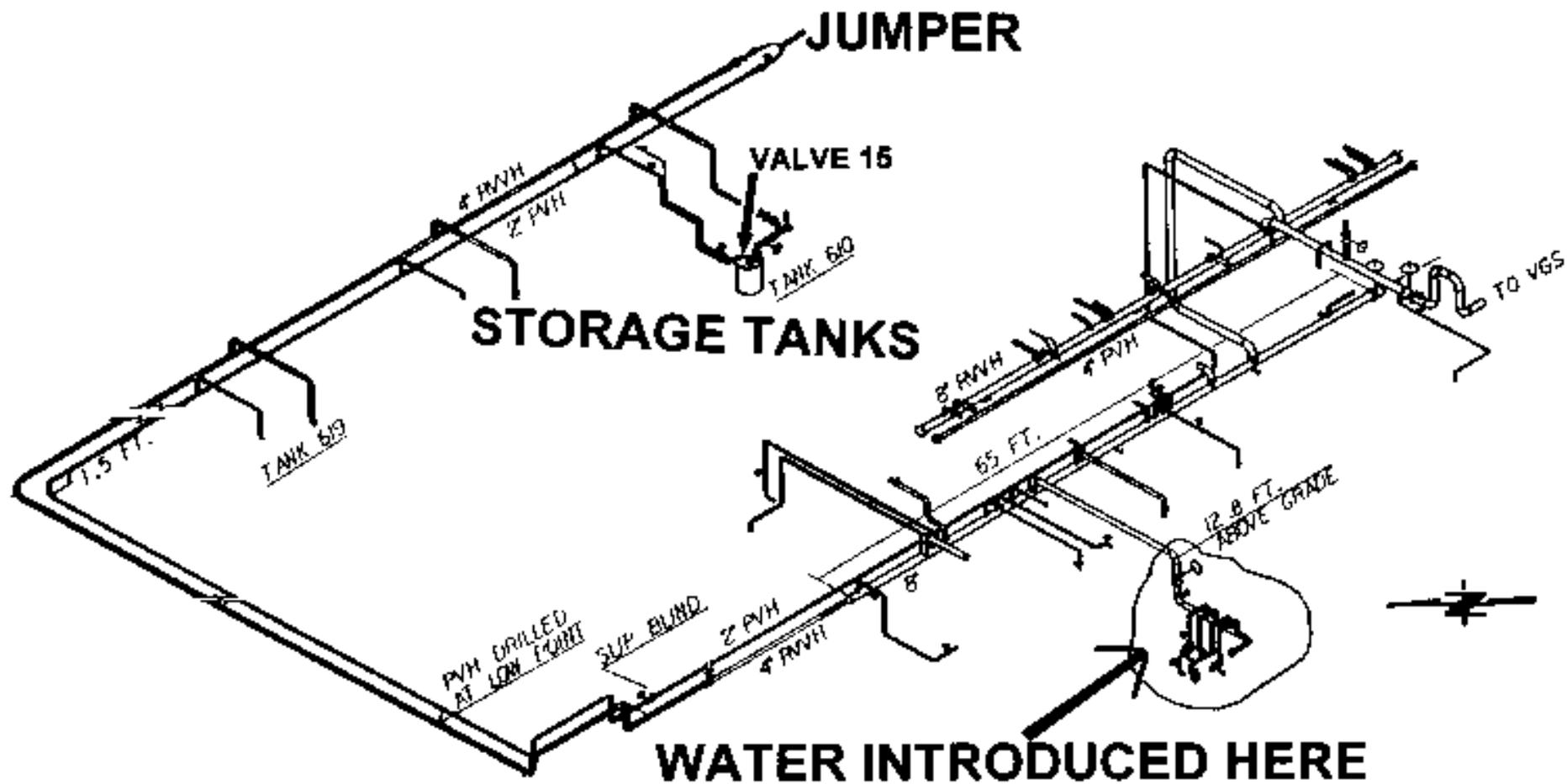
## Inadequate Response

- Warning siren activated upon leak, but only for a few minutes
- Public response panicked, evacuation slow and uncoordinated
- Response of medical workers hampered by lack of info about MIC

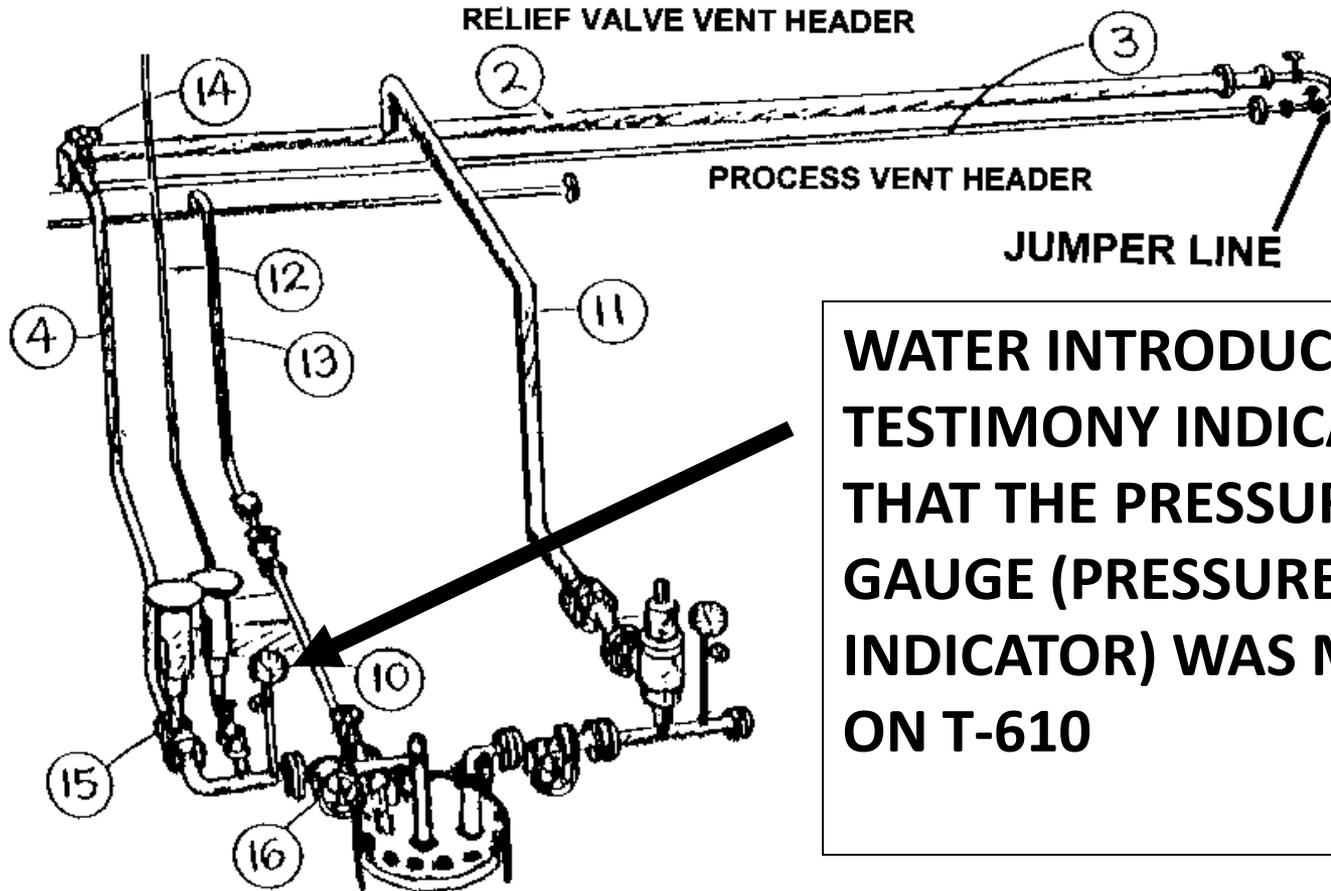
# Investigation

- *New York Times* – large volume of water entered tank 610 causing the accident
  - “Water Washing Theory” - Employee violates policy and fails to use slip blind
- Union Carbide – large volume of water entered tank 610 causing the accident
  - Accident
  - Deliberate connection
  - Reveals several cover ups and possible sabotage by disgruntled employee
- Indian Government – similar to *New York Times*

# The Water Washing Theory



# Sabotage Theory



**WATER INTRODUCED  
TESTIMONY INDICATED  
THAT THE PRESSURE  
GAUGE (PRESSURE  
INDICATOR) WAS MISSING  
ON T-610**

# What really happened?



# Incident Causes

- Many theories can be put forward and all mechanisms give insights into the vulnerability of the system
- Main objective is to learn from the consequences; multiple possible causes only serve to highlight the weaknesses

# Lessons learned

- Reduce inventory of hazardous material (MIC)
- Keep all the safety related equipment in order
- Keep residential areas away from the plant
- Proper Management
- Emergency training/response schemes
- Community awareness

# Conclusions

- Every business decision has safety consequences.
- A negative safety outcome is a negative business outcome.
- In order to do the right thing, politics and the local community must be assessed, understood, and protected.