Key Lessons from CSB Investigations

2025 Michigan Safety Conference

Lauren Johnson

April 15, 2025

U.S. Chemical Safety and Hazard Investigation Board

Today's Agenda…

- Overview of CSB
- Key Lessons from CSB Investigations
  - Optima Belle
  - FFG
  - Marathon Martinez
  - BPH
- Other key CSB info
- Q&A

The CSB

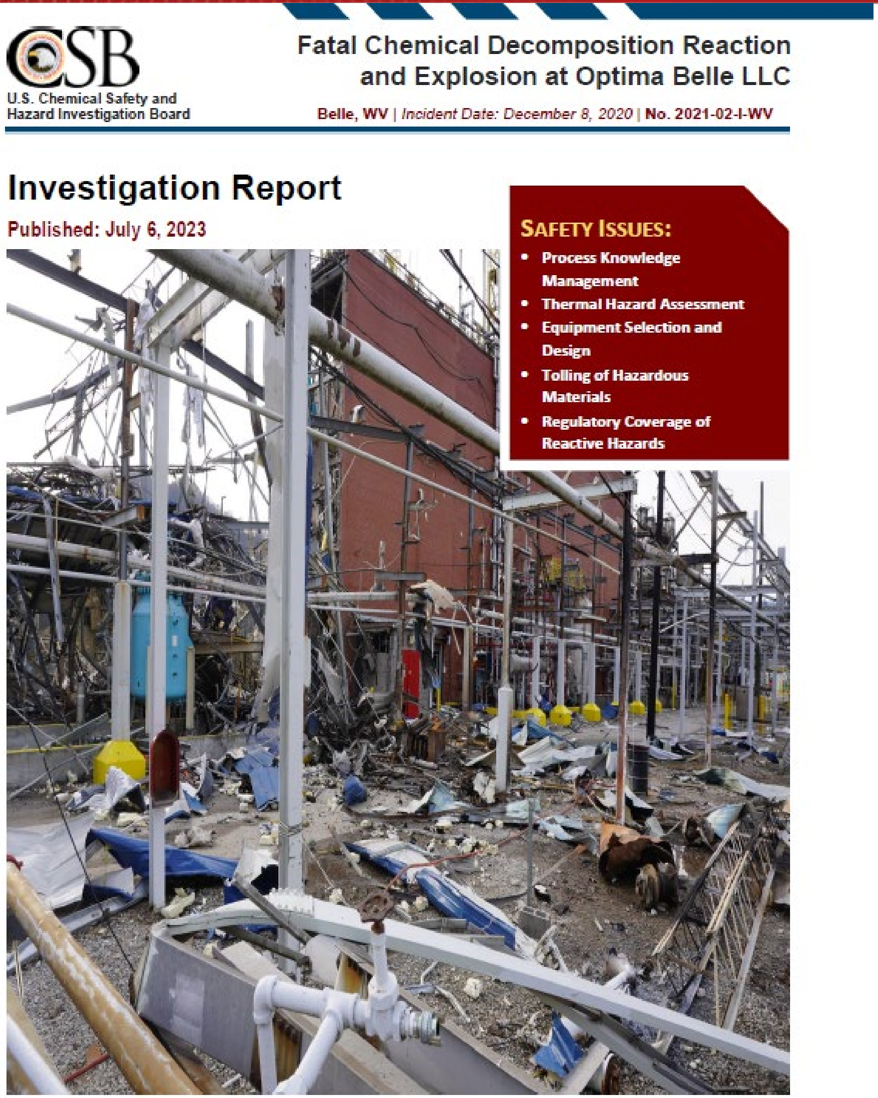
- Independent Federal Agency
- Investigate – not enforcement

- Mission – Drive chemical safety excellence through independent investigations to protect communities, workers, and the environment.

About the CSB

Key Lessons from CSB Investigations

Optima Belle


U.S. Chemical Safety and Hazard Investigation Board

Fatal Chemical Decomposition Reaction and Explosion at Optima Belle LLC

Belle, WV | *Incident Date: December 8, 2020* | No. 2021-02-I-WV

Investigation Report

Published: July 6, 2023

SAFETY ISSUES:

- Process Knowledge Management
- Thermal Hazard Assessment
- Equipment Selection and Design
- Tolling of Hazardous Materials
- Regulatory Coverage of Reactive Hazards

Optima Belle Final Report

Optima Belle Incident Overview

- Belle, WV; December 8, 2020, ~10:00 p.m.
- Pressure-rated dryer explosion, release of toxic gases
- 1 fatality, 2 injuries
- Significant property damage ~$33 million
- Debris found 0.5 mile from site
- Shelter in place for 2-mile radius for over 4 hours
- Optima Belle was a toll manufacturer for Clearon
- Dehydrating a chlorinated isocyanurate compound (CDB-56 ®)
- Unexpected decomposition reaction, release of gas, overpressure and explosion of dryer

SAFETY ISSUES:

- Process Knowledge Management
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Optima Belle Incident Overview

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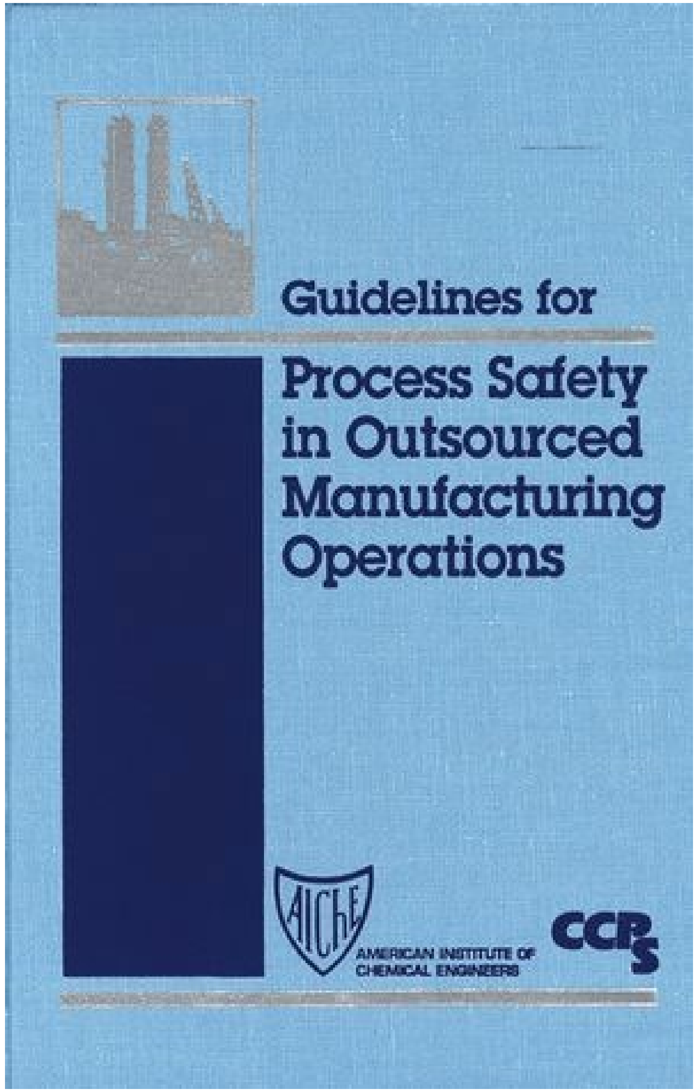
Tolling of Hazardous Materials.

Companies often augment in-house production by outsourcing chemical processes and other operations. These agreements are called tolling contracts.

Clearon established a tolling contract with RCI, a tolling broker, who in turn contracted with Optima Belle.

The Center for Chemical Process Safety (CCPS) provides industry guidance for safe and effective tolling arrangements.

The dryer explosion might have been prevented had Clearon and Optima Belle applied the suggested industry guidance.



Industry Guidance to evaluate chemical reactivity or explosivity:
- Process Safety Progress "*The Oxygen Balance Criterion for Thermal Hazards Assessment*" and "*An Index-Based Method for Assessing Exothermic Runaway Risk*"
- CHETAH from ASTM International
- CRW software/database from CCPS
- O.R.E.O.S. Method – ACS Organic Process Research & Development *"Explosive Hazard Identification in Pharmaceutical Process Development: A Novel Screening Method and Workflow for Shipping Potentially Explosive Materials"*

Optima Belle "Key Lessons"

U.S. Chemical Safety and Hazard Investigation Board

KEY LESSON

To ensure that hazards associated with new processes are identified and controlled, facilities should (1) evaluate process safety information on the involved chemicals to determine whether the chemicals can be safely used at the laboratory scale, (2) examine the process at the laboratory and pilot scales to determine whether and how to safely scale the process to the production scale, and (3) involve site safety and process engineering personnel to determine whether the process can be conducted at the tolling facility safely at full production scale with the existing equipment.

KEY LESSON

Knowledge Management and Sharing: Companies must ensure that chemical hazard information identified from previous incidents, studies, and laboratory tests are maintained and organized in a manner that will allow employees to be aware of the information's existence and to use it appropriately for future applications.

KEY LESSON

There are many tools available to identify whether a chemical has thermal or reactive hazards that could lead to a process safety incident. These tools include the Oxygen Balance method, Differential Scanning Calorimetry (DSC), Accelerating Rate Calorimetry (ARC), Yoshida Correlations, the CHETAH tool, the CCPS screening tool, the Chemical Reactivity Worksheet (CRW), the O.R.E.O.S. Method, and the Stoessel Criticality tool. Some of these tools involve simple calculations that can be conducted to determine whether further laboratory testing is required.

KEY LESSON

Outsourcing the production or processing of a hazardous material does not outsource the responsibility for process safety. Effective process safety and the prevention of catastrophic incidents are responsibilities that should be shared by all parties involved in a tolling operation.

Optima Belle: “To Do” List

U.S. Chemical Safety and Hazard Investigation Board

- [ ] **Develop and implement a written thermal and reactive hazards evaluation and management program.** The program should adhere to industry guidance provided in publications such as the Center for Chemical Process Safety’s Essential Practices for Managing Chemical Reactivity Hazards. At a minimum, the program should identify the process that Optima Belle will use to manage chemical reactivity hazards, resources for collecting and assessing reactivity hazards, steps for determining how and when to test for chemical reactivity, documentation requirements, and training.

- [ ] **Develop and implement a formalized program for the development of toll manufacturing agreements using resources such as the Center for Chemical Process Safety’s *Guidelines for Process Safety in Outsourced Manufacturing Operations* and *Guidelines for Risk Based Process Safety*.** Ensure that the program provides for the following:
  a) Identification of roles and responsibilities of all parties, including the client, toller, and any third-party technical service providers, for all phases of a proposed arrangement;
  b) Evaluation of equipment requirements/specifications to ensure that they are adequate for intended operation; and
  c) Participation by all parties in the tolling process development, including process hazards analysis and emergency planning, and appropriate stages of the pre-planning, pre-startup, and production phases.

- [ ] **Develop and implement a comprehensive process knowledge management program or evaluate and revise existing process safety management procedures to ensure consistency with industry guidance publications such as the Center for Chemical Process Safety’s Guidelines for Risk Based Process Safety.** The program should:
  a) assign specific responsibilities for compiling content and maintaining robust process technology and safety information packages that incorporate relevant knowledge for all hazardous processes and substances operated, manufactured, and/or handled by Clearon Corporation;
  b) ensure that key process personnel are aware of critical reactive chemistry information, including thermal stability and calorimetry data, chemical compatibility information, and descriptions of any past reactive incidents and safety studies involving the materials; and
  c) define procedures for the transmittal of such information to toll manufacturers.

- [ ] **Develop and implement a written program for tolling process design and equipment selection using guidance from the Center for Chemical Process Safety’s *Guidelines for Risk Based Process Safety* and *Guidelines for Process Safety in Outsourced Manufacturing Operations*** to ensure that:
  a) equipment design basis is adequate for any new tolling process or product;
  b) safeguards and ancillary equipment are considered and adequately designed, installed, and function as designed and required; and
  c) new processes are evaluated for potential process hazards at the laboratory and/or pilot scale before production scale.
  This written program should incorporate the information developed in Optima Belle’s thermal and reactive hazards evaluation program to ensure that chemical hazards are fully understood and controlled.

Foundation Food Group (FFG)


U.S. Chemical Safety and Hazard Investigation Board

Fatal Liquid Nitrogen Release at Foundation Food Group

Gainesville, GA | *Incident Date: January 28, 2021* | No. 2021-03-I-GA

Investigation Report

Published: December 2023

SAFETY ISSUES:

- Single Point of Failure
- Atmospheric Monitoring and Alarm Systems
- Emergency Preparedness
- Process Safety Management System
- Product Stewardship

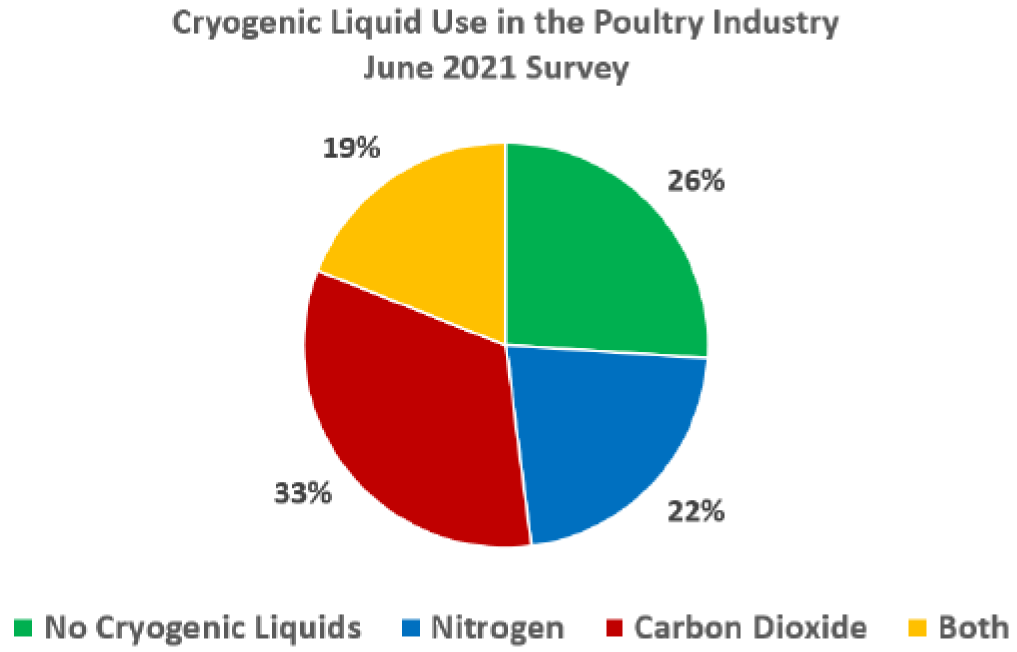


Figure 7. Cryogenic use in the poultry industry. (Credit: U.S. Poultry & Egg Association, formatted by CSB)

[FFG Final Report]

FFG Incident Overview

- Gainesville, GA ; January 28, 2021, ~8:45 – 10:15 a.m.
- Cryogenic liquid nitrogen release from freezer while maintenance workers were troubleshooting operational issues
- 6 fatalities, 4 serious injuries
- Fatalities: 2 maintenance workers, 4 additional employees
- Serious injuries: 3 employees and 1 firefighter (asphyxiation symptoms)
- Property damage ~$1.7 million FFG, ~$245,000 Messer

SAFETY ISSUES:

- Single Point of Failure
- Atmospheric Monitoring and Alarm Systems
- Emergency Preparedness
- Process Safety Management System
- Product Stewardship

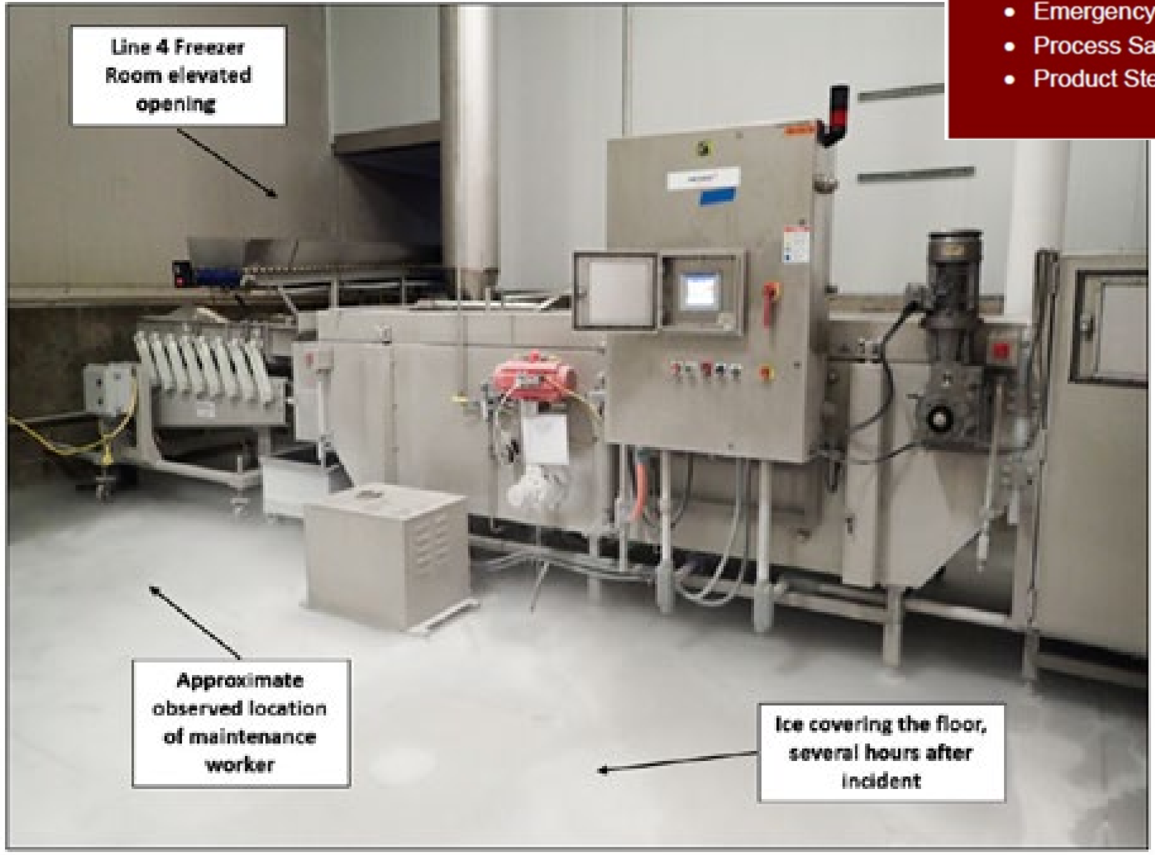
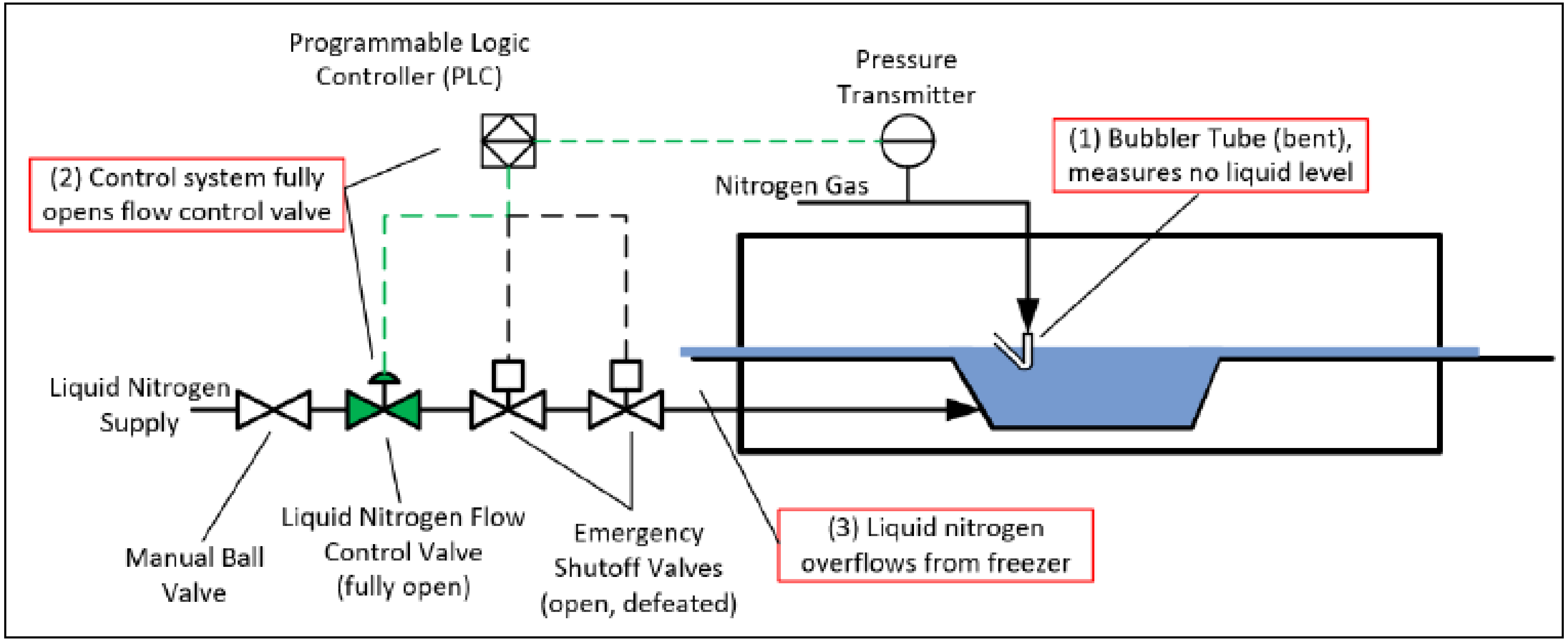


Figure 9. Line 4 immersion-spiral freezer in Line 4 freezer room several hours after the incident. (Credit: Hall County Fire Services, annotations by CSB)

FFG Incident Overview

U.S. Chemical Safety and Hazard Investigation Board



RAGAGEP:

- CGA P-86 *Guideline for Process Safety Management*
- CGA P-12 *Guideline for Safe Handling of Cryogenic and Refrigerated Liquids*
- CGA P-18 *Standard for Bulk Inert Gas Systems*
- CGA P-76 *Hazards of Oxygen-Deficient Atmospheres*

FFG "Key Lessons"

Product Stewardship.

Messer did not practice effective product stewardship prior to the incident. Messer was aware of several instances of FFG's process safety deficiencies and poor safety practices yet still commissioned the freezer to FFG.

Using more effective product stewardship, Messer could have prevented this incident by
1) objecting to the placement of the freezer in a room particularly susceptible to oxygen deficiency, 2) refusing to commission its freezer equipment until FFG provided adequate atmospheric monitoring and alarm systems, 3) suspending supply of liquid nitrogen until safety deficiencies had been addressed, or 4) ending the relationship with FFG and removing its equipment.

KEY LESSON

Food manufacturers are not immune from chemical hazards and process safety risks. Whenever an organization introduces a hazardous chemical into its process, it should implement robust process safety management practices to effectively control the risks, regardless of whether any regulation requires the organization to do so.

KEY LESSON

It is critical for workers to be trained on the hazards of the materials they encounter. Non-flammable, non-toxic chemicals, such as nitrogen, can be incorrectly assumed to be non-hazardous without proper training and hazard communication. Companies handling these materials have an obligation to train and inform their employees.

KEY LESSON

A PHA can only be effective if it is specific to the process it evaluates. Not considering facility-specific scenarios misses opportunities to effectively identify, evaluate, and control hazards. Companies installing equipment into a process at their facility should always perform a PHA considering the hazards introduced by the process, equipment, facility or room layout, ventilation, surrounding area, and external factors.

KEY LESSON

Processes and equipment that utilize hazardous materials should be designed robustly enough that the failure of a single component cannot result in a catastrophic incident.

KEY LESSON

Facilities that handle hazardous gases or cryogenic asphyxiants should have a functioning atmospheric monitoring and alarm system based on a properly conducted risk assessment. Functioning atmospheric monitoring systems consist of equipment that has been properly designed, installed, maintained, inspected, and tested, and will alert personnel of a hazardous atmosphere using audible and visual alarms.

KEY LESSON

Safety leadership begins with management. Designating competent and resourced staff with responsibility over specific safety programs is key to ensuring effective process safety. Management must be knowledgeable and involved in each of these safety programs to provide effective oversight.

KEY LESSON

Regulations are minimum requirements. The need for robust process safety management practices exists wherever hazardous chemicals are manufactured, processed, stored, and used, regardless of their regulatory coverage. Companies must be cognizant of the hazards posed by the chemicals they handle and should implement effective process safety management systems to control process safety risks.

FFG: “To Do” List

- [ ] **Include in the emergency action program provisions for proactively interacting with and informing local emergency response resources of all emergencies** at the former FFG Plant 4 facility to which Gold Creek expects them to respond. At a minimum, Gold Creek should:
a) inform local emergency responders of the existence, nature, and location of hazardous substances at its facilities, including liquid nitrogen;
b) inform local emergency responders of the location of emergency-critical equipment such as bulk storage tanks, points of use, isolation valves, E-stop switches, and any other emergency equipment or systems with which emergency responders may need to interact; and,
c) provide local emergency responders with information, such as facility plot plans, engineering drawings, or other information needed to mount an effective emergency response.

- [ ] **Update the company product stewardship policy** to:
a) include participation by Messer in customers’ process hazard analyses (PHAs). The policy should require that these PHAs be conducted in a manner which conforms with CCPS Guidelines for Hazard Evaluation Procedures prior to the startup of a cryogenic freezing process;
b) require verification that proper signage, in accordance with CGA P-76 Hazards of Oxygen-Deficient Atmospheres, is displayed on and/or near equipment; and,
c) require a facility and/or equipment siting review to ensure that emergency shutoff devices, including E-stops, are located such that they can be safely actuated during a release of liquid nitrogen.

- [ ] Create an informational product that provides Messer customers with information on the safety issues described in this report. In this informational product, recommend that Messer customers **develop and implement effective safety management systems to control asphyxiation hazards from inert gases** based on the guidance published in CGA P-86 Guideline for Process Safety Management, CGA P-12 Guideline for Safe Handling of Cryogenic and Refrigerated Liquids, CGA P-18 Standard for Bulk Inert Gas Systems, and CGA P-76 Hazards of Oxygen-Deficient Atmospheres.

Marathon Martinez


U.S. Chemical Safety and Hazard Investigation Board

Fired Heater Tube Rupture and Fire at Marathon Martinez Renewables Facility

Martinez, CA | *Incident Date: November 19, 2023* | No. 2024-01-I-CA

Investigation Report

Published: March 2025

SAFETY ISSUES:

- Safe Operating Limits
- Worker Proximity to Fired Heater
- Low Flow Through Fired Heater
- Burner Operation
- Valve Misalignment
- Corporate Oversight

[Marathon Martinez Final Report]

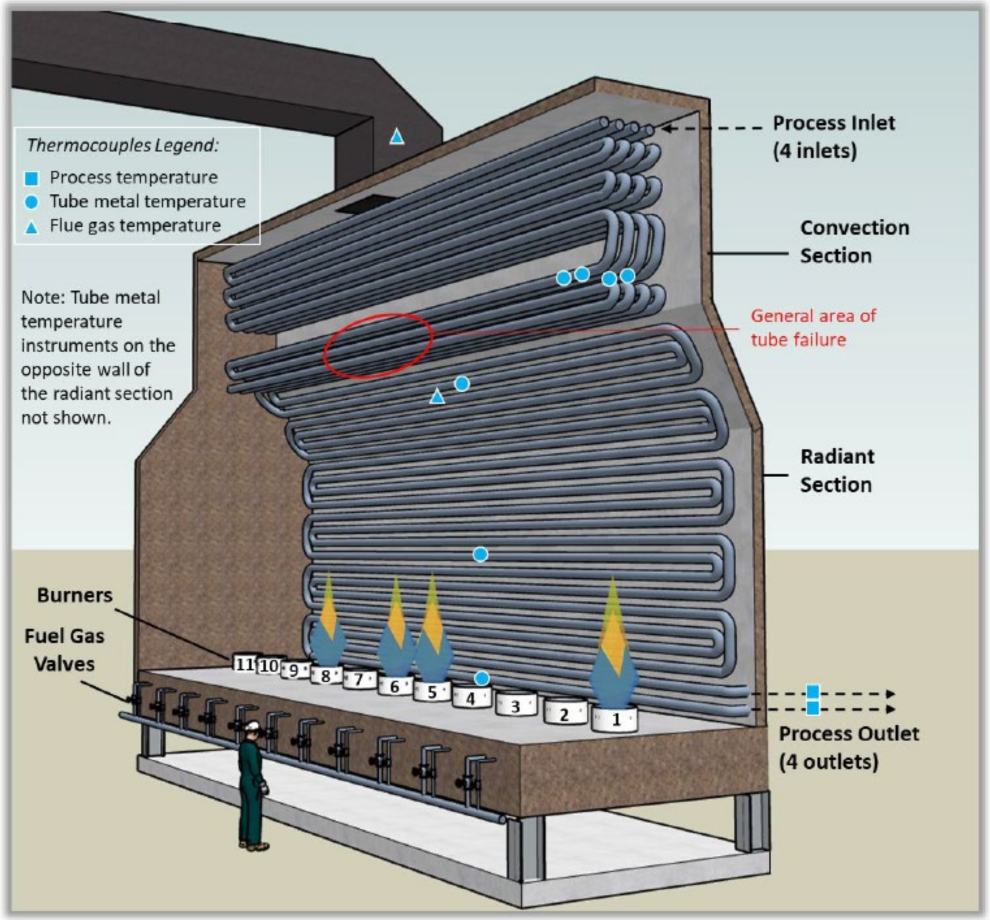


Figure 3. Interior of the fired heater. Note: The lit burners in the illustration do not necessarily depict their actual state at the time of the incident. (Credit: CSB)

Marathon Martinez Incident Overview

U.S. Chemical Safety and Hazard Investigation Board

- Martinez, CA; November 19, 2023 ~12:20 a.m.
- Fired heater tube rupture during startup of renewable diesel hydroprocessing unit
- >200,000 lbs renewable diesel; ~2,200 lbs hydrogen released
- 1 serious injury (3rd degree burns over 80% of body)
- Significant property damage ~$350 million
- Manual upstream valve was left open; diversion of flow around heater
- Insufficient flame detection and combustibles monitoring
- No DCS data to alert board operators since flow diversion was downstream of SIS system.

SAFETY ISSUES:

- Safe Operating Limits
- Worker Proximity to Fired Heater
- Low Flow Through Fired Heater
- Burner Operation
- Valve Misalignment
- Corporate Oversight

Marathon Martinez Incident Overview

U.S. Chemical Safety and Hazard Investigation Board

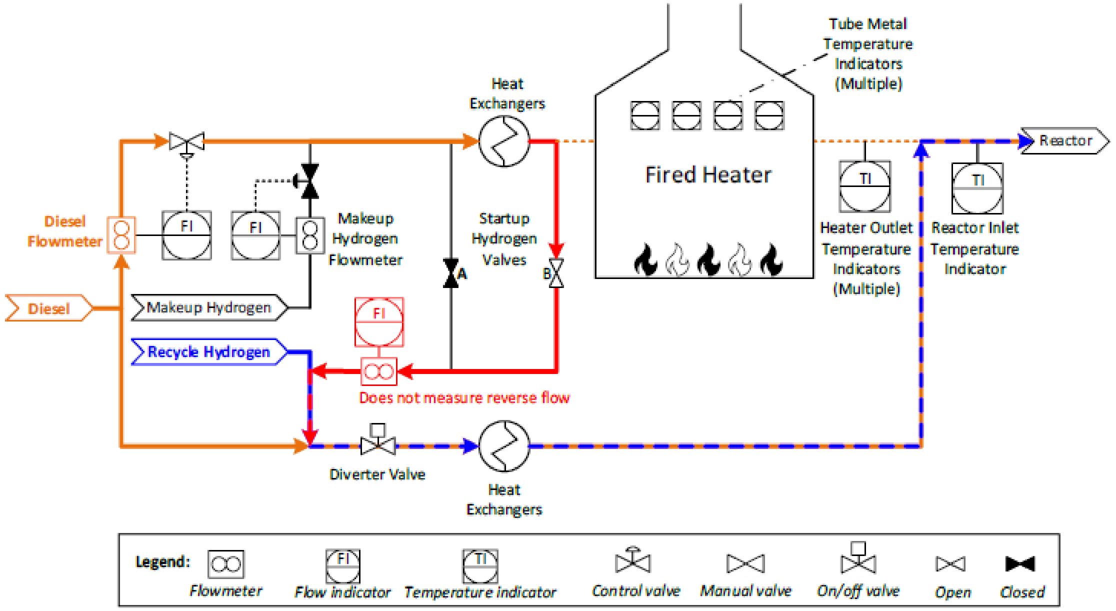


Figure 10. Flow diversion from the heater. Reverse flow indicated in red. (Credit: CSB)[a]

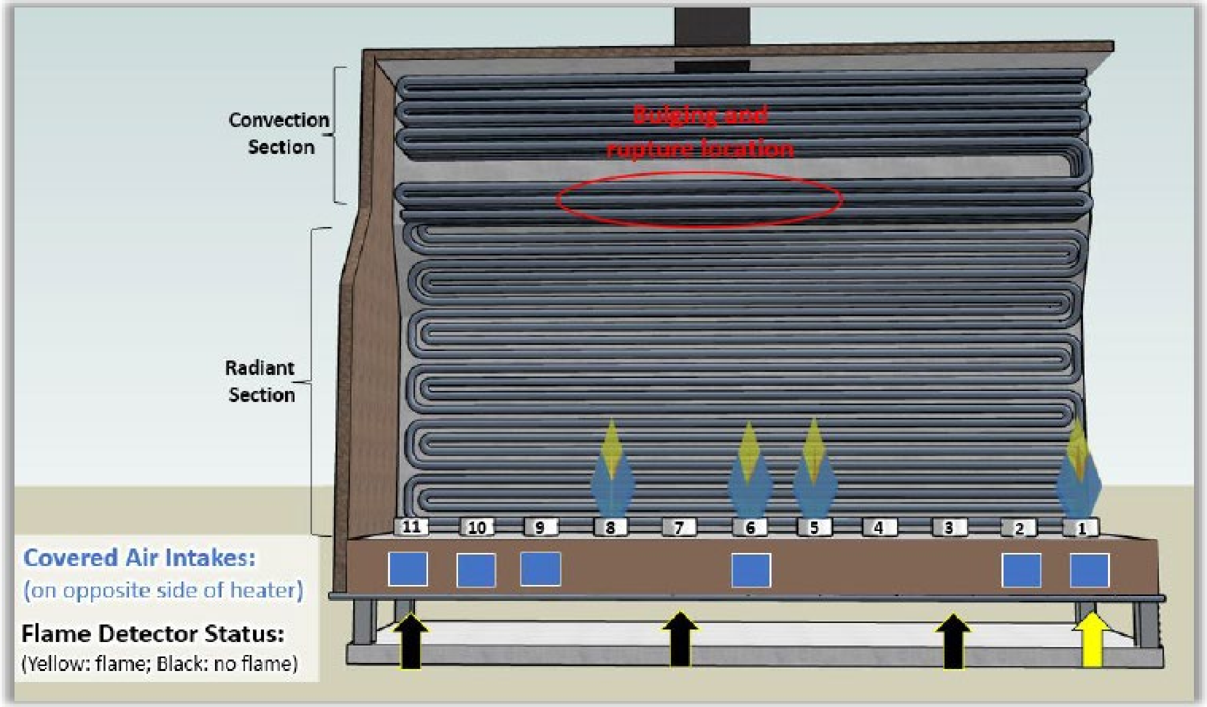


Figure 11. Burner configuration when heater was restarted approximately one hour before the incident. (Credit: CSB)

Marathon Martinez "Key Lessons"

U.S. Chemical Safety and Hazard Investigation Board

KEY LESSON

Process equipment must be configured with safe operating limit (not-to-exceed limit) alarms that alert personnel that the equipment has reached an unsafe condition, troubleshooting efforts need to end, and predetermined actions must be taken swiftly to shut down or return the equipment to a safe state.

KEY LESSON

Companies should ensure the safety of their workers by preventing workers from being in close proximity to a fired heater when tube temperatures are high or the fired heater is otherwise in an unsafe condition. Companies should create clear requirements for when troubleshooting in close proximity to fired heaters should be stopped and other actions, such as shutting down a fired heater remotely, should be taken. Enabling safe and remote adjustment of individual fired heater burners could also prevent workers from being in close proximity to fired heaters during troubleshooting efforts.

KEY LESSON

Companies should ensure that fired heaters are adequately protected from operating with low flow by evaluating all process connections between flow meters associated with the safety instrumented system and the heaters they are intended to protect, including considerations for reverse and misdirected flow.

KEY LESSON

Operating procedures and operator training should include verification that air intake covers (where used) are removed prior to lighting a burner. Improper air-fuel mixing at the burners could lead to poor combustion control and high localized temperatures inside the heater.

KEY LESSON

Fired heaters should be equipped with continual combustibles monitoring at the bridgewall (transition area from the radiant section to the convection section) to detect the onset of incomplete combustion. The combustibles data (such as CO and methane) should be viewable by the board operators in the control room and should be equipped with alarms at appropriate setpoints. This will help ensure proper combustion control inside the heater and allow quick response to hazardous flameouts or afterburning.

KEY LESSON

Companies should implement Walk the Line practices to minimize equipment lineup errors. Walk the Line activities include verifying valve positions before starting up a unit, understanding operating procedures and equipment routings, and properly communicating and documenting shift turnover information.

KEY LESSON

Companies should have effective oversight to ensure that processes are safe, equipment meets or exceeds local, state, federal, industry, and internal company safety standards, and workers are adequately trained and prepared before startup of a new or revamped process.

RAGAGEP:

- API RP 556 *Instrumentation, Control, and Protective Systems for Gas Fired Heaters*
- API 535 *Burners for Fired Heaters in General Refinery Services*
- API RP 571 *Damage Mechanisms*
- API RP 584 *Integrity Operating Window*
- CCPS *Inherently Safer Chemical Processes – A Life Cycle Approach*

Marathon Martinez: "To Do" List

U.S. Chemical Safety and Hazard Investigation Board

- [ ] **Implement engineering safeguards to detect and prevent afterburning in the fired heater** involved in the November 19, 2023, incident. The safeguards may include the use of instrumentation such as combustibles measurements, flame detectors, and/or thermocouples that measure tube metal, flue gas, and process fluid temperatures. The safeguards shall be capable of being monitored from the control room.

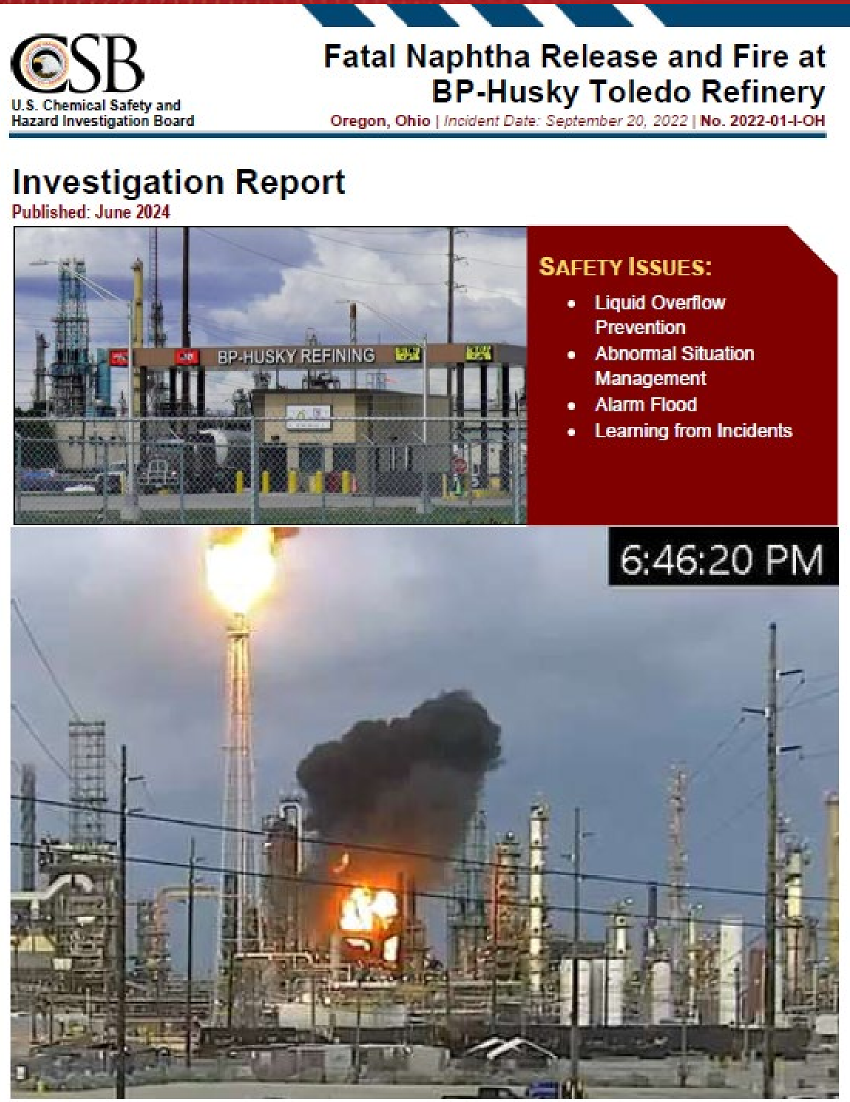
- [ ] For the fired heater involved in the incident, after Marathon Petroleum Corporation's "Process Heater Not-to-Exceed (NTE) Limits and Alarms" standard is updated according to 2024-01-I-CA-R5, **implement tube metal temperature alarming consistent with corporate guidance to alert operators when safe operating limits are exceeded and to specify predetermined response actions**, such as shutting down the fired heater remotely. The predetermined response actions must include actions that specify when to stop troubleshooting and remove personnel from the vicinity of the fired heater.

- [ ] **Implement changes to improve Walk the Line performance** at the Martinez facility by ensuring that the facility's practices are consistent with tools in the AFPM Safety Portal and guidance in Marathon Petroleum Corporation's refining reference document titled Operations Excellence. At a minimum:
  (a) Require that operator field walkdowns ensure that valves are correctly aligned before all unit startup activities from planned or unplanned shutdowns, such as those due to non-normal operations, emergencies, turnarounds, and major maintenance;
  (b) Improve policies and practices for communications among and between shifts to ensure that operators understand abnormal line-ups in their units; and
  (c) Reinforce Walk the Line concepts, including the expectation for only trained operators to control valve line-ups at their units, through training for all levels of management in the Operations department.

- [ ] **Complete a comprehensive gap assessment of the** Martinez **facility against** Marathon Petroleum **Corporation policies.** At a minimum, address the following policies:
  (a) Operating Limits;
  (b) Process Hazard Analysis; and
  (c) PSM/RMP Refining Operating Procedures.
  Develop and implement action items to effectively address findings from the assessment.

- [ ] **Update the corporate "Heater Application Standard"** with the following requirements:
  (a) Requirements for protecting fired heaters from low process flow where process piping diverges downstream of a flow meter. Requirements may include achieving proof of flow to the heater through valve position indicators and interlocks on branch connections downstream of flow meters to prevent backflow, reverse flow, or other diverted flow scenarios that could defeat the safety instrumented system; and
  (b) Engineering safeguard requirements to detect and prevent afterburning in fired heaters. The safeguards may include the use of instrumentation such as combustibles measurements, flame detectors, and/or thermocouples that measure tube metal, flue gas, and process fluid temperatures. The safeguards shall be capable of being monitored from the control room.

BP-Husky Toledo


U.S. Chemical Safety and Hazard Investigation Board

Fatal Naphtha Release and Fire at BP-Husky Toledo Refinery

Oregon, Ohio | Incident Date: September 20, 2022 | No. 2022-01-I-OH

Investigation Report

Published: June 2024

SAFETY ISSUES:

- Liquid Overflow Prevention
- Abnormal Situation Management
- Alarm Flood
- Learning from Incidents

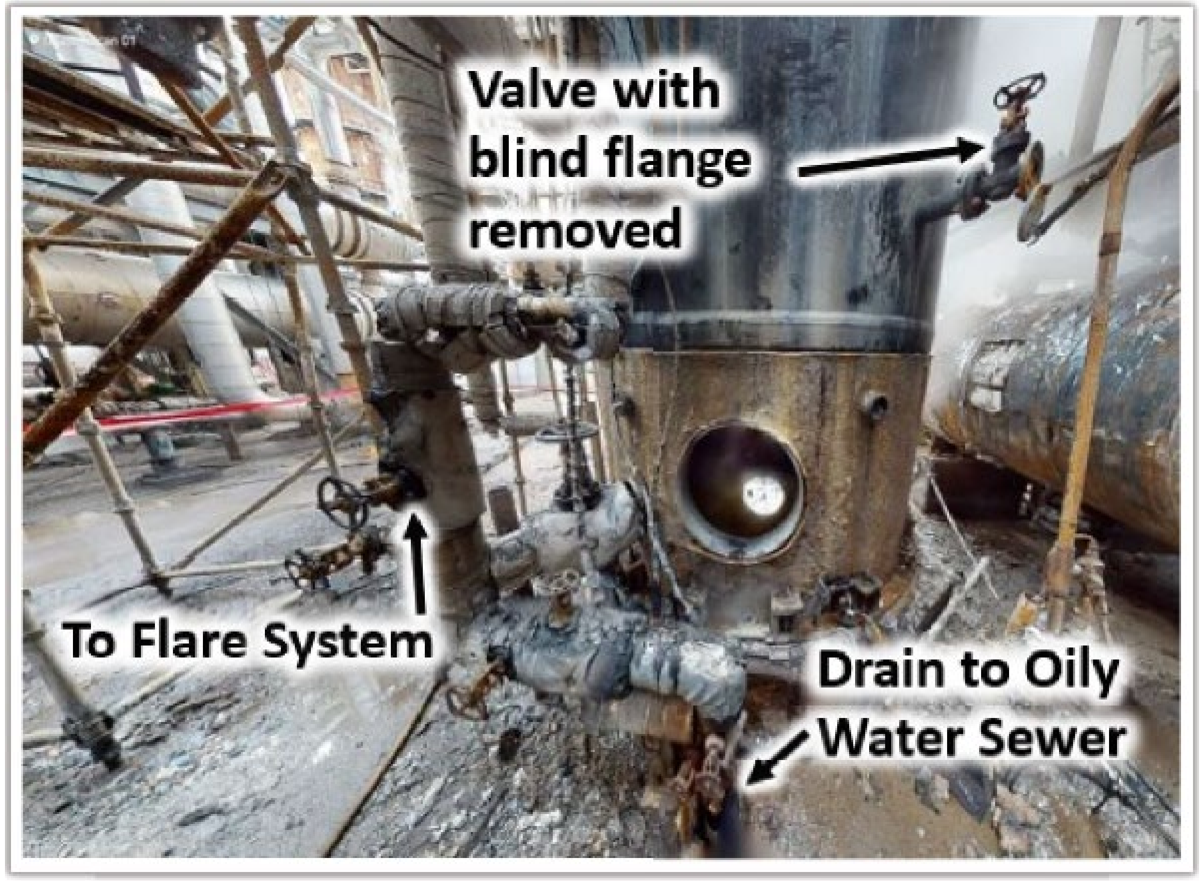


Figure 13: Fuel Gas Mix Drum post-incident. (Credit: BP with annotations by CSB)

[BP-Husky Final Report]

BP Husky Toledo Incident Overview

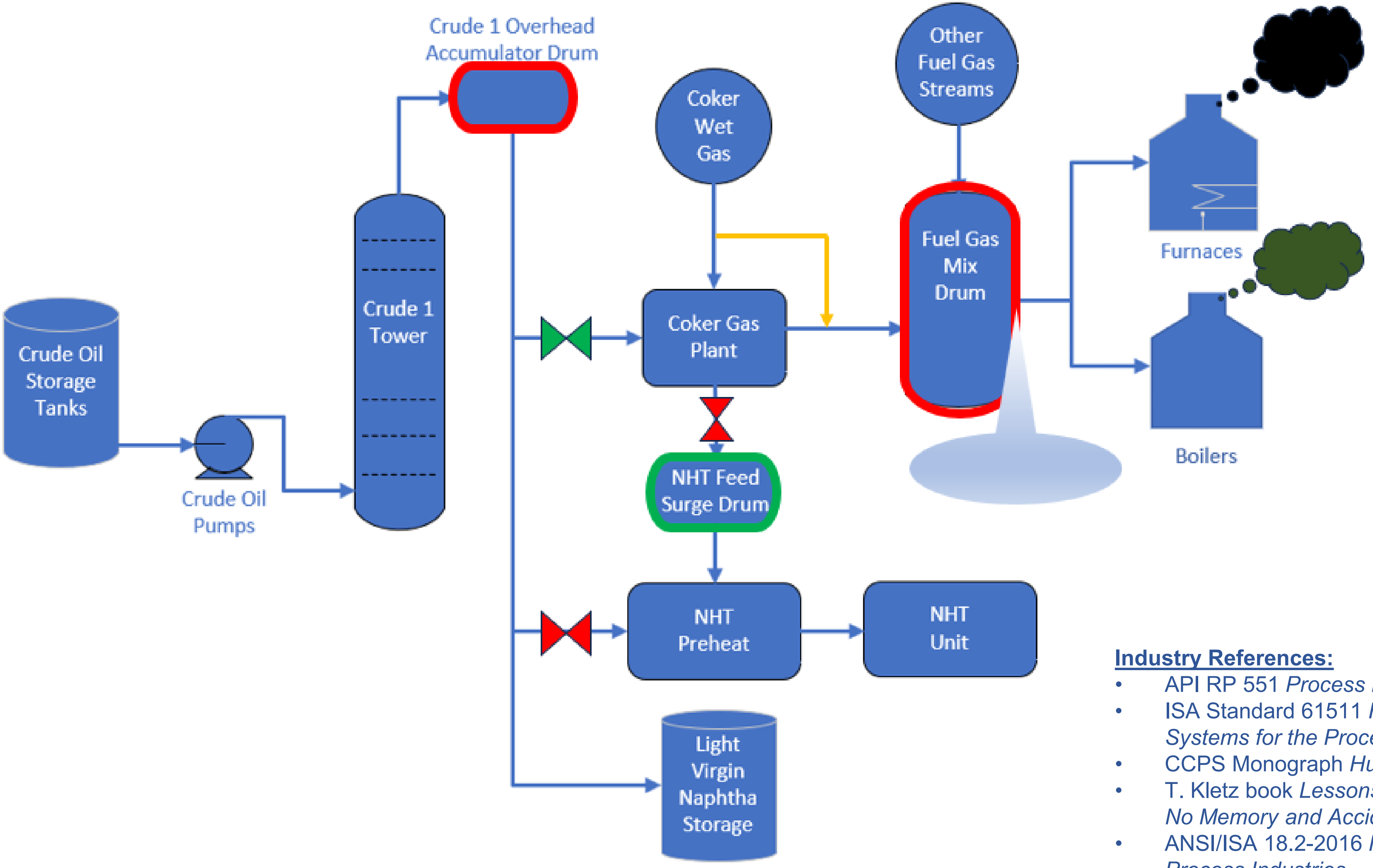
U.S. Chemical Safety and Hazard Investigation Board

- Oregon, OH; September 20, 2022 ~6:46 p.m.
- > 23,000 lbs naphtha released from a pressurized vessel & ignited
- 2 employees fatally injured
- Significant property damage ~$597 million
- Vessel typically only contained vapor
- Filled with naphtha through a vapor bypass line when upstream tower overflowed
- Operators instructed by board operator to drain the vessel as fast as they could, then they opened the vessel, releasing liquid naphtha to the ground

SAFETY ISSUES:

- Liquid Overflow Prevention
- Abnormal Situation Management
- Alarm Flood
- Learning from Incidents

BP Husky Toledo Incident Overview



Industry References:

- API RP 551 *Process Measurement*
- ISA Standard 61511 *Functional Safety – Safety Instrumented Systems for the Process Industry Sector*
- CCPS Monograph *Human Factors Primer for Front Line Leaders*
- T. Kletz book *Lessons from Disaster: How Organizations Have No Memory and Accidents Recur*
- ANSI/ISA 18.2-2016 *Management of Alarm Systems for the Process Industries*

BP Husky Toledo Incident Overview

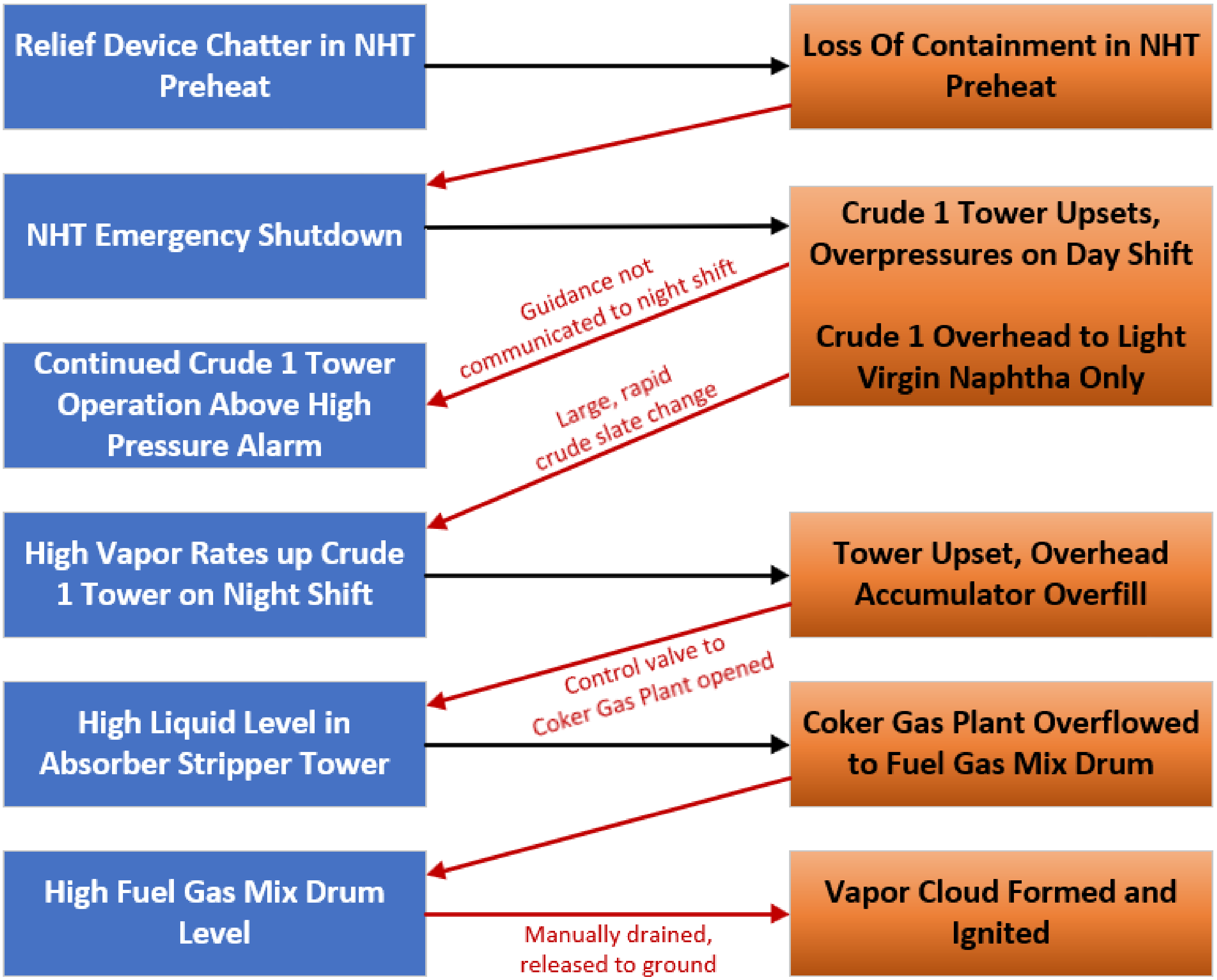
U.S. Chemical Safety and Hazard Investigation Board

"A disturbance in an industrial process with which the basic process control system cannot cope."

Guidelines for Managing Abnormal Situations (CCPS)

Abnormal situations can

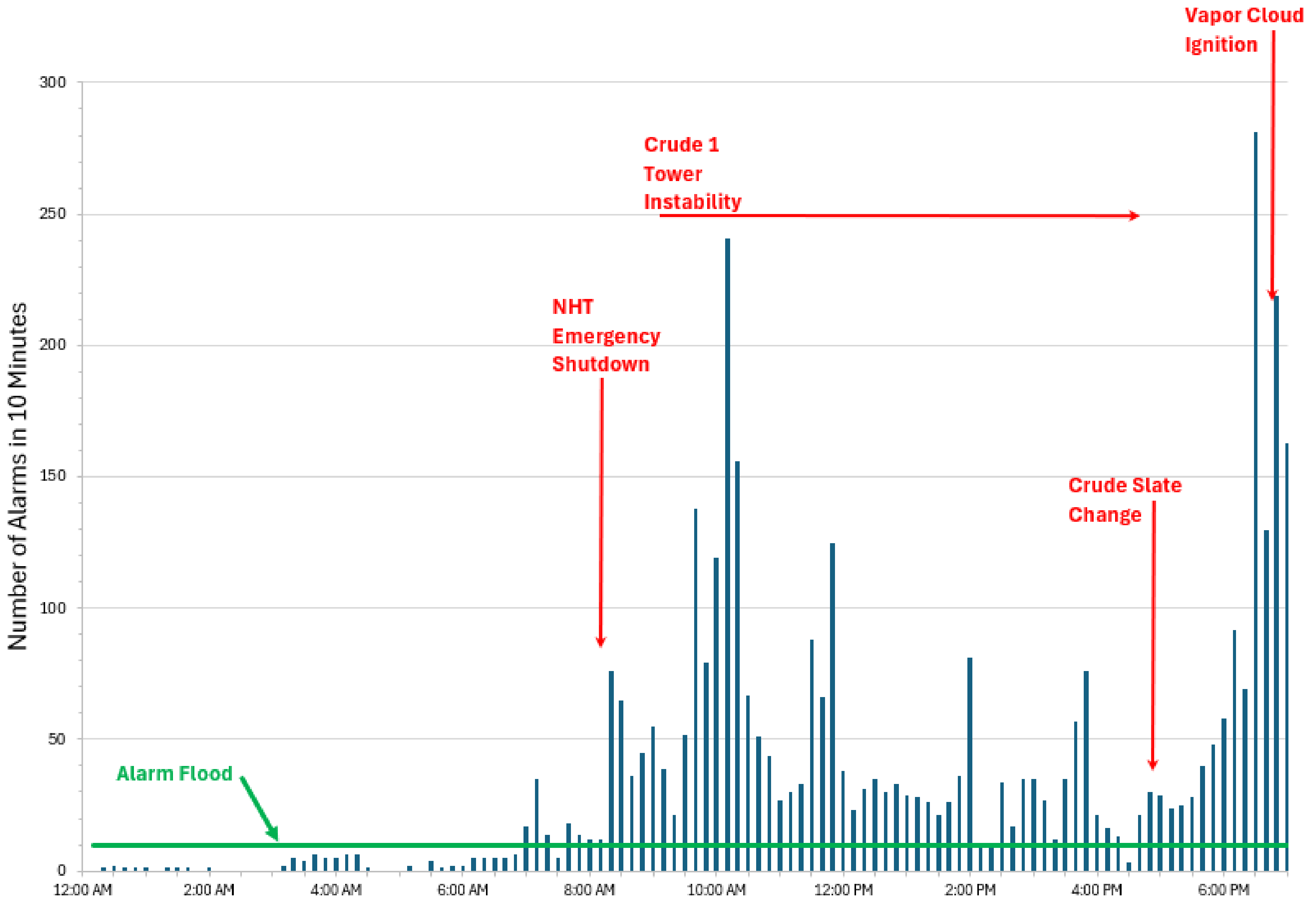
- Introduce stress
- Cause poor decision making
- Exacerbate the situation
- Cascade to further abnormal situations if not properly managed



BP Husky Toledo Incident Overview

U.S. Chemical Safety and Hazard Investigation Board

- Greater than 10 alarms in 10 minutes
- Over 3,700 alarms in 12 hours
- Peak alarm rate = 281 / 10 minutes
- Contributed to
  - Overloading board operators
  - Miscommunication
  - Alarm response errors
  - Missed critical alarms



BP-Husky Toledo "Key Lessons"

U.S. Chemical Safety and Hazard Investigation Board

KEY LESSON

Companies must ensure (through training, clearly written procedures, and other means) that employees not only are clearly empowered to exercise Stop Work Authority, but that employees also clearly understand they are expected to do so. However, companies should not rely on Stop Work Authority programs alone to prevent a catastrophic process incident since they require humans to take action to shut down a job or a process. Stop Work Authority is not a substitute for effective process safety management systems.

KEY LESSON

PHA scenarios should consider both preventive and mitigative safeguards and not unrealistically rely on human intervention.

KEY LESSON

PHAs should evaluate overfill hazards and consider scenarios in which a vessel may not overfill to the top but may instead overflow or backflow through other piping connections.

KEY LESSON

Companies should evaluate their PHAs for opportunities to implement additional safeguards to prevent initiating events that reduce the reliance on human intervention.

KEY LESSON

Companies should define operating limits beyond which Abnormal Situation Management procedures should be followed and clearly define those corrective actions to be followed, in order to stop a chain of abnormal events.

BP-Husky Toledo “Key Lessons”

U.S. Chemical Safety and Hazard Investigation Board

KEY LESSON

“Abnormal situations introduce stress, and operators under stress can make poor decisions, which then exacerbate the situation. How companies prepare and equip their operators to deal with these problematic and stressful situations is critical to ensuring the return of the unit to a safe state. Often, process safety incidents are a result of organizations failing in this area.” — CCPS, *Guidelines for Managing Abnormal Situations* [1, p. 24].

KEY LESSON

Thinking through abnormal situations *before* they occur, having plans in place, and practicing those plans can greatly improve operator and manager confidence and decision-making during an abnormal situation. Simulators, desktop drills, incident reviews, or field walkthroughs can improve abnormal situation management skills.

KEY LESSON

Managing abnormal situations goes beyond PSM compliance alone. PSM tools can be used, but for abnormal situations, the tools must be applied with abnormal situations specifically in mind, particularly cascading abnormal situations.

KEY LESSON

Companies should ensure that alarms are well justified. While DCS technology allows alarms to be created easily, it also can cause board operators to be inundated with low priority or irrelevant information during an abnormal situation if alarms are not properly designed. This also places additional stress on board operators, reducing their effectiveness when it is needed most.

KEY LESSON

Accident investigation techniques, such as *Five Whys*, suggest that there is only one root cause and one linear path to an accident [24, p. 291]. Using such approaches for process safety incidents, even if recommended in company safety procedures, can lead an investigation team to a superficial analysis that does not prevent an accident from recurring.

KEY LESSON

Organizations should develop systems to ensure that learnings from internal and external incidents are incorporated throughout the organization to prevent recurring failures, such as overflow of process vessels, that can lead to a catastrophic incident.

BP Husky Toledo: “To Do” List

U.S. Chemical Safety and Hazard Investigation Board

- [ ] Revise the safeguards used in the refinery’s process hazard analyses high level and overflow scenarios. At a minimum, **establish effective preventive safeguards that use engineered controls to prevent liquid overfill and do not rely solely on human intervention**.

- [ ] **Revise the Abnormal Situation Management policy to incorporate guidance provided by the ASM Consortium and the Center for Chemical Process Safety (CCPS).** The revised policy should include, at a minimum:
a) A broader definition of abnormal situations, such as that defined by the CCPS,
b) Additional predictable abnormal situations and their associated corrective procedures. At a minimum include the following abnormal situations:
1) unplanned crude slate changes,
2) continued operation of the Crude 1 unit with the naphtha hydrotreater unit shut down, and
3) an emergency pressure-relief valve opening.
c) Guidance to determine when an abnormal situation is becoming too difficult to manage and the appropriate actions to take, such as shutting down a process, putting it into a circulation mode, or implementing proper procedures for bringing it to a safe state.

- [ ] **Develop and implement a policy or revise existing policy that clearly provides employees with the authority to stop work that is perceived to be unsafe until the employer can resolve the matter**. This should include detailed procedures and regular training on how employees would exercise their stop work authority. Emphasis should be placed on exercising this authority during abnormal situations, including alarm floods.

- [ ] **Revise the ‘Toledo Alarm Philosophy’ by incorporating the Engineering Equipment and Manufacturers Users Association (EEMUA) guidance for alarm rate following an upset and not limiting alarm performance to a single metric averaged over a month.** In addition to including analyzing individual alarm flood events, the revised philosophy document should improve refinery alarm performance to reduce alarm flood duration and peak rate for events similar to the September 20, 2022, incident. Consult EEMUA Publication 191, Chapter 6.5.1, for guidance regarding abnormal condition performance levels. Apply the improved performance levels where applicable, but specifically to the Crude 1 control board alarm performance.

Key Lessons from CSB Investigations

Key Lessons - Summary

U.S. Chemical Safety and Hazard Investigation Board

- PSM integration in toll manufacturing contracts
- Beware of single points of failure
- Food manufacturers are susceptible to process safety risks
- Proximity of workers to equipment during unsafe conditions should be minimized
- Ensure SIS systems can’t be rendered inoperable due to misdirected flow
- Walk the line
- Stop work authority is not a substitute for effective process safety management systems
- Consider PHA scenarios where vessels can backflow through other connections vs overfill
- CCPS “Guidelines for Managing Abnormal Situations”
- Beware of linear thinking when utilizing the 5 Why investigation technique
- Organizations need to institutionalize learning to prevent similar incidents

CSB things to look out for…

U.S. Chemical Safety and Hazard Investigation Board

- ARRR incident reports Volume I and Volume II
- Current Investigations – Published Investigation Updates:
  - Honeywell (HF release – significant property damage)
  - Dow (EO release – significant property damage)
  - TS USA (Molten salt eruption – 1 fatality)
  - Cuisine Solutions (Anhydrous ammonia release – 4 serious injuries)
  - Bio-Lab (Chlorine gas release – significant community impact and property damage)
  - PEMEX (Hydrogen sulfide release – 2 fatalities, 13 injuries)
  - Givaudan (Release and explosion – 2 fatalities, 11 injuries, significant property damage, and community impact)
- BP Texas City 20th Anniversary Investigation Digest
- Remote Isolation of Process Equipment Safety Study
- Award-winning CSB Videos!

Extra slides at the end of slide deck:
Wacker Polysilicon (HCl release, SIMOPs)
Didion Milling (Combustible Dust, process safety management

Questions?

U.S. Chemical Safety and Hazard Investigation Board

U.S. Chemical Safety and Hazard Investigation Board

Extra slides…

Wacker Polysilicon

Wacker Polysilicon


Equipment Fracture and Fatal Hydrogen Chloride Release at Wacker Polysilicon North America

U.S. Chemical Safety and Hazard Investigation Board

Charleston, TN | *Incident Date: November 13, 2020* | No. 2021-01-I-TN

Investigation Report

Published: June 2023

KEY ISSUES:

- Written Procedures
- Control of Hazardous Energy
- Simultaneous Operations
- Means of Egress

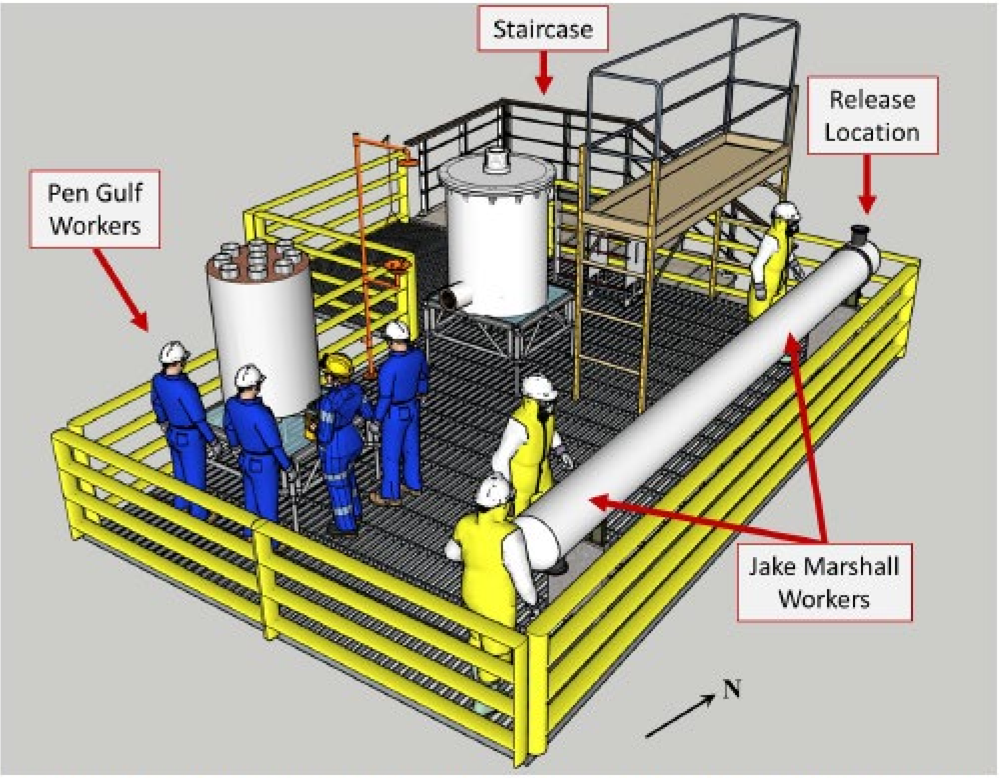


Figure 8. Pen Gulf and Jake Marshall work locations. Figure is not to scale and is intended to provide a general spatial representation of workers and equipment. (Credit: CSB via SketchUp)

[Wacker Final Report]

[Wacker CSB Video]

Wacker Polysilicon Incident Overview

CSB U.S. Chemical Safety and Hazard Investigation Board

- Charleston, TN; November 13, 2020
- Cracked graphite heat exchanger, release HCl gas
- 1 fatality, 2 injuries (fall injuries)
- Property damage ~$214,000
- During maintenance, excessive torque applied to bolts
- Heat exchanger piping contained HCl
- 2 contract firms working on same platform; different jobs (3 insulators and 4 pipefitters), different PPE requirements (FRC and full-body chemical-resistant suits)
- 3 pipefitters attempted to climb down the side of the structure during release – 1 fatally injured, 2 seriously injured

KEY ISSUES:
- Written Procedures
- Control of Hazardous Energy
- Simultaneous Operations
- Means of Egress

Figure 10. Image of HCl release at the time of release (left) and 15 seconds after release (right). (Credit: Wacker)

Wacker Polysilicon Incident Overview

U.S. Chemical Safety and Hazard Investigation Board

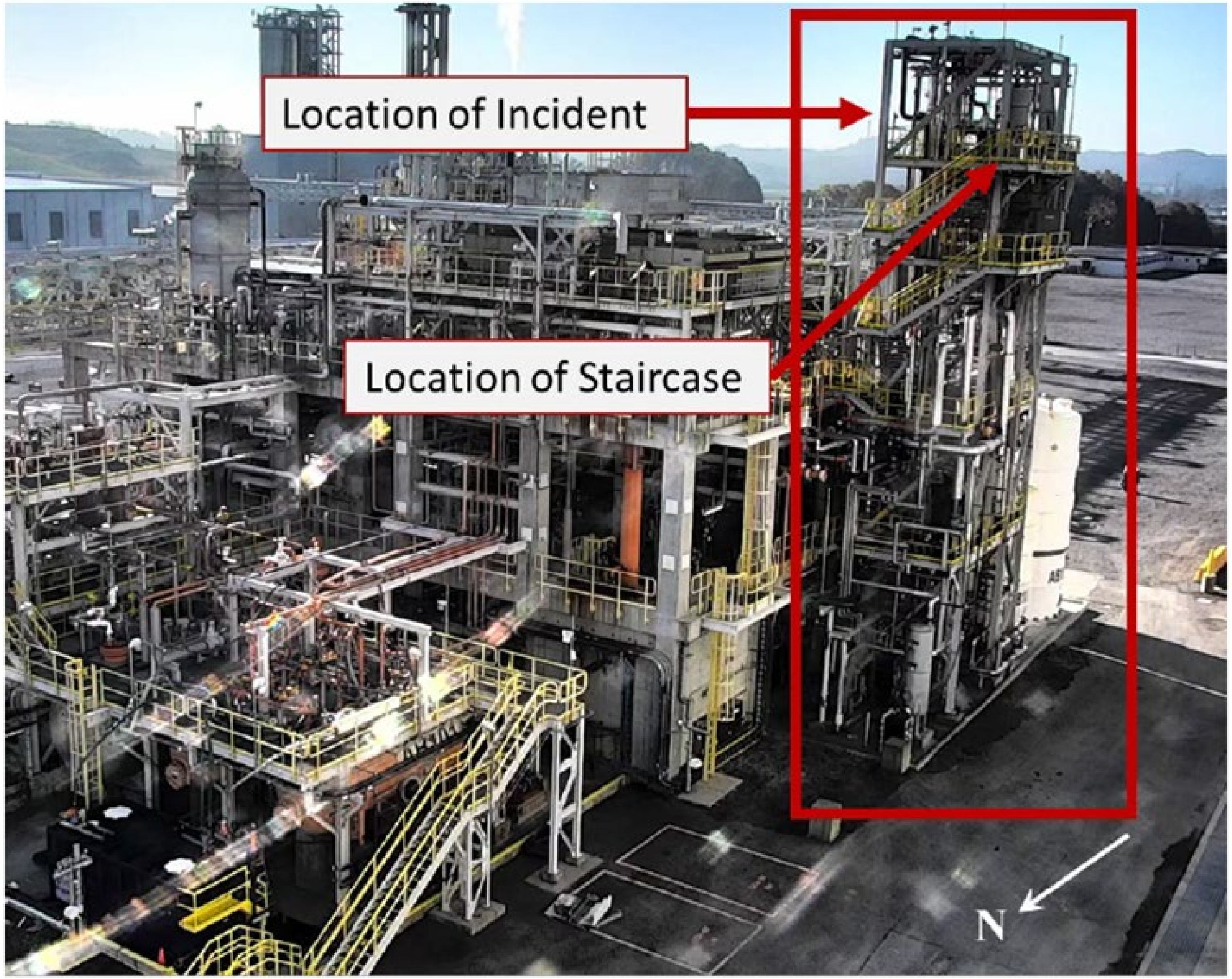


Figure 3. Equipment access structure where incident occurred. Directional arrow is approximate. (Credit: Wacker, annotations by CSB)

Wacker Polysilicon Incident Overview

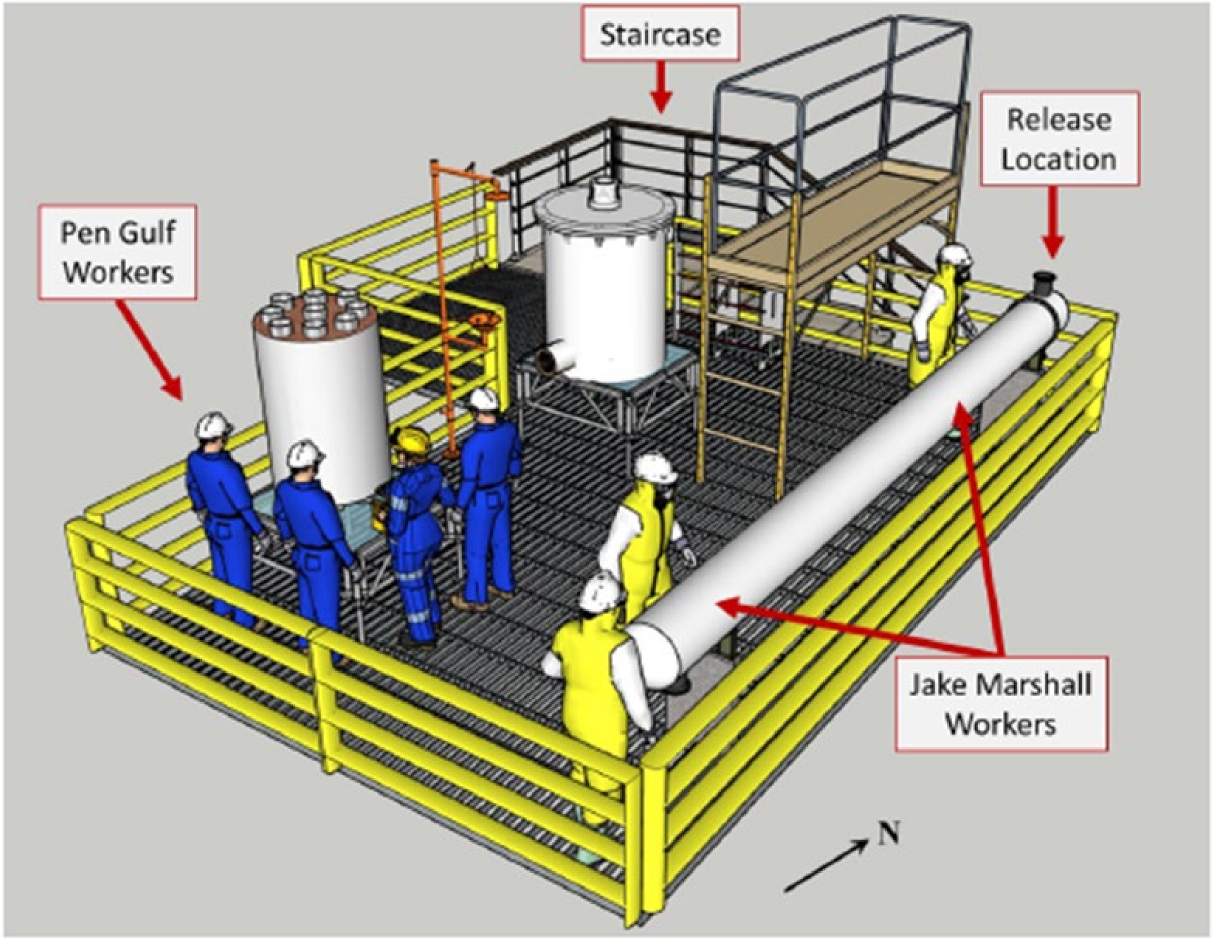
CSB U.S. Chemical Safety and Hazard Investigation Board

Simultaneous Operations (SIMOPs).

When the incident occurred, four workers from a separate contractor company were performing an unrelated pipe insulation task on the structure, as permitted by Wacker, and were present on the fifth-floor platform near the pipefitter work crew. Wacker did not have a policy or procedure for evaluating SIMOPs, a situation in which two or more operations occur together at a time and place. In addition, there is a general lack of industry and regulatory guidance on SIMOPs considerations available to companies such as Wacker. As a result, Wacker did not evaluate the risks associated with the simultaneous work tasks, and the contract workers not involved in the torquing task were unnecessarily exposed to the HCl release.

Means of Egress.

During the incident, seven workers were present on the fifth-floor platform, which was equipped with only a single point of egress. Wacker designed the equipment access structure with a single point of egress based on building code requirements for an “unoccupiable equipment platform”. The CSB found that the current International Building Code and National Fire Protection Association building requirements do not provide for sufficient means of egress from elevated work platforms used for accessing equipment containing hazardous materials. Additionally, three months before the incident during the Process Hazard Analysis, Wacker employees identified the need for a second point of egress, but Wacker did not take any action to address this recommendation before the incident.



Wacker Polysilicon “Key Lessons”

U.S. Chemical Safety and Hazard Investigation Board

KEY LESSON

Language, vernacular, and jargon, when undefined and undocumented, can result in different interpretations of the same terminology. It is important that localized terminology referring to actions and tasks on process equipment be officially defined in a site-specific policy or procedure.

KEY LESSON

Written procedures are a critical tool for ensuring safe operations and maintenance activities. Procedures consolidate information required to execute a given task into easy-to-understand step-by-step instructions, with specific reference to safety precautions and crucial actions. Written procedures for hazardous operations should be prepared as part of robust safe work practices, including on temporary or ancillary maintenance activities.

KEY LESSON

The control of hazardous energy should be considered whenever equipment containing hazardous energy is repaired, adjusted, serviced, and maintained, not only in situations in which equipment is intentionally opened. Prior to working on equipment containing hazardous energy, a risk assessment should always be performed to evaluate the need for energy isolation or other protective measures.

KEY LESSON

Owners and operators should always consider how simultaneous operations, or SIMOPs, could impact a given operation, whether by influencing a hazard or affecting the risk of the operation. SIMOPs should be identified and controlled via a hazard assessment prior to commencing a given operation or task. An established system to manage work permits can also identify risks associated with SIMOPs before they occur. A well-established system must be able to document the specific task to be executed, readily coordinate the issued permits, and identify scenarios of potential interaction between permitted work groups.

KEY LESSON

The Process Hazard Analysis (PHA) is an important tool for identifying, evaluating, and controlling process- and facility-specific hazards. While building codes are an important foundation in facility design, they do not necessarily consider the specific hazards posed by a given process. Owners and operators should prioritize the implementation of PHA recommendations and employee input to control hazards that have been identified by those closest and most familiar with facilities and operations.

Wacker Polysilicon: "To Do" List

U.S. Chemical Safety and Hazard Investigation Board

- [ ] **Develop and implement a formalized Simultaneous Operations (SIMOPs) program addressing planned and/or permitted co-located work tasks** including:
a. Identification of potential SIMOPs;
b. Identification of potential hazardous interactions;
c. Evaluation and implementation of necessary safeguards to allow for safe SIMOPs;
d. Coordination, including shared communication methods, between the SIMOPs; and
e. Inclusion of emergency response personnel or services in the planning and coordination of the SIMOPs.
Ensure relevant staff are trained on execution of the SIMOPs program.

- [ ] **Develop policy requirements to ensure torquing activities performed on equipment containing hazardous energy are performed safely,** such as through de-inventorying equipment or restriction of nonessential personnel and ensuring that essential workers wear proper PPE. Document these requirements in procedures, such as Lock, Tag and Try; First Line Break – Return to Service; or other procedures as applicable. Ensure employees and contractors are trained on these procedures in accordance with the Process Safety Management (PSM) standard requirements found in 29 CFR 1910.119(f)(4) and 29 CFR 1910.119(g) and the Risk Management Program (RMP) rule found in 40 CFR 68.69(d) and 40 CFR 68.71.

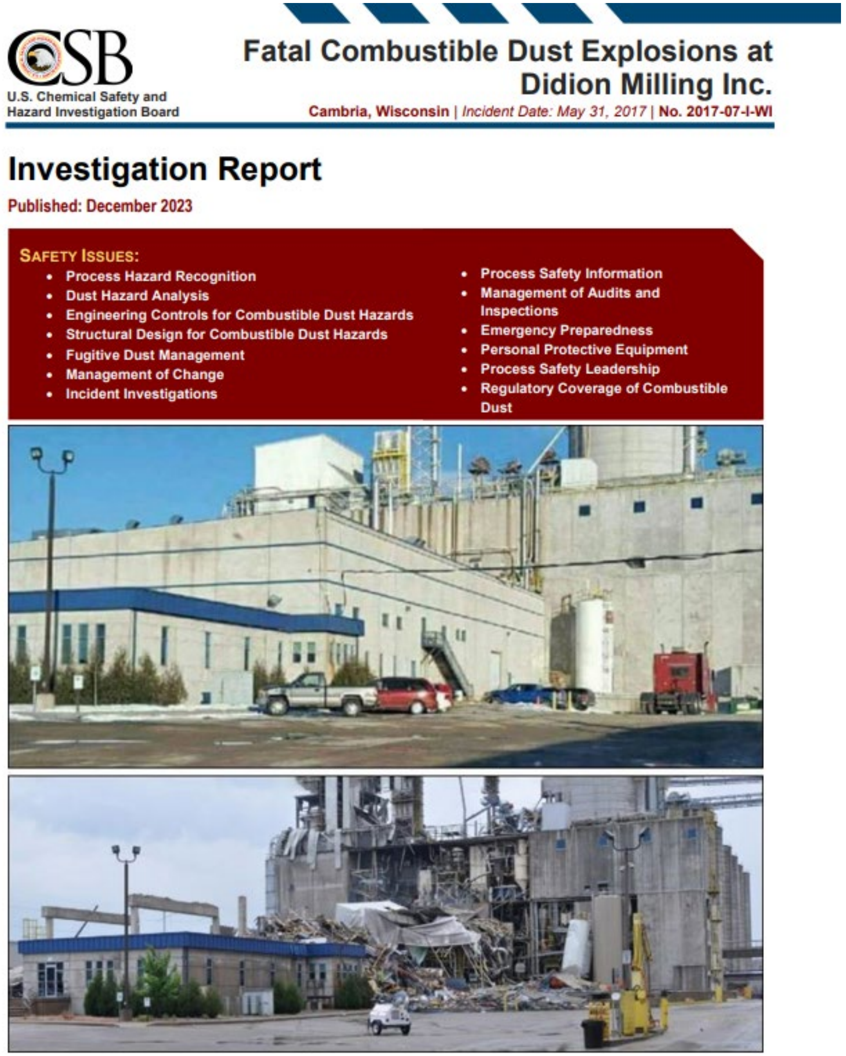
- [ ] **Install additional means of egress for the T230 desorption tower platforms and other multi-floor equipment structures on-site**. After completing these installations, ensure workers are made aware of exit locations from the structure platforms through training, drills, or other techniques as appropriate.

- [ ] **Develop detailed maintenance procedures for torquing activities** which:
a. Clearly communicate differing equipment torque specifications, such as those for bolts installed at PTFE-to-PTFE and PTFE-to-graphite connections through visual means such as annotated photographs, signage, physical differentiation, and other methods, as appropriate;
b. Include procedural requirements for all torquing activities conducted on equipment containing hazardous material to perform an engineering and risk analysis and implement safeguards as a result of the risk analysis, per American Society of Mechanical Engineers (ASME) PCC-1-2019 Guidelines for Pressure Boundary Bolted Flange Joint Assembly and ANSI/ASSP Z244.1-2016 The Control of Hazardous Energy Lockout, Tagout and Alternative Methods;
c. Ensure that terms such as "hot torque" are clearly defined, and that employees and contractors are trained on these terms; and
d. Ensure that procedures and training conform to the mechanical integrity requirements of the Process Safety Management (PSM) standard found in 29 CFR 1910.119(j) and the Risk Management Program (RMP) rule found in 40 CFR 68.73.

Industry Guidance on SIMOPs:
- IMCA publication "*Guidance on Simultaneous Operations*"
- UK HSE, HSG250 "*Guidance on Permit-to-Work Systems*"
- AIChE 2017 article in *Process Safety Progress*, vol. 36 "Simultaneous Operation (SIMOP) Review: An Important Hazard Analysis Tool

Didion Milling

U.S. Chemical Safety and Hazard Investigation Board


U.S. Chemical Safety and Hazard Investigation Board

Fatal Combustible Dust Explosions at Didion Milling Inc.

Cambria, Wisconsin | Incident Date: May 31, 2017 | No. 2017-07-I-WI

Investigation Report

Published: December 2023

SAFETY ISSUES:

- Process Hazard Recognition
- Dust Hazard Analysis
- Engineering Controls for Combustible Dust Hazards
- Structural Design for Combustible Dust Hazards
- Fugitive Dust Management
- Management of Change
- Incident Investigations
- Process Safety Information
- Management of Audits and Inspections
- Emergency Preparedness
- Personal Protective Equipment
- Process Safety Leadership
- Regulatory Coverage of Combustible Dust

[Didion Milling Final Report]

Combustible Dust Hazards

Didion Milling: "To Do" List

U.S. Chemical Safety and Hazard Investigation Board

Contract a competent third party **to develop a comprehensive combustible dust process safety management system,** such as OSHA's Process Safety Management standard or the requirements in the 2019 edition of NFPA 652, Standard on the Fundamentals of Combustible Dust, Chapter 8, which includes, at a minimum, the following elements:
a. Management of Change for combustible dust;
b. Process Safety Information management;
c. Management of Audits and Inspections;
d. Fugitive Dust Management;
e. Incident Investigation;
f. Dust Hazard Analyses;
g. Management of Engineering Controls for combustible dust;
h. Personal Protective Equipment; and
i. Emergency Preparedness.

Contract a competent third party to **develop and implement modifications to the pneumatic conveying and dust collector ductwork systems in accordance with guidance** such as NFPA 61, Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities, NFPA 652, Standard on the Fundamentals of Combustible Dust, and NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, to include, at a minimum:
a. Ensure minimum required transport velocity is maintained throughout the system.
b. Implement a periodic inspection and testing program for pneumatic conveying and dust collector ductwork systems, following industry guidance such as NFPA 91, Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids, and FM Global guidance. The program should include cleaning on a set frequency and measuring transport velocities on a routine basis to ensure proper system function.

Contract a competent third party to perform dust hazard analyses (DHAs) on all buildings and units that process combustible dust. Ensure that the DHAs are revalidated at least every five years. Implement pre-deflagration detection, deflagration venting, deflagration suppression, deflagration isolation, and deflagration pressure containment engineering controls identified in the initial and revalidation DHA in accordance with NFPA 61, Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities, NFPA 68, Standard on Explosion Protection by Deflagration Venting, NFPA 69, Standard on Explosion Prevention Systems, and NFPA 652, Standard on the Fundamentals of Combustible Dust.

Contract a competent third party to assess and implement engineering controls for the structural design and venting requirements of the reconstructed facility to ensure they meet the requirements and guidance in NFPA 68, Standard on Explosion Protection by Deflagration Venting, for adequacy of venting capacity.

Incorporate recording any paper-based process safety information into Didion's **existing electronic records management system** so that the information can be reliably retained, retrieved, and analyzed in the event of a catastrophic incident.

Contract a competent third party to perform personal protective equipment hazard analyses, such as those prescribed by NFPA 2113, Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire, and require appropriate flame-resistant garments for all operations that handle combustible dusts during normal and upset conditions.

Contract a competent third party to **update the facility emergency response plan and train all employees on updated emergency response plan.** The update should include the guidance in NFPA 61, Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities, and NFPA 652, Standard on the Fundamentals of Combustible Dust, Chapter 8 and Section A.8.10.1, which includes, at a minimum, the following elements:
a. A signal or alarm system;
b. Emergency shutdown procedures;
c. Provide instructions for when and how to trigger emergency evacuations;
d. Provide instructions for when to notify emergency responders for need of assistance;
e. Response to potential fire scenarios, such as smoldering fires inside equipment; and
f. Prevent firefighting of process fires inside equipment.

Contract a competent third party to **assess and update the pre-deflagration detection and suppression engineering controls**, such as those discussed in Chapter 9 of the 2019 edition of NFPA 69, Standard on Explosion Prevention Systems, for adequacy to detect and alarm employees of an emergency situation, such as a smoldering fire, and trigger an evacuation.

Contract a competent third party to **develop and implement a process safety leadership and culture program, based on the guidance of the CCPS's Guidelines for Auditing Process Safety Management Systems and Process Safety: Leadership from the Boardroom to the Frontline**. The program should include, at a minimum, the following elements:
a. A process safety policy;
b. A process safety leadership and culture committee;
c. Appropriate goals for process safety;
d. A commitment to process safety culture;
e. Leading and lagging process safety metrics;
f. Process Safety Culture Assessments; and
g. Engagement with external process safety leadership and culture experts.

AB Specialty Silicones

U.S. Chemical Safety and Hazard Investigation Board


CSB U.S. Chemical Safety and Hazard Investigation Board

Chemical Reaction, Hydrogen Release, Explosion, and Fire at AB Specialty Silicones

Waukegan, IL | *Incident Date: May 3, 2019* | No. 2019-03-I-IL

Investigation Report

Published: September 24, 2021

Safety Issues:

- Mixing of Incompatible Materials
- Hazard Analysis Program
- Storage and Handling of Incompatible Materials
- Batch Equipment and Ventilation System Design
- Gas Detection System
- Emergency Preparedness
- Double Initial Procedure Program
- Process Safety Culture
- Safety Management System that Addresses Process Safety
- Regulatory Coverage of Reactive Hazards

Mixing of Incompatible Materials. An AB Specialty operator pumped an incorrect chemical into a tank, which was incompatible with another chemical that was added to the tank. The chemicals reacted to produce hydrogen gas, which found an ignition source and ignited to cause the explosion. (Section 3.1) **Hazard Analysis Program.** AB Specialty assessed proposed product manufacturing operations through what it called technical service requests (TSRs), which evaluated a mix of business and safety risks. AB Specialty's TSR process did not and was not intended to assess the hazards of performing a process operation or establish safeguards to reduce risk. (Section 3.2) **Storage and Handling of Incompatible Materials.** AB Specialty did not have a written procedure requiring employees to segregate incompatible chemical drums in the production building's manufacturing area or remove ingredient containers after use. The incompatible chemicals that were mixed were stored in similar 55-gallon blue plastic drums. The similar appearance of the drums likely contributed to the operator adding the incorrect chemical to the tank. (Section 3.3) **Batch Equipment and Ventilation System Design.** As a result of the tanks used in the EM 652 batch process having an open hatch-type lid and no vent pipe to direct gases to a safe location, the hydrogen gas produced during the incident released directly into the production building, where workers were located. The ventilation system, including an air mover—designed to introduce outside air to the building and which was positioned near the location where the batch operation was being performed— may have helped distribute the hydrogen in the production building and mix it with air, creating a large and explosive gas cloud. (Section 3.4) **Gas Detection and Alarm System.** The AB Specialty production building did not have a hydrogen gas or flammable gas detection and alarm system to warn employees of a hazardous atmosphere. The lack of a system to detect hydrogen gas and automatically activate an alarm contributed to personnel remaining inside the production building between the start of the hydrogen release and the time of ignition. (Section 3.5) **Emergency Preparedness.** During the incident, workers recognized that a process upset had occurred when the tank contents foamed, overflowed the tank, and a fog formed. However, despite recognizing the process upset, the workers did not recognize the immediate hydrogen hazard created by the upset. Hydrogen is a colorless and odorless gas indistinguishable from air without the use of additional technology, such as gas detectors. Without gas detectors and alarms alerting of the hazardous conditions, or effective training, the workers did not realize the necessity to evacuate. (Section 3.6) **Double Initial Procedure Program.** AB Specialty developed a double initial procedure practice in 2014 in an effort to prevent employees from charging the wrong materials to batch processes, which was proceduralized in 2019. The occurrence of the May 3 incident indicates that AB Specialty's double initial procedure program did not prevent a wrong material from being added to the tank. (Section 3.7) **Process Safety Culture.** In the years leading up to the incident, AB Specialty exhibited characteristics of a weak process safety culture, including the lack of engineering controls to mitigate employee exposure to known hydrogen gas risks and heavy reliance on procedural controls as primary safeguards, among others. In addition, the company did not require incompatible chemicals to be visibly differentiated or perform a thorough hazard analysis of the EM 652 batch process after a 2014 drum explosion. (Section 3.8) **Safety Management System that Addresses Process Safety.** AB Specialty did not have a safety management system that addressed process safety in place at the time of the incident. Industry best practice publications provide guidance on establishing process safety management systems for facilities with known or potential reactive chemical hazards. (Section 3.9) **Regulatory Coverage of Reactive Hazards.** While AB Specialty processed chemicals capable of undergoing a highly hazardous chemical reaction that resulted in a large explosion and four fatalities, the chemicals used at the AB Specialty facility are not listed for coverage in either the Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) Standard or the Environmental Protection Agency (EPA) Risk Management Plan (RMP) Rule. As such, AB Specialty was not required to implement baseline process safety management system elements to manage the safety of its processes under these regulations. (Section 3.10)

[AB Specialty Silicones Full Report]

AB Specialty Silicones: “To Do” List

U.S. Chemical Safety and Hazard Investigation Board

Ensure hydrogen gas detection and alarm systems are properly installed, maintained, and configured based on the facility’s application and environment, manufacturer specifications, current codes, standards, and industry good practice guidance. The program must address sensor technology selection, installation, calibration, inspection, maintenance, sensor replacement, training, and routine operations. **Establish a safety management system that addresses process safety** at the AB Specialty Waukegan, Illinois facility. Include in that system elements recommended in industry guidance publications, for example, Center for Chemical Process Safety (CCPS) publications Guidelines for Risk Based Process Safety and Guidelines for Implementing Process Safety Management. Incorporate into operations and activities at AB Specialty the specific elements recommended in CCPS’s Essential Practices for Managing Chemical Reactivity Hazards, which are:

1. Put into place a system to manage chemical reactivity hazards
2. Collect reactivity hazard information
3. Identify chemical reactivity hazards
4. Test for chemical reactivity
5. Assess chemical reactivity risks
6. Identify and implement process controls and risk management options
7. Document chemical reactivity risks and management decisions
8. Communicate and train on chemical reactivity hazards
9. Investigate chemical reactivity incidents
10. Review, audit, manage change in, and improve hazard management practices and programs