

# It Happened 40 Years Ago: Why Do We Keep Revisiting Bhopal?

Purdue Process Safety and Assurance Center (P2SAC)

2024 Fall P2SAC Conference

December 4, 2024



Dr. Bruce K. Vaughen, PE, CCPS  
Center for Chemical Process Safety (CCPS)

Kenneth Bloch  
Author of *Rethinking Bhopal*

1

## Mission of Process Safety Professionals

*To reduce process safety risks that cause:*

- *Harm to people*
- *Environmental damage*
- *Asset or business losses*

*Focusing on incidents*

- *Runaway reactions*
- *Toxic releases*
- *Fires*
- *Explosions*

2

## Mission of P2SAC



*One of the few research centers on earth  
focused on the prevention of major industrial accidents.*

## Mission of CCPS



*A World Without Process Safety Incidents™*

## Mission of Today's Presentation



*What would you do to solve the issue?*

## A Very Brief History Lesson

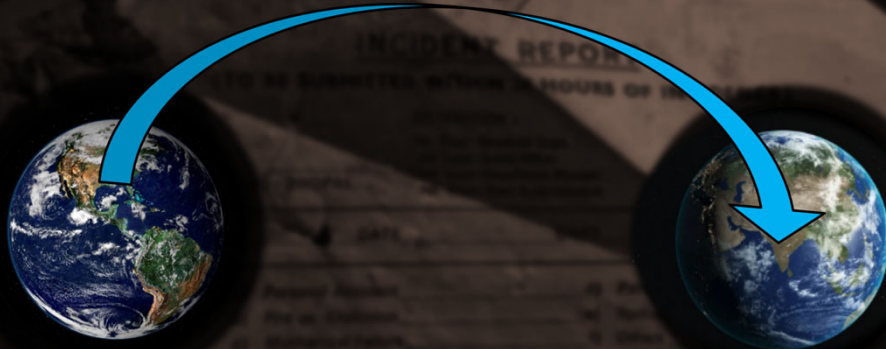
How many of you have **NOT** heard of the Bhopal incident?

In 1984, an estimated 28-ton toxic release occurred at a four-year-old plant in India.

It was the worst (and is still the worst) process safety event that has ever occurred.

There were thousands of fatalities within the first day.

## A Very Brief History Lesson



The plant in Bhopal, India was built with the same design standards as its American counterpart.

It was being *decommissioned* at the time of the toxic release.

## Outline

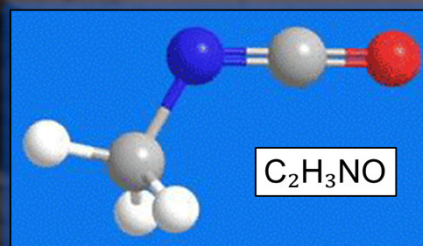
- **Hazardous Materials**
- Design Issues
  - The Equipment
  - The Procedures
  - The Safeguards
- The Incident
- Some Concluding Thoughts



## Hazardous Materials

### Methyl Isocyanate (MIC)

MIC is a *highly reactive* and *toxic* intermediate chemical used to manufacture pesticides



Serious  
Health Hazard



Acute  
Toxicity



Corrosive

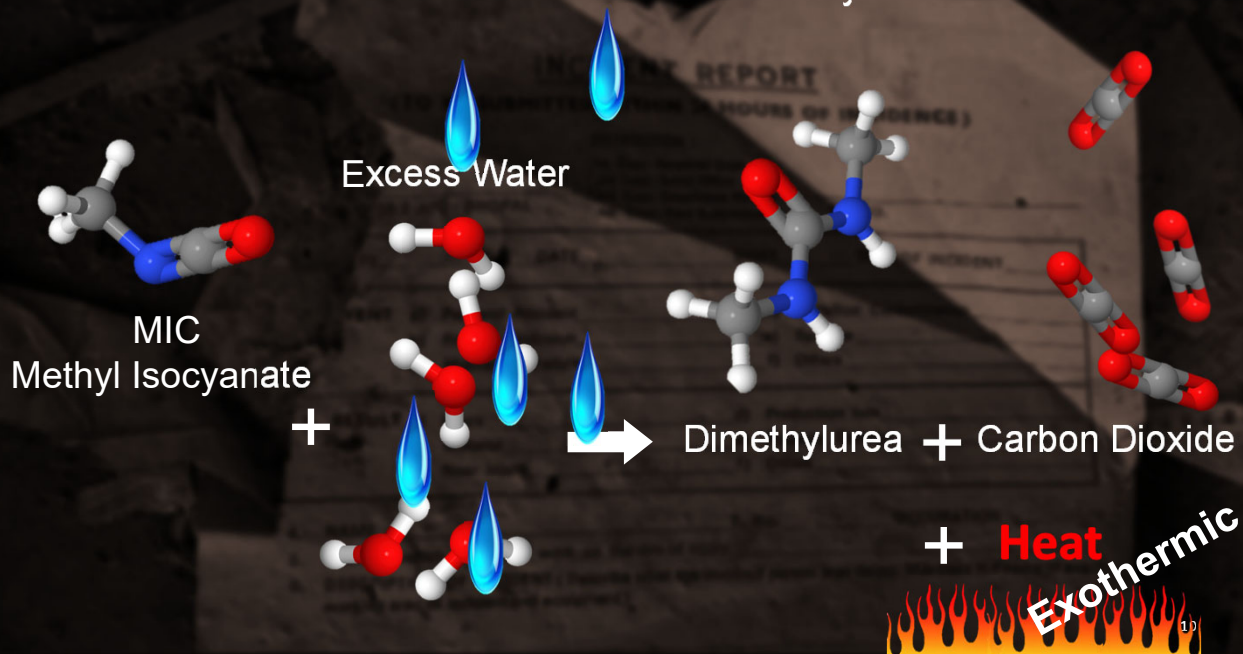


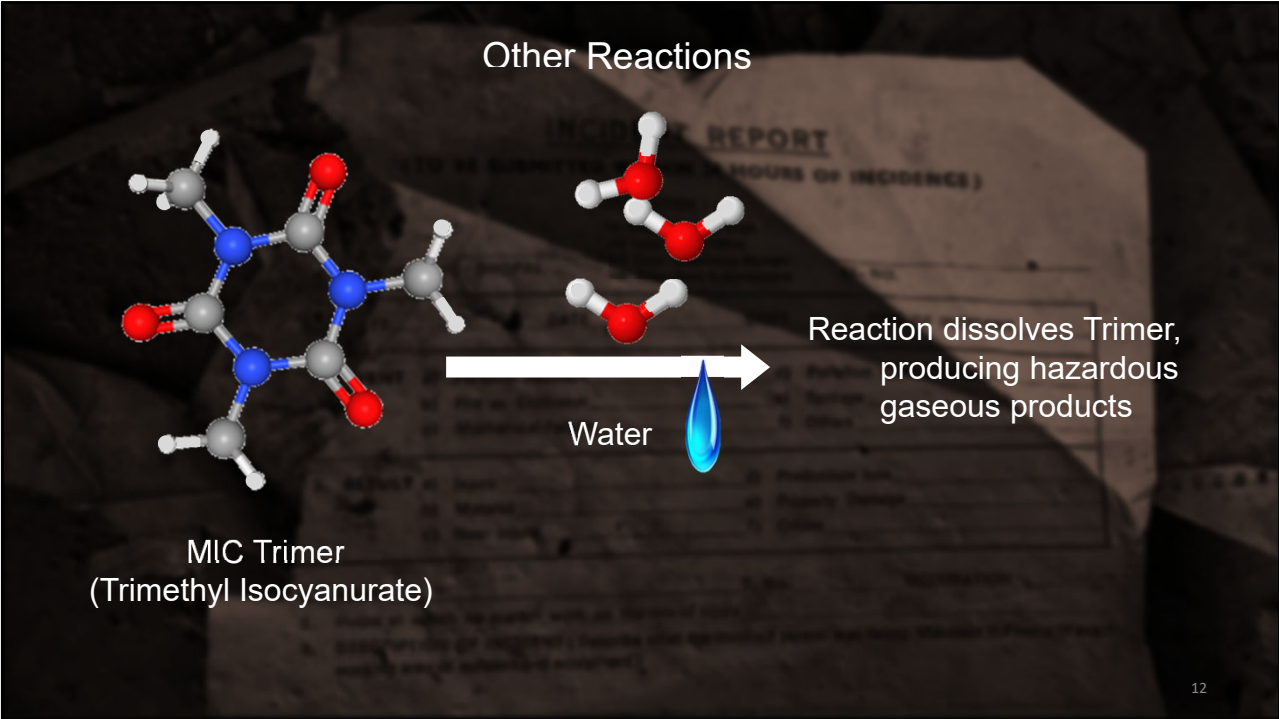
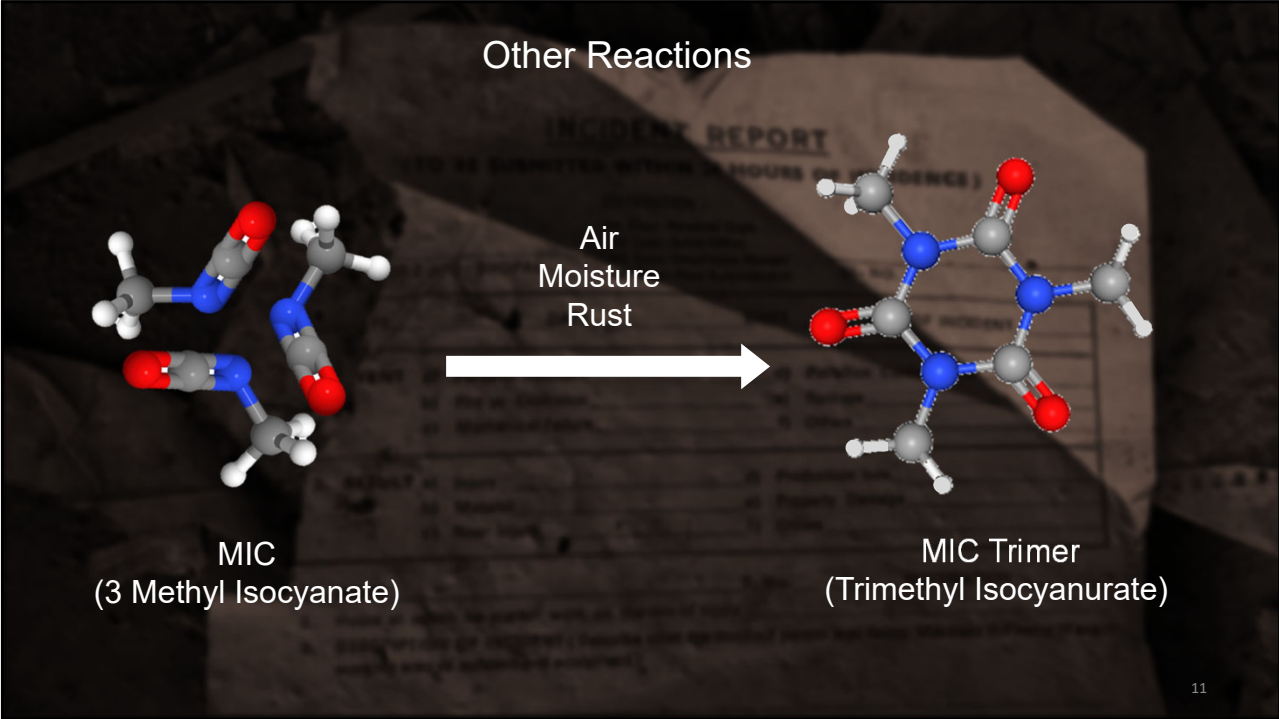
Flammable



Hazardous to  
the environment

## Known Hazardous Interaction – Runaway Reaction





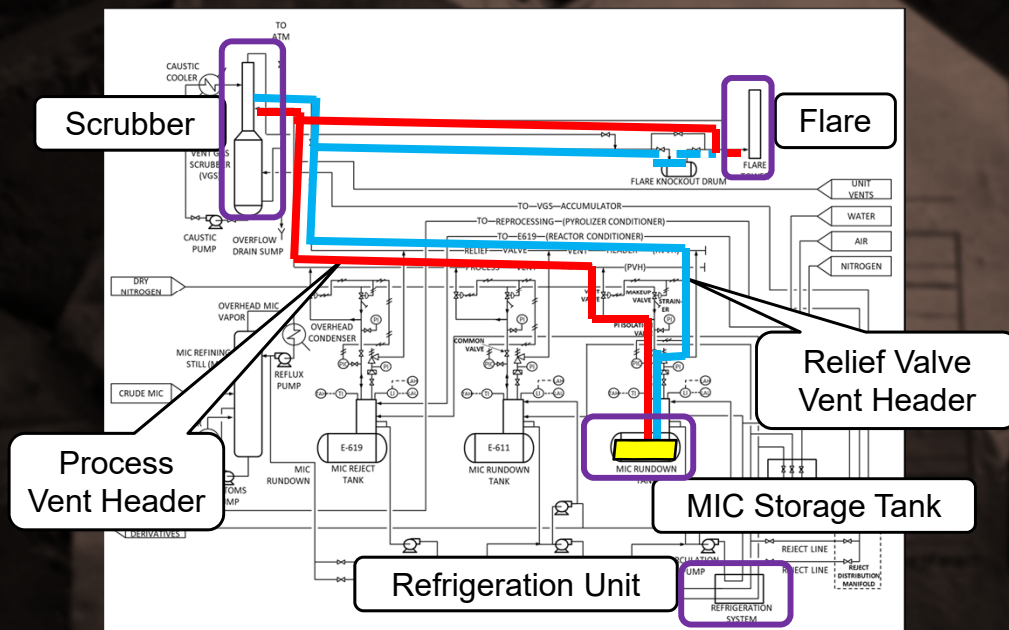
## Outline

- Hazardous Materials
- Design Issues
  - The Equipment
  - The Procedures
  - The Safeguards
- The Incident
- Some Concluding Thoughts

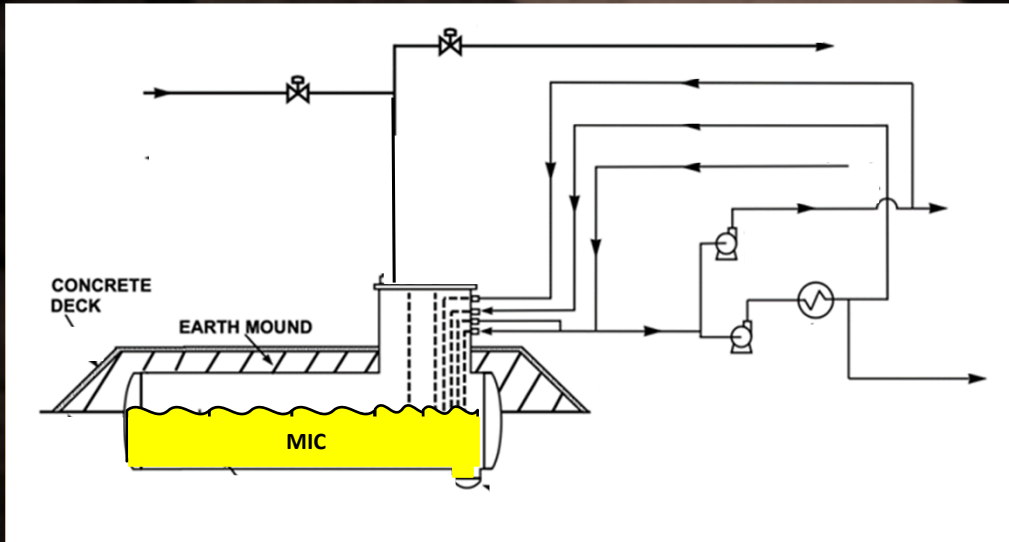


13

## An Overview of the MIC Process

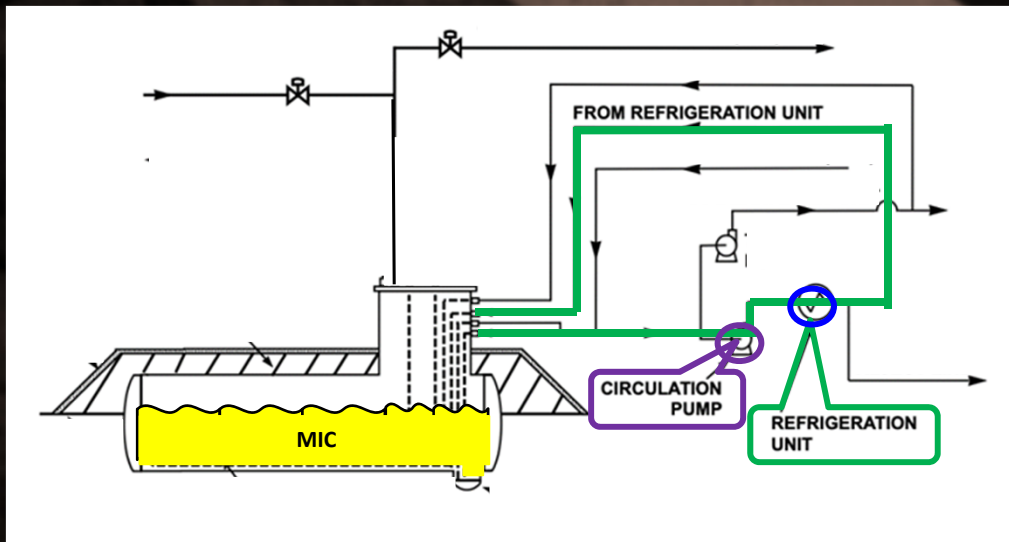


## The MIC Storage Tank



15

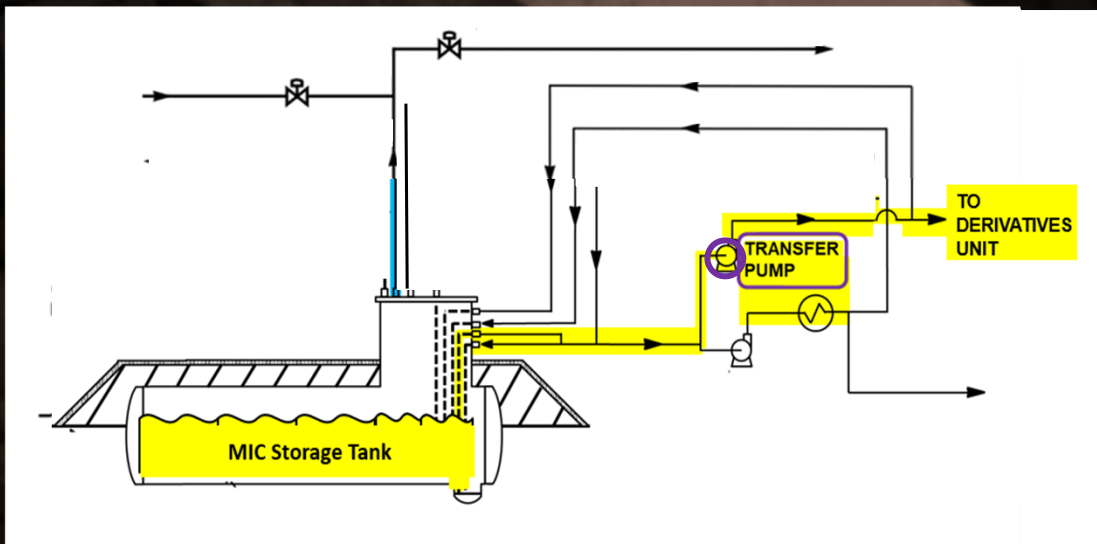
## The Refrigeration System



16

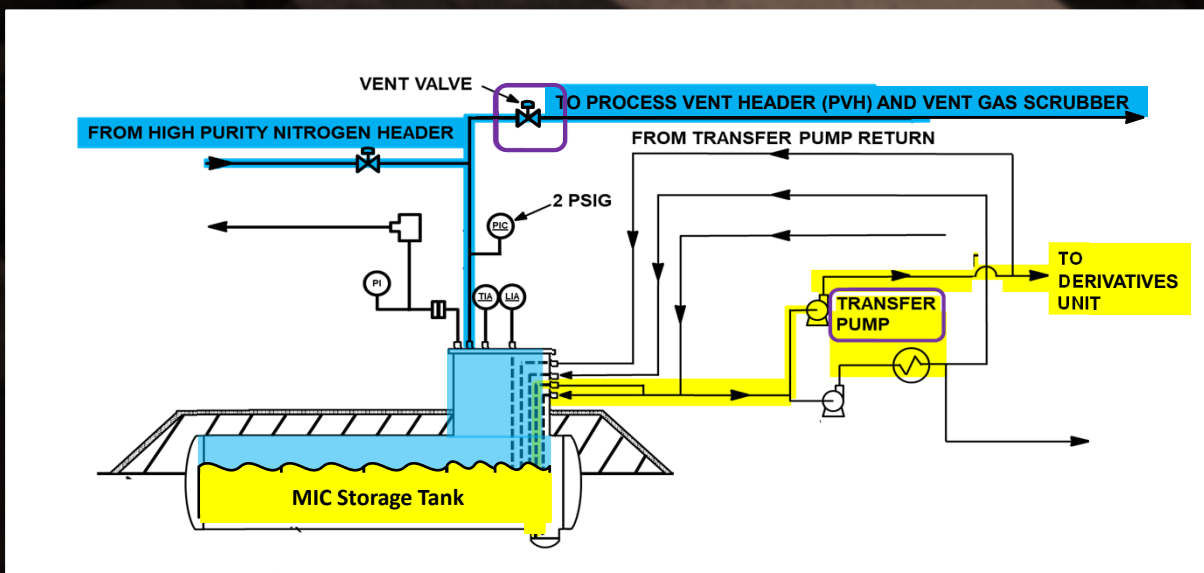


## The MIC Transfer Pump

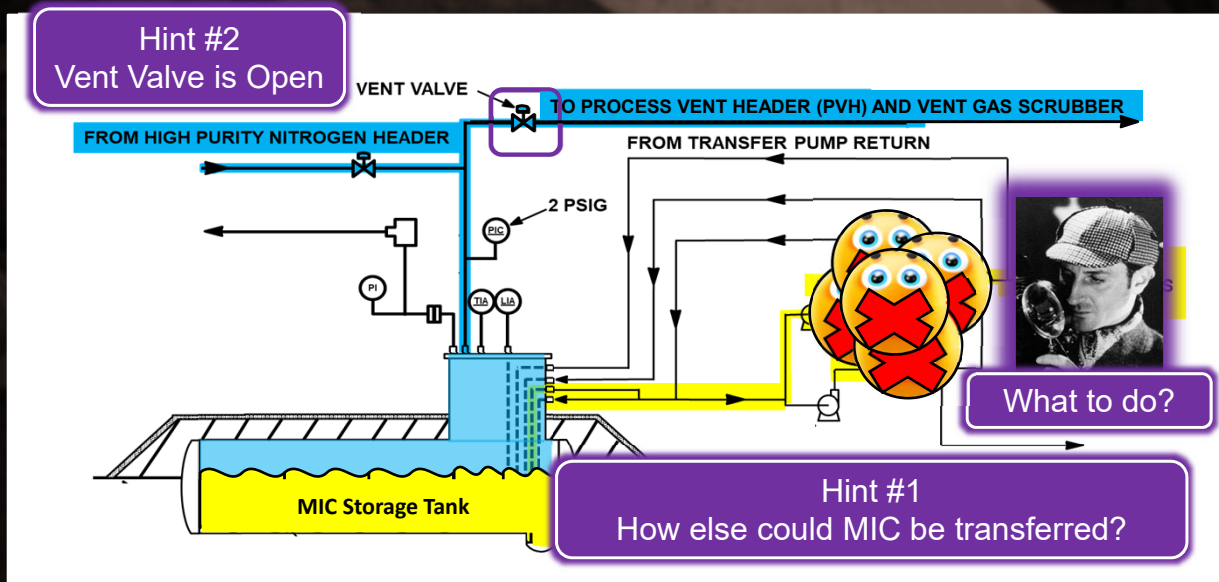


17

## The Nitrogen System



## First Issue: Transfer Pump Failures

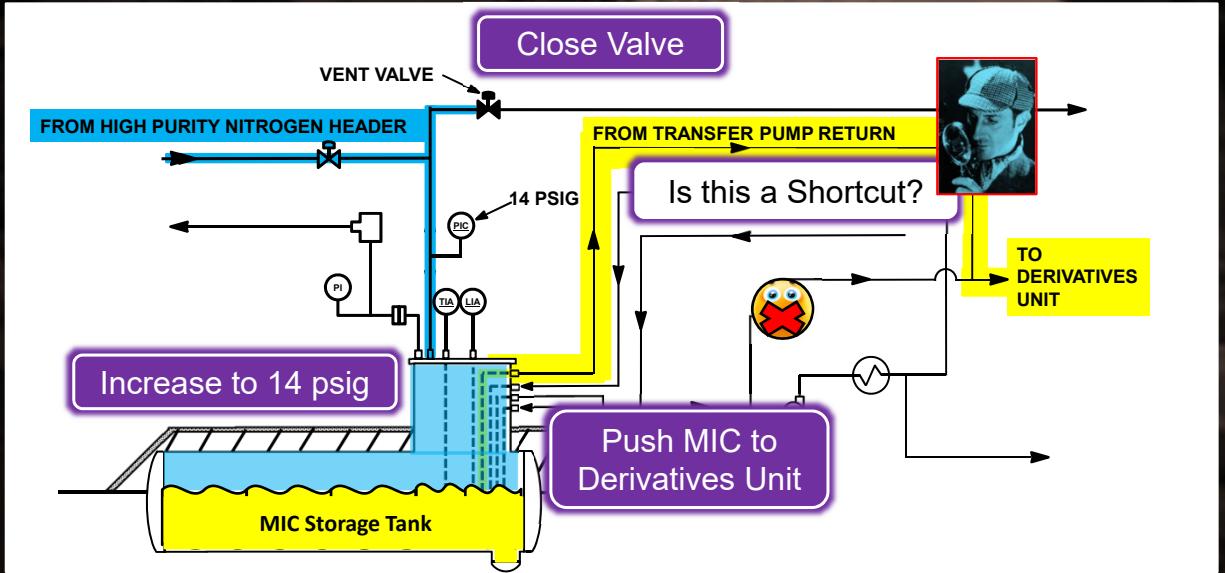


## Outline

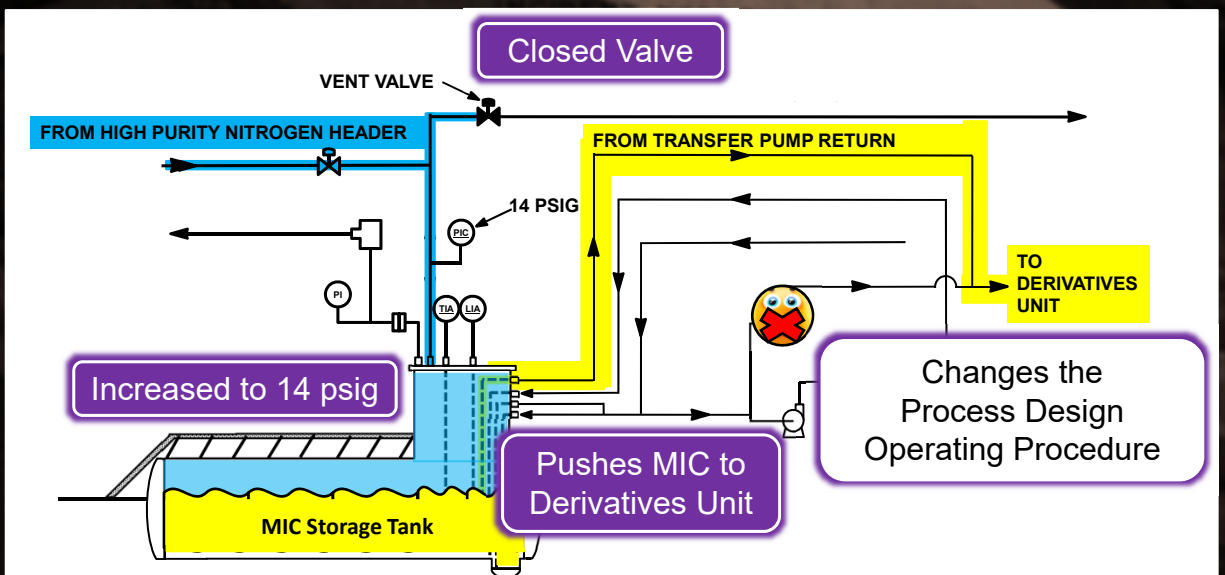
- Hazardous Materials
- Design Issues
  - The Equipment
  - The Procedures
  - The Safeguards
- The Incident
- Some Concluding Thoughts



## Solution to Issue # 1: Change Operating Procedure



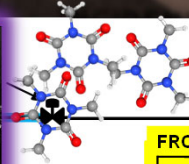
## Solution # 1 is a Workaround



## Second Issue: Due to the Operation's Workaround

MIC-Trimer forms at Vent Valve

FROM HIGH PURITY NITRO



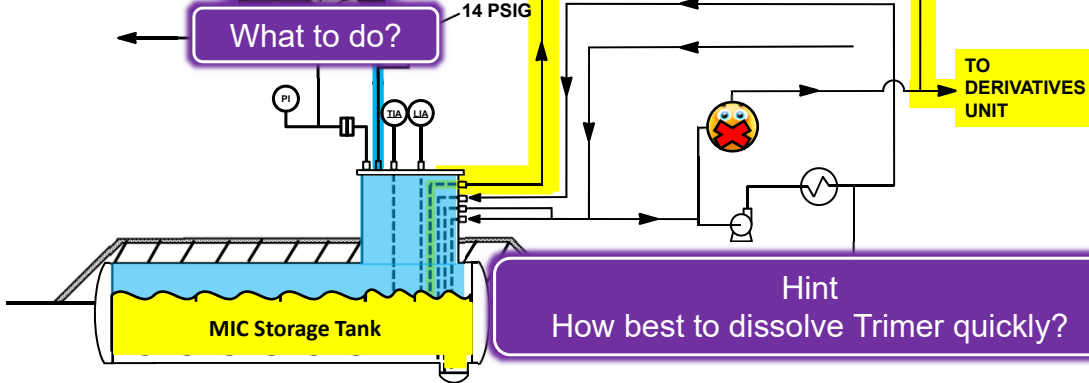
Valve will not seal closed

What to do?

FROM TRANSFER PUMP RETURN

14 PSIG

TO DERIVATIVES UNIT



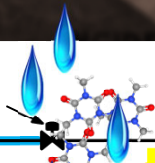
Hint  
How best to dissolve Trimer quickly?

## Solution to Issue # 2: Add Water

Dissolve MIC-Trimer at Vent Valve with Water

VENT VALVE

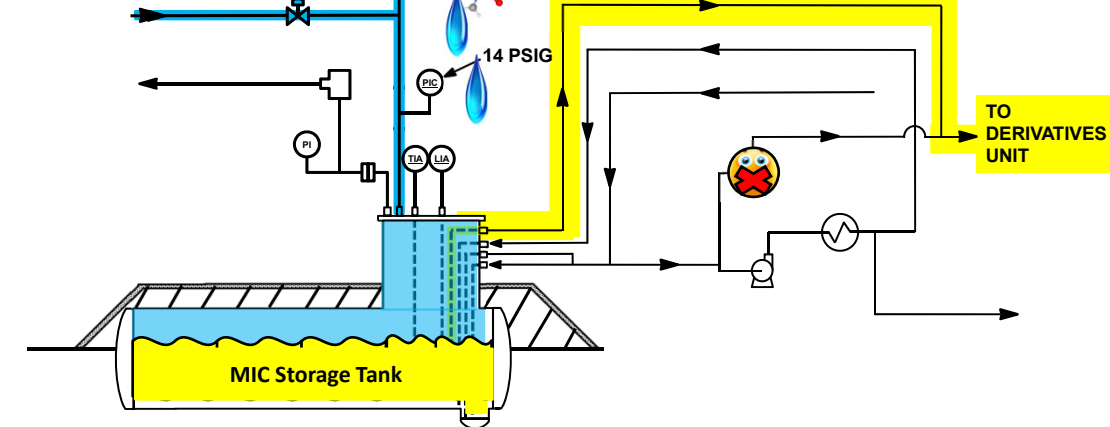
FROM HIGH PURITY NITROGEN HEADER



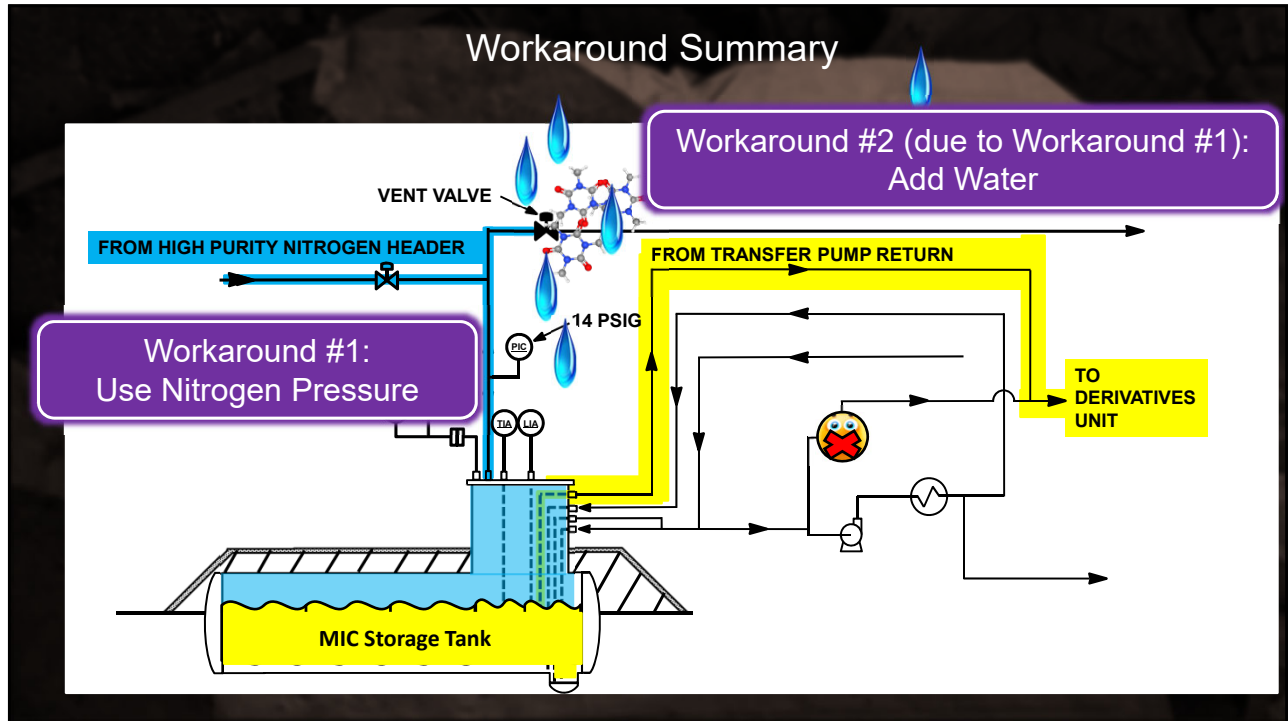
14 PSIG

FROM TRANSFER PUMP RETURN

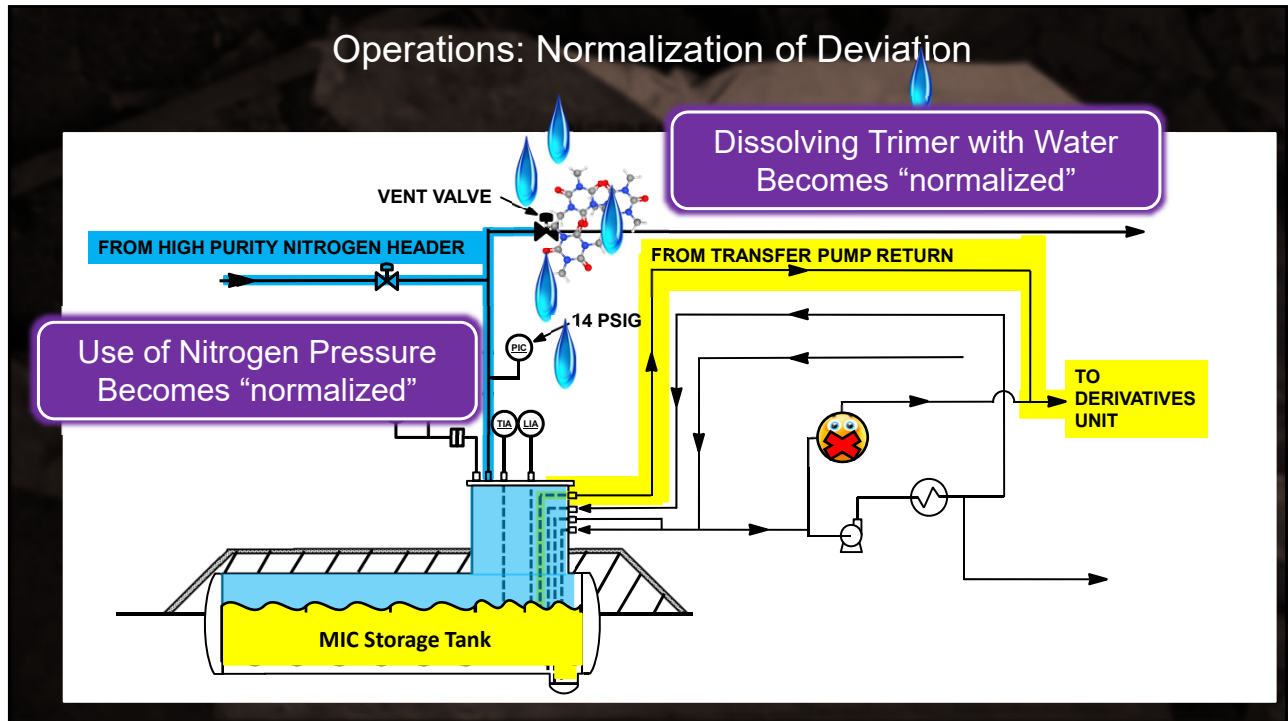
TO DERIVATIVES UNIT



## Workaround Summary

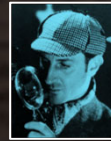


## Operations: Normalization of Deviation



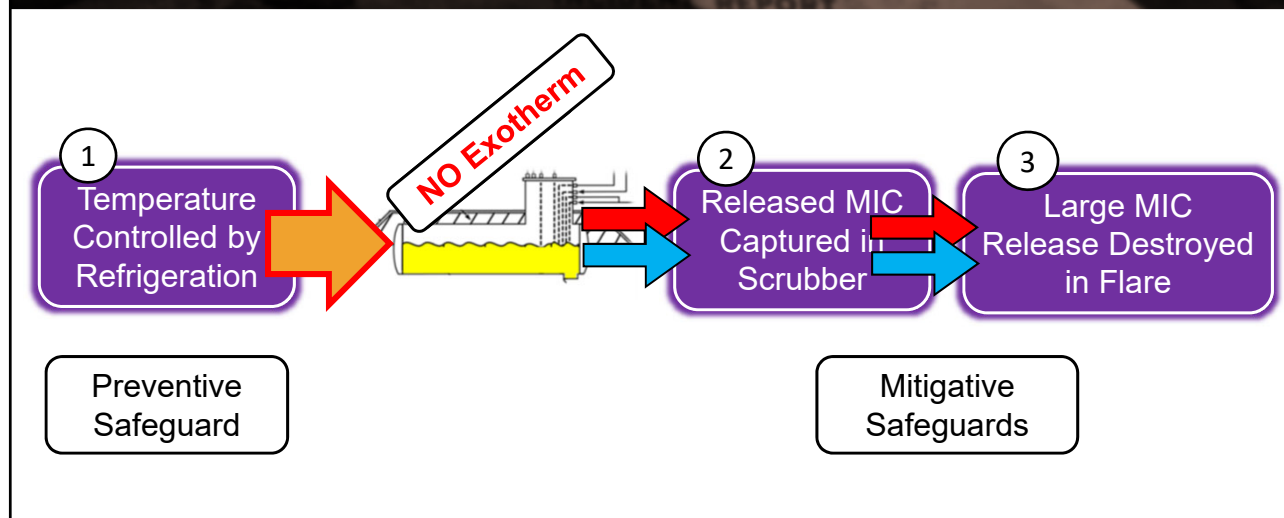
## Outline

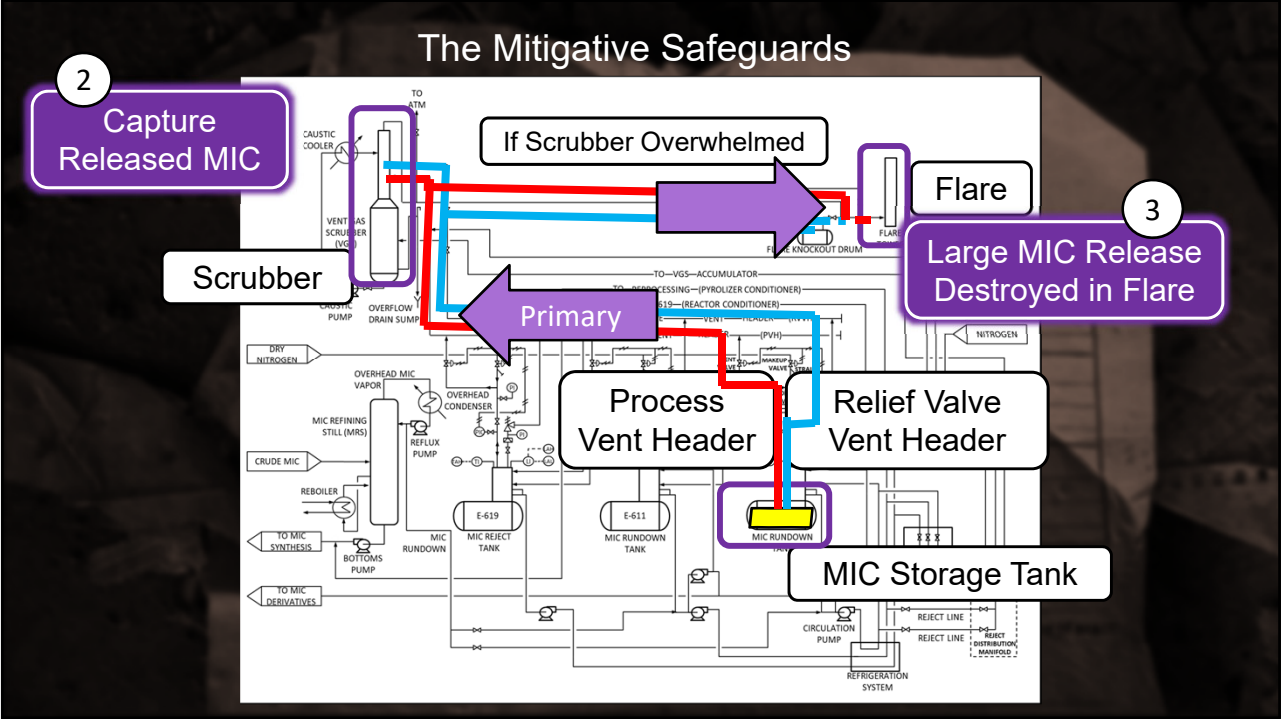
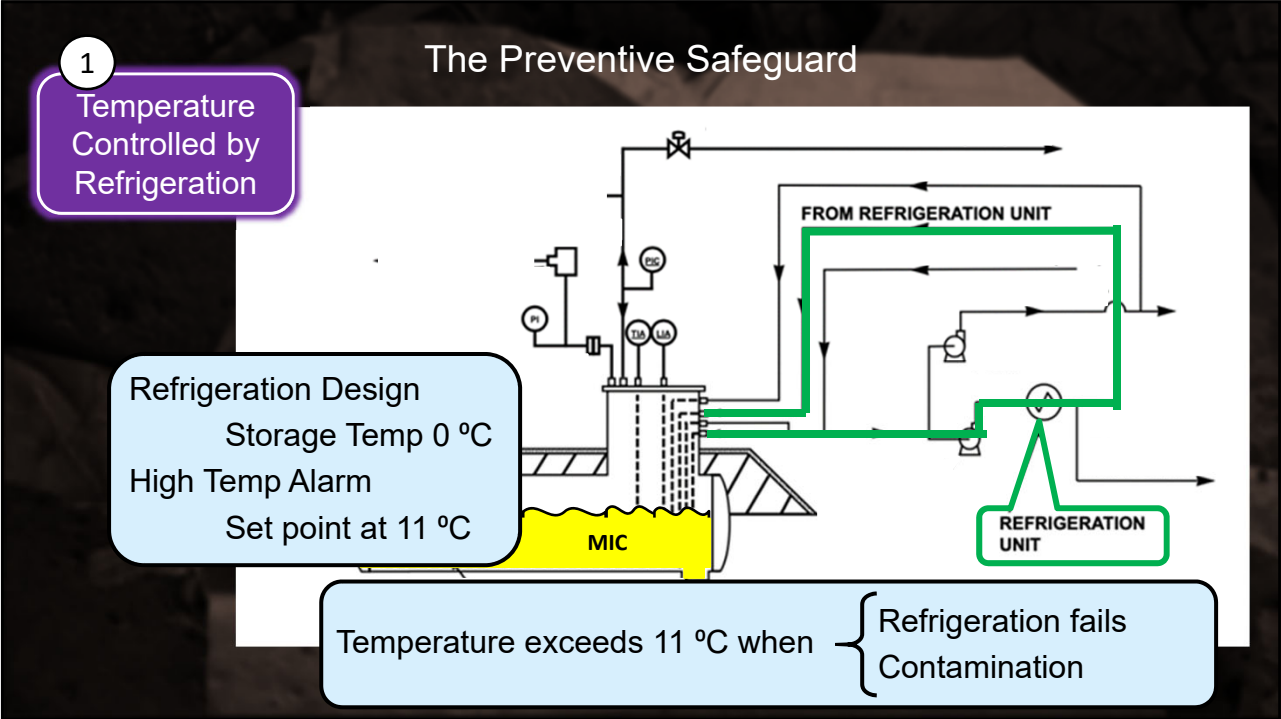
- Hazardous Materials
- Design Issues
  - The Equipment
  - The Procedures
  - **The Safeguards**
- The Incident
- Some Concluding Thoughts



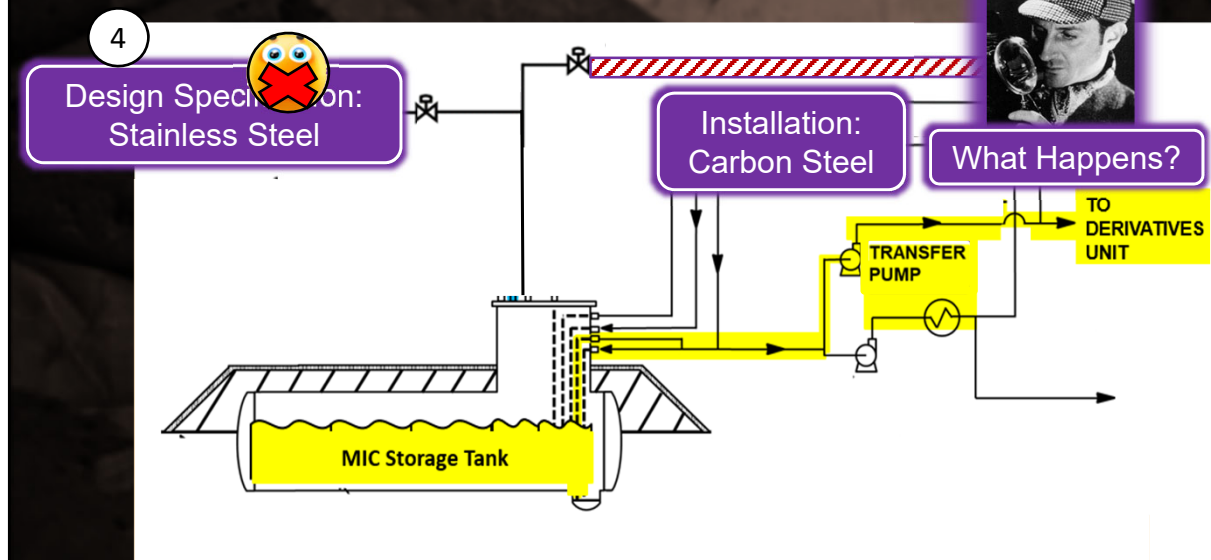
27

## Some Safeguards per Bhopal Design



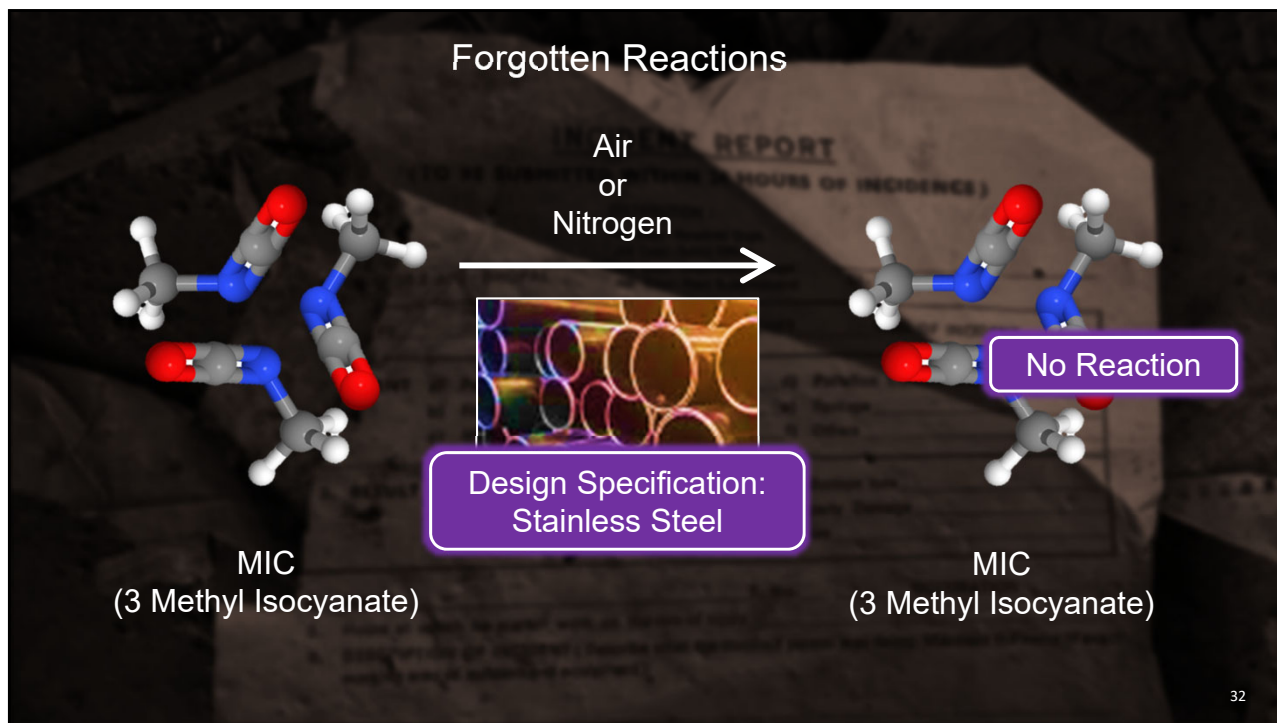


## A Forgotten Preventive Safeguard



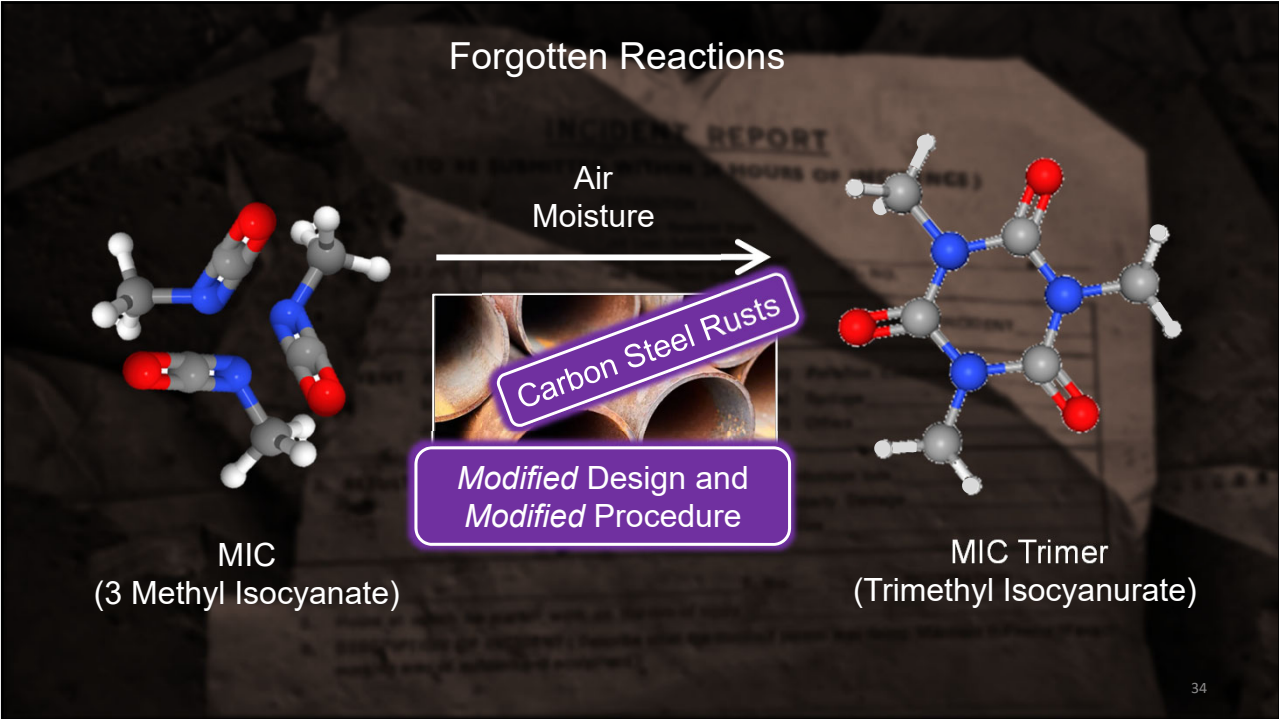
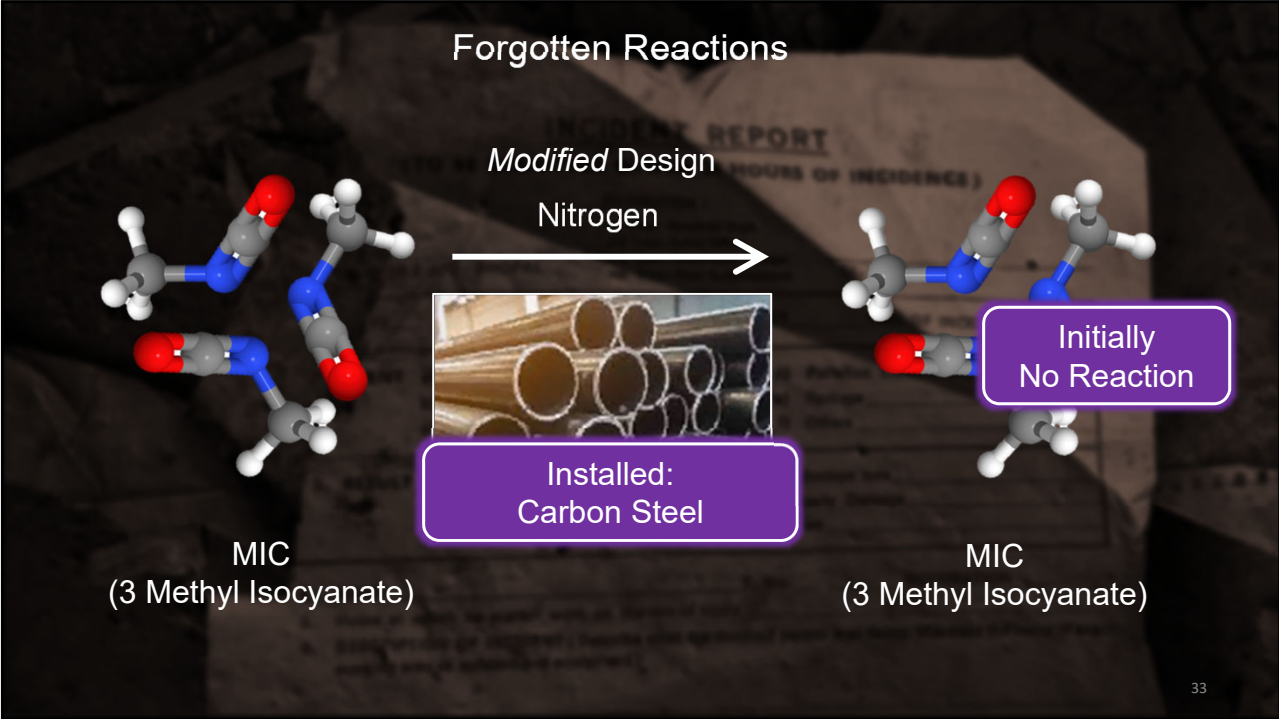
31

## Forgotten Reactions



32





## Outline

- Hazardous Materials
- Design Issues
  - The Equipment
  - The Procedures
  - The Safeguards
- **The Incident**
- Some Concluding Thoughts

35

## The Bhopal Incident

December 1984

An exothermic runaway reaction was initiated when water mixed with MIC in a storage tank



36



Temperature Controlled by Refrigeration

## No Longer a Preventive Safeguard

Refrigeration Stopped  
Storage Temp 15-20 °C  
High Temp Alarm Unchanged  
Set point at 11 °C

Day of Release  
Temperature exceeded 11 °C with

No Refrigeration and  
Water Contamination

Exotherm

REFRIGERATION UNIT

FROM REFRIGERATION UNIT

## The Bhopal Incident

The reaction raised the liquid MIC temperature

The unreacted liquid MIC vaporized into a gas



MIC gas discharged from the scrubber, condensed and generated a heavier-than-air fog that drifted into the surrounding community

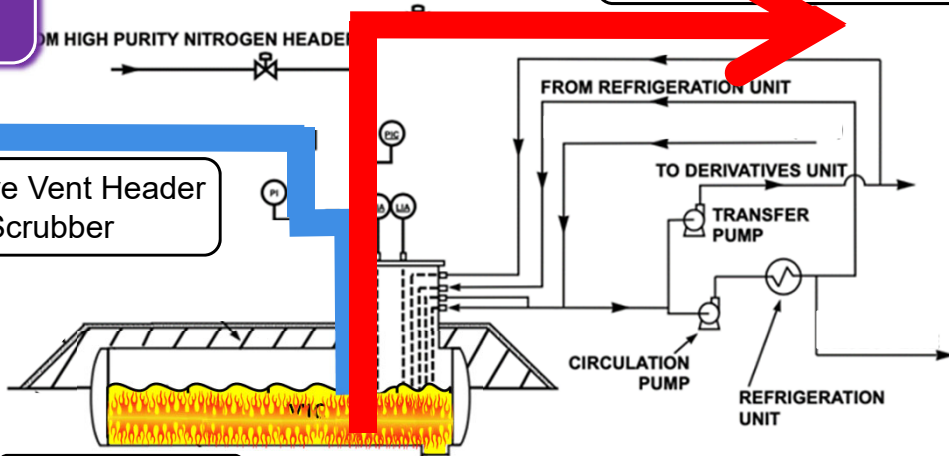
## The Mitigative Safeguards

2

Released MIC Captured in Scrubber

Process Vent Header To Scrubber

Relief Valve Vent Header To Scrubber



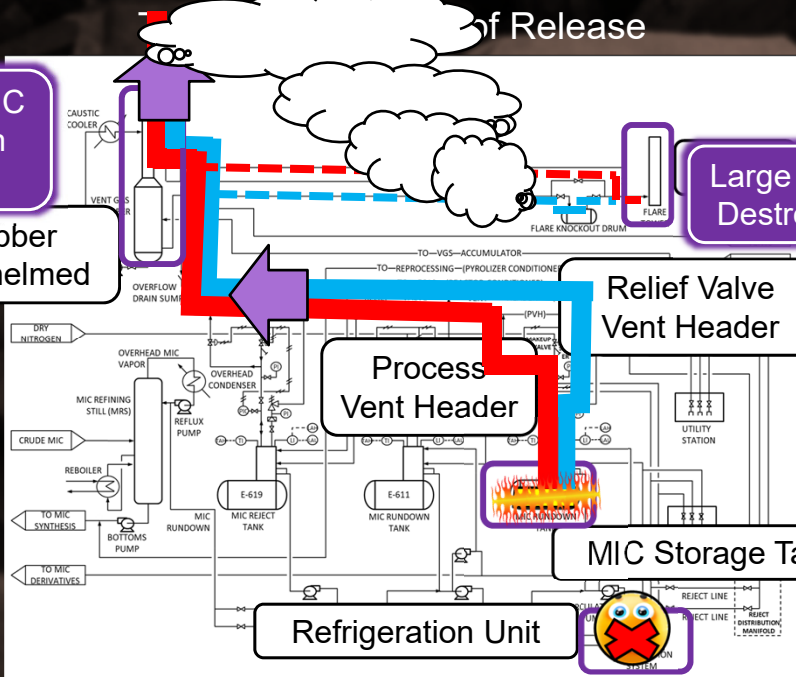
Day of Release



Released MIC Captured in Scrubber

Scrubber Overwhelmed

Large MIC Release Destroyed in Flare



Refrigeration Unit

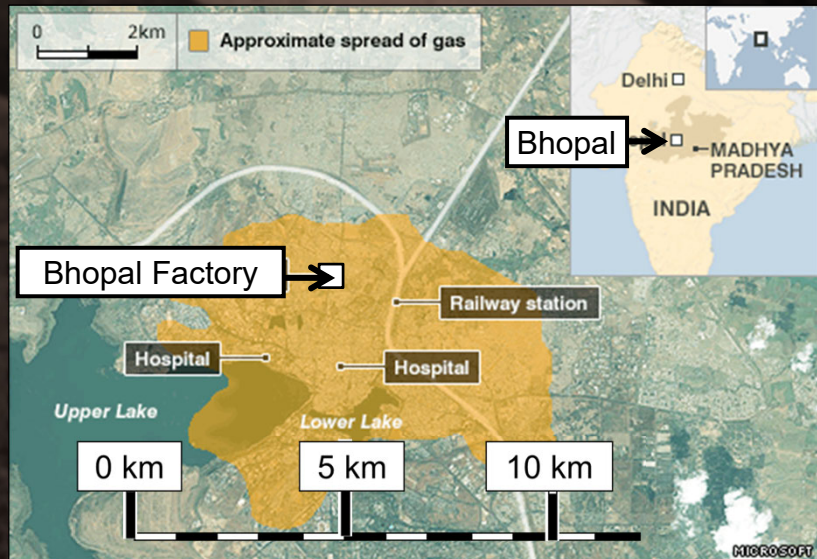


## The Bhopal Incident

It is estimated that 28 tons of MIC were released

On December 3, more than 2,000 fatalities and 200,000 serious injuries

40 years later, people and the environment are still burdened by the effects of the release



41

## Outline

- Hazardous Materials
- Design Issues
  - The Equipment
  - The Procedures
  - The Safeguards
- The Incident
- **Some Concluding Thoughts**

42

## It Happened 40 Years Ago: Why *Do* We Keep Revisiting Bhopal?



43

## Why Revisit Bhopal?

### *At Bhopal*

We learn why a Workaround

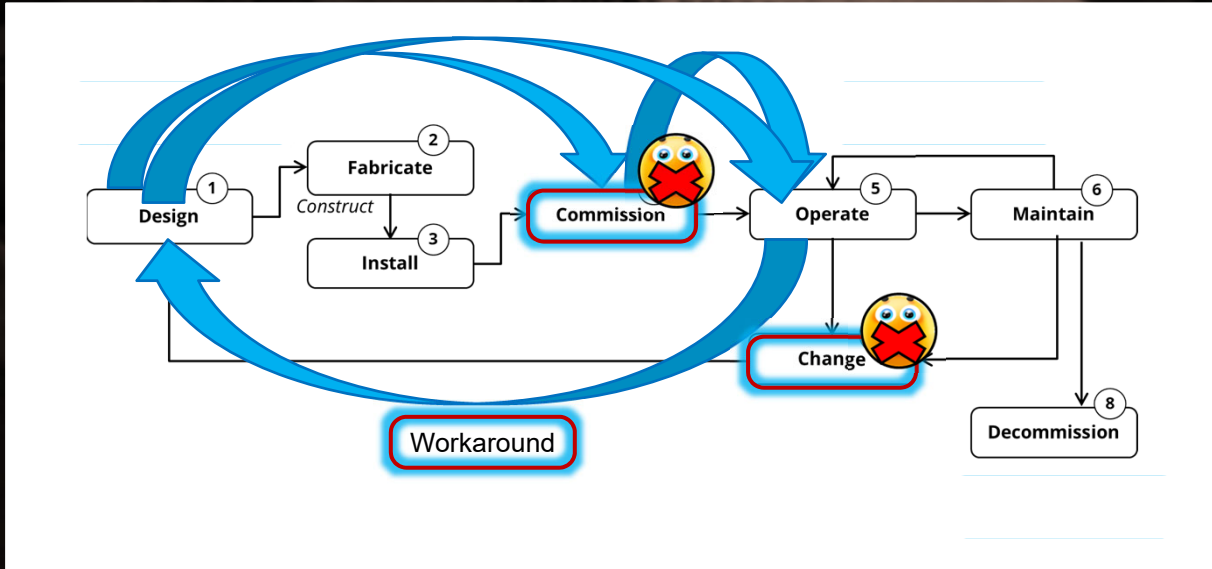
- Exists

*Performance Gap?*

Workarounds exist to address a *performance gap*  
between the engineering design and field operations

44

## Why Workarounds Exist: The Equipment Lifecycle



## Why Revisit Bhopal?

We learn why a Workaround

- Exists
- Is not a shortcut

A shortcut *saves time* by bypassing certain process safety steps to complete the task faster

## Why Revisit Bhopal?

We learn why a Workaround

- Exists
- Is not a shortcut
- Must not be adopted

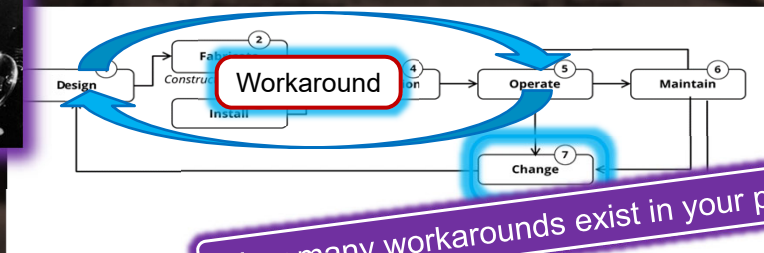
When adopted,  
a workaround becomes a *“Normalization of Deviation”*

47

## Why Revisit Bhopal?

We learn that

Workarounds must not be accepted  
unless a rigorous MOC is used



How many workarounds exist in your process?

48



## Why Revisit Bhopal?



We learn that

- The integrity of all safeguards must be sustained
- Safeguards must be functional until all hazards are removed

Safeguards must be functional during Decommissioning

How many of your safeguards are out of service?

## Why Revisit Bhopal?

To prevent process safety incidents that result in:

- *Harm to people* ✓ Bhopal
- *Environmental damage* ✓
- *Asset and business loss* ✓

Caused by a

- *Runaway reaction* ✓
- *Toxic release* ✓
- *Fire*
- *Explosion*



