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INCIDENT REPORTS

EVENTS REPORTED TO THE CSB UNDER THE ACCIDENTAL RELEASE REPORTING RULE

U.S. Chemical Safety and Hazard Investigation Board

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Summary

This volume of Incident Reports covers 26 accidental release events in 15 states. These events resulted in 5 fatalities, 17 serious injuries, and approximately $697 million in property damage.

Accidental Release Events							
Number	Incident Date	Company	City	State	Fatality	Serious Injury	Substantial Property Damage ($ Million)
1	2020-04-10	Valero Meraux Refinery	Meraux	Louisiana		1	5.15
2	2020-04-11	LACC	Westlake	Louisiana		1	
3	2020-07-24	Wacker Polysilicon	Charleston	Tennessee		2	
4	2020-12-03	Formosa Plastics Corporation	Point Comfort	Texas		1	
5	2021-06-14	Lubrizol Chemtool	Rockton	Illinois			380
6	2021-10-06	ConocoPhillips	Carlsbad	New Mexico		1	
7	2022-01-15	Rubicon	Geismar	Louisiana		2	
8	2022-12-19	Home Market Foods	Norwood	Massachusetts	1	1	4
9	2022-12-24	Suncor Energy	Commerce City	Colorado		1	40
10	2023-01-07	Tyson Foods	Perry	Iowa		1	
11	2023-01-17	Dow St. Charles Operations	Hahnville	Louisiana		1	
12	2023-01-17	Phillips 66 Refinery	Borger	Texas	1	1	3.1
13	2023-01-19	Georgia-Pacific	Rincon	Georgia		1	
14	2023-01-21	CITGO Petroleum Refinery	Sulphur	Louisiana			1.5
15	2023-01-31	Kinder Morgan Gas Plant	Snyder	Texas			14
16	2023-02-11	Kinder Morgan Crude Oil Production Facility	Snyder	Texas			1.5
17	2023-02-21	Georgia-Pacific	La Mirada	California		1	
18	2023-02-23	Pemex Refinery	Deer Park	Texas			2.3
19	2023-02-24	ConocoPhillips	Watford	North Dakota	1		
20	2023-02-24	Georgia-Pacific	Alcolu	South Carolina		1	
21	2023-03-14	Pemex Refinery	Deer Park	Texas			1
22	2023-03-29	Domtar Paper Mill	Hawesville	Kentucky		1	
23	2023-04-08	Flint Hills Resources Refinery	Rosemount	Minnesota			2.235
24	2023-05-04	Polycarbon Industries	Newburyport	Massachusetts	1		48
25	2023-06-22	Darling Ingredients	Wadesboro	North Carolina	1		
26	2023-09-05	BASF TotalEnergies	Port Arthur	Texas			194
				Total	**5**	**17**	**697**

1. Valero Meraux Refinery

April 10, 2020

Meraux, Louisiana

Incident Summary

On April 10, 2020, at 12:46 a.m., a mixture of hydrogen and hydrocarbon gas was accidentally released within the Hydrocracker unit of the Valero Meraux Refinery ("Valero") in Meraux, Louisiana. The flammable gas formed a vapor cloud that ignited, resulting in an explosion and fire (**Figure 1**) that seriously injured one Valero operator and caused approximately $5.15 million in property damage.

Figure 1. Surveillance camera images before (left) and during (right) the fire at Valero Meraux Refinery. (Credit: Valero Meraux Refinery)

After a heavy rainstorm, the flow to the Hydrocracker unit's flare began increasing. Valero operators found that although the unit's cold separator was operating at normal working pressure, its emergency pressure-relief valve had malfunctioned and remained open, allowing flammable gas to flow into the flare system. Two managers at the refinery phoned the complex manager, who gave the onsite managers verbal approval to proceed with immediate actions to stop the flaring by reseating the safety device.

Valero uses the term "reseating" when referring to its practice of trying to close and seal a malfunctioning emergency pressure-relief valve by incrementally closing the inlet (upstream) isolation valve to lower the inlet pressure to the safety device. If the emergency pressure-relief device successfully closes (reseats), its inlet valve is reopened, which returns the safety device to its protective condition.

Valero's onsite managers used the refinery's management of change process for isolating a safety device to document Valero management's approval for the operations team to perform the urgent reseating activity. One of the onsite managers—the operations supervisor—worked with two field operators to perform the reseating activity while the board operator monitored the system pressure from the control room. Operations personnel raised safety concerns related to accessing either of the two 6-inch inlet valves, resulting in a decision to close the 20-inch outlet valve on the downstream side between the emergency pressure-relief valve and the flare system instead of trying to close one of the inlet valves.

The hazard of closing the outlet valve instead of closing one of the inlet valves was not recognized. Although the two 6-inch inlet valves were designed for high-pressure conditions—2,470 pounds per square inch (psi), the 20-inch outlet valve to the flare system was rated for just 275 psi. Closing the 20-inch outlet valve would subject this valve to about 2,100 psi of pressure from the flammable vapor flowing from the cold separator, much greater than the valve's 275 psi pressure rating.

When the operations team had the outlet valve about 90 percent closed (**Figure 2**), the valve failed—releasing a high-pressure mixture of hydrogen and hydrocarbon vapor into the surrounding air. The flammable gas formed a vapor cloud, which ignited resulting in the explosion and fire.

Valero reported that about 49,000 pounds of the hydrogen and hydrocarbon mixture were released.

Figure 2. Nearly closed outlet valve. (Credit: Valero Meraux Refinery, modified by CSB)

Probable Cause

Based on Valero's investigation, the CSB determined that the probable cause of the accidental release, explosion, and fire was the closure of the 20-inch manual isolation outlet valve (located downstream of the emergency pressure-relief valve) instead of one of the two inlet (upstream) 6-inch isolation valves that were rated for the high-pressure condition.

2. LACC

April 11, 2020

Westlake, Louisiana

Incident Summary

On April 11, 2020, at 11:25 p.m., a spent caustic release occurred at the LACC, LLC ("LACC") facility in Westlake, Louisiana (**Figure 1**). One LACC operator was seriously injured by skin exposure to the corrosive liquid.

Figure 1. Spent Caustic Storage and Handling Equipment at the LACC Facility. (Credit: LACC)

At the time of the incident, the operator was implementing a temporary procedure to remove liquid from a chemical hose connected to fill a portable storage tank ("frac tank") that the company was using to store spent caustic. Once the frac tank was full, air was used to clear the chemical hose before moving the hose to an empty frac tank.

When the operator opened the valve at the frac tank, pressurized fluid in the chemical hose flowed into the tank, erupting spent caustic from the unsecured top hatch (manway) and splashing the corrosive liquid onto the operator. The operator's personal protective equipment (PPE) did not protect from caustic liquid exposure. It took the operator about two minutes to reach the closest plant safety shower to rinse off the corrosive liquid because there was no safety shower near the frac tank, despite the site requirement for a safety shower within 25 feet of the tank. The operator then went to the control room and reported the incident. Emergency responders transported the operator to a hospital, where she was admitted for treatment of chemical burns.

LACC estimated that approximately 20 gallons of spent caustic were released. The spent caustic was comprised of water, sodium hydroxide, sodium sulfide, sodium carbonate, and pyrolysis gasoline.

Probable Cause

Based on LACC's investigation, the CSB determined that the probable cause of the spent caustic release was pressurized fluid flowing from a chemical hose into a nearly full frac tank of spent caustic with an unsecured top hatch (manway). Contributing to the incident was the company's use of these frac tanks to address a short-term reliability issue with LACC's oxidizing reactor. Reliability problems with the oxidizing reactor resulted in the continual use of these frac tanks.

LACC's written procedure to remove liquid from the chemical hose connected to the frac tank, which did not address securing the frac tank's top hatch and provided a path for the spent caustic to be ejected from the tank, also contributed to the incident.

Not wearing appropriate PPE that could protect from caustic liquid exposure and the prolonged time it took for the operator to reach a safety shower and obtain medical treatment contributed to the severity of the worker's injuries. Had safety showers been equipped with an alarm system and located closer to the area, the severity of the operator's injuries could have been reduced.

3. Wacker Polysilicon

July 24, 2020

Charleston, Tennessee

Incident Summary

On July 24, 2020, at 1:20 p.m., an accidental release of approximately 100 milliliters of silicon tetrachloride seriously injured two contract workers at the Wacker Polysilicon North America ("Wacker") facility in Charleston, Tennessee (**Figure 1**).

Figure 1. Wacker facility in Charleston, Tennessee. (Credit: Google Earth)

At the time of the event, contract workers were disassembling a 2-inch flange to remove a blind (a solid metal plate used for isolating equipment) before reinstalling a section of piping that had been taken out and cleaned. This type of equipment opening is commonly called a "line opening" or "performing a line break."

The contract workers performing the line opening wore personal protective equipment ("PPE"), including full-face respirators, chemical gloves, and fall protection. The contractor's pre-job safety analysis form did not require using chemical suits or rubber boots because the piping system had been taken apart the previous day for the cleaning activity. This additional protective equipment was required by Wacker's safe work permit, authorizing the contractor to perform the line opening work. As the workers disconnected the flanged connection bolts, they were splashed with corrosive liquid silicon tetrachloride that had leaked past an isolation valve and pressurized the piping, seriously injuring the two contract workers with chemical burns.

OSHA investigated the event and cited the contractor for not ensuring workers used the chemical suits and rubber boots required by the safe work permit. OSHA's investigation file noted confusion between the contractor and Wacker about line opening work and who could perform it. The contractor told OSHA that the company had performed many similar equipment opening tasks at the Wacker facility. Wacker told OSHA, however, that only Wacker employees were allowed to perform this type of line opening work.

The scope of Wacker's investigation was narrow and insufficient. Wacker's investigation found that the contractor was responsible for the incident because the contractor (1) had performed this line opening work and (2) did not use suitable PPE during that work—violations of Wacker's policies and administrative controls. However, Wacker's investigation did not evaluate Wacker's role in the incident's causation. For example, Wacker personnel authorized these contractors to perform the line opening work, which Wacker stated its policies require Wacker employees to perform. In addition, Wacker did not ensure that this piping was effectively isolated, flushed, and drained to remove silicon tetrachloride before tasking the contract workers to perform the line opening work. Furthermore, Wacker's policies required that a Wacker manager confirm that the personnel performing the line opening work had the required PPE, which did not occur.

Probable Cause

Based on the factual investigative information the CSB obtained from Wacker and OSHA, the CSB determined that the probable cause of the accidental silicon tetrachloride release was Wacker's failure to effectively isolate, flush, and drain the piping system before turning it over to the contract workers for disassembly. Not using PPE that could protect the workers from being splashed with corrosive silicon tetrachloride contributed to the severity of the incident.

4. Formosa Plastics Corporation

December 3, 2020

Point Comfort, Texas

Incident Summary

On December 3, 2020, at approximately 2:30 p.m., an accidental release of toxic chlorine gas occurred at a Formosa Plastics Corporation, Texas ("Formosa") facility in Point Comfort, Texas, and seriously injured one employee (**Figure 1**).

Figure 1. Formosa Plastics Corporation - Point Comfort Facility (Credit: Google Earth).

At the time of the incident, four Formosa employees were involved in replacing an empty chlorine container with a full 2,000-pound (one-ton) container at the facility's Ethylene Glycol unit. Formosa used chlorine gas as a biocide in its cooling water treatment system.

As a Formosa employee disconnected the supposedly empty chlorine container from the process equipment, chlorine gas escaped because, unknown to the Formosa workers, the container still held 1,250 pounds of chlorine (62.5 percent of its original inventory). Because the chlorine container was understood to be empty, the Formosa employee was not wearing respiratory protection. After three failed attempts to stop the release, an emergency responder was able to close the chlorine container's vapor valve and stop the release after 50 minutes.

The Formosa employee who disconnected the chlorine container was life-flighted to the hospital after showing respiratory difficulties from exposure to chlorine. Formosa reported that approximately 10 pounds of chlorine gas were released.

Formosa's investigation team recommended installing a scale for each container to address the false indication of an empty ton container of chlorine in the future. Knowing the weight of the chlorine container could help plant workers confirm that a container is empty or alert them that the container is not

empty. In addition, Formosa strengthened its operating procedures to clarify that respiratory protection is needed when changing a chlorine container.

Probable Cause

Based on Formosa's investigation, the CSB determined that the probable cause of the accidental chlorine release was disconnecting process equipment from the chlorine container while the system was pressurized with chlorine. The lack of instrumentation or other equipment to allow the operators to confirm the amount of chlorine in the container contributed to the incident. Another factor contributing to the incident was Formosa's use of chlorine in its cooling water treatment program. Had Formosa used a safer alternative, such as bleach, this incident could have been prevented.

5. Lubrizol Chemtool

June 14, 2021

Rockton, Illinois

Incident Summary

On June 14, 2021, at approximately 6:50 a.m., an accidental release of mineral oil occurred at Lubrizol's Chemtool facility in Rockton, Illinois. The mineral oil ignited and caused a fire. The event resulted in $380 million in property damage and the permanent closure of the Chemtool facility (**Figure 1**). Before the incident, Chemtool employed approximately 200 people.

Figure 1. Damages After the Fire at Chemtool. (Credit: Chemtool)

Leading up to the incident, Chemtool had hired a contractor to replace insulation on its heating oil piping system. To reach a portion of this piping, the contractor used a scissor lift.

As the contractor began raising the scissor lift near the work location, the top guardrail of the lift impacted a section of a ½-inch piping assembly that included a valve. This threaded piping was connected to a four-inch pipe containing mineral oil, which was part of a hot oil system that provided heating for other process equipment.

After the guardrail impacted the piping, a leak formed at the ½-inch threaded connection to the four-inch piping (**Figure 2**). The hot mineral oil, which was over 500 degrees Fahrenheit, was released as an aerosol. The mineral oil formed a white cloud and created the electrostatic conditions that most likely ignited the mineral oil.

Figure 2. Damaged Mineral Oil Piping. (Credit: Chemtool)

Upon seeing the white cloud, Chemtool workers responded to the release. The workers tried to contain the spill by placing absorbent barriers around mineral oil on the floor. Additionally, the workers shut off the oil heating system. The Chemtool workers also lowered the pressure of the hot oil system, but the leak could not be remotely isolated from a safe location. As a result, the mineral oil ignited, and the fire grew and destroyed the facility.

The CSB estimated that less than 100 pounds of mineral oil was released between the start of the release and the time of ignition.

Probable Cause

Based on Chemtool's investigation, the CSB determined that the probable cause of the mineral oil release was piping damage that resulted from force applied by the scissor lift. The flammable mineral oil was most likely ignited by static electricity. The hot oil system did not allow for the remote isolation of the damaged piping. Had Chemtool been able to stop the flow of mineral oil through remote isolation from a safe location, the incident could have been less severe.

6. ConocoPhillips

October 6, 2021

Carlsbad, New Mexico

Incident Summary

On October 6, 2021, an accidental release of crude oil and produced water occurred during vacuum truck loading operations at the ConocoPhillips' Craig State 36B facility south of Carlsbad, New Mexico. An unknown amount of flammable vapors from the released fluids ignited, resulting in a flash fire that seriously injured the vacuum truck driver.

An emulsion layer periodically developed at the oil and water interface within the heater treater (**Figure 1**) at the Craig State 36B facility and grew thicker over time. The presence of the emulsion layer impaired the heater treater's efficiency. To address this problem, ConocoPhillips periodically removed the emulsion layer by transferring fluids from the heater treater to a vacuum truck.

Figure 1. Damaged Heater Treater After the Fire at ConocoPhillips. (Credit: ConocoPhillips)

ConocoPhillips' investigation identified the sequence of events as follows:

1. The contractor vacuum truck driver discussed the planned work with a ConocoPhillips operator, and the operator approved the truck driver to start the loading operation;
2. The vacuum truck driver connected a three-inch hose between the truck and the heater treater;
3. The driver opened valves on each end (the truck inlet valve and the process valve);

4. After these valves were opened, produced water and crude oil flowed from the pressurized heater treater into the vacuum truck (the truck's vacuum pump was not operating);
5. When the vacuum truck driver detected crude oil, he closed the process valve on the heater treater to stop additional fluid from entering the hose; and
6. The vacuum truck driver disconnected the hose from the heater treater, and the contents flowed out of the truck and into the atmosphere through the open hose. The released fluid contained flammable hydrocarbon vapor that ignited, creating a flash fire that seriously injured the driver.

The company's investigation concluded that the fired heater treater components may have been the ignition source. The heater treater burner was inadvertently left online during the vacuum truck loading operation. ConocoPhillips' investigation team did not eliminate static electricity as the potential ignition source because the hose components were non-conductive, and the truck was not electrically bonded or grounded.

ConocoPhillips' investigation identified additional causal factors, including:

A. The procedures, training, and administrative controls did not effectively control the hazards associated with draining an emulsion layer from its heater treaters;
B. No safety or hazard analysis was performed to identify or control potential hazards before performing this work;
C. There was no pre-determined location to electrically ground or bond the vacuum truck; and
D. Using system process pressure from the vessel to transfer the fluid to the vacuum truck rather than using the truck's vacuum pump to pull the fluid into the truck contributed to the incident.

Among other corrective actions, ConocoPhillips now requires the heater treater to be fully isolated and depressured before removing the emulsion layer. In this configuration, the truck's vacuum pump pulls the emulsion layer from the heater treater.

Probable Cause

Based on ConocoPhillips' investigation and CSB interviews, the CSB determined that the probable cause of the accidental release of flammable hydrocarbon vapor was disconnecting the hose while it contained hydrocarbon material and the truck's isolation valve was open. A component of the fired heater treater likely ignited the flammable vapor.

7. Rubicon

January 15, 2022

Geismar, Louisiana

Incident Summary

On January 15, 2022, at 4:51 a.m., 201 pounds of hot methylene diphenyl diisocyanate (MDI) were accidentally released, seriously injuring two workers at the Rubicon LLC ("Rubicon") facility in Geismar, Louisiana. Rubicon is a joint venture between Huntsman and Lanxess.

Rubicon's investigation of this event concluded that the accidental release occurred when a rupture disc activated prematurely. The design activation pressure was 30 pounds per square inch (psi), and process data indicated that this emergency pressure-relief system activated at about 13 psi.

The equipment protected by this rupture disc was typically operated under vacuum conditions. At the time of the incident, however, the equipment was operating at an elevated pressure due to a problem that had developed within the system used to create and maintain the low-pressure (vacuum) conditions. Although the operating pressure was elevated, it was within safe operating limits.

When the rupture disc activated, a 400-degree Fahrenheit mixture of liquid and vapor MDI discharged into 8-inch piping that was vertically orientated downward and ended about eight inches above the concrete floor (**Figure 1**). At the time of the incident, non-essential workers were not restricted from the area near the rupture disc discharge piping because the system was operating within the safe operating limits.

When the high-velocity, two-phase mixture exited the discharge piping, it hit the solid floor, spraying two contract maintenance workers installing a pump near the rupture disc's discharge piping. The two maintenance workers were hospitalized with thermal burns from exposure to the hot fluid.

Although Rubicon's process hazard analysis had identified personnel exposure to hot MDI as a potential consequence of activating the rupture disc, the company had not mitigated the potential hazard of personnel working near the rupture disc discharge piping.

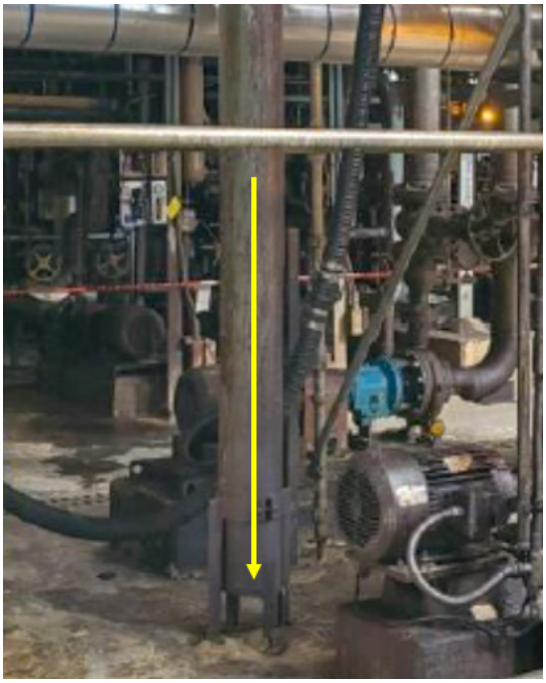

Figure 1. Rupture Disc Discharge Piping. (Credit: Rubicon with annotation by CSB)

Probable Cause

Based on Rubicon's investigation, the CSB determined that the probable cause of the MDI release was the activation of an emergency pressure-relief device (rupture disc). The design of the pressure-relief system, which discharged the hot MDI near workers, contributed to the severity of the incident. Had Rubicon ensured that the pressure-relief system discharged the MDI to a safe location, the incident could have been prevented.

8. Home Market Foods

December 19, 2022

Norwood, Massachusetts

Incident Summary

On December 19, 2022, at approximately 11:10 a.m., an accidental release of anhydrous ammonia occurred at the Home Market Foods ("HMF") facility in Norwood, Massachusetts. Exposure to the toxic ammonia vapor fatally injured one contract worker and seriously injured another contract worker. In addition, the release caused about $4 million in property damage.

HMF had hired a contractor to install an electrical (ceiling-mounted) heater to replace an existing leaking steam heater that provided comfort heating inside the facility's ammonia refrigeration room. The work plan included using a scissor lift to access the installation area. At the time of the incident, two contract workers were on the scissor lift to install the electric heater. While the scissor lift was in an elevated position, the lift was moved forward and then upward, impacting an ammonia refrigeration system valve (**Figure 1**).

Figure 1. Damaged Ammonia Piping. (Credit: HMF)

After the scissor lift impacted the piping, a leak formed at the partially severed ½-inch threaded piping connection to the larger ammonia system piping. The anhydrous ammonia was released as a vapor and engulfed the workers. Contractor 1, who was directly in front of the damaged piping, was unable to escape and was fatally injured by the release. Contractor 2, who was further away from the point of release, jumped over the lift's guardrail to escape from the area.

Two HMF employees heard the sound of the release and saw the ammonia vapor cloud through a door window. One of these employees grabbed a two-way radio and instructed maintenance to initiate an evacuation of the building. Alarms in the ammonia machine room and throughout the building were activated, alerting all HMF employees to evacuate from the building. Evacuating employees found Contractor 2 outside the building. After checking on Contractor 2, one of the HMF employees called emergency responders. Emergency responders recovered Contractor 1's body from the scissor lift and transported Contractor 2 to a nearby hospital to treat his serious injuries.

HMF reported that approximately 22,000 pounds of ammonia was released during the incident.

Probable Cause

Based on HMF's investigation, the CSB determined that the probable cause of the anhydrous ammonia release was piping damage caused by the force applied by the scissor lift.

9. Suncor Energy

December 24, 2022

Commerce City, Colorado

Incident Summary

On December 24, 2022, at approximately 10:55 a.m., an accidental release of approximately 1,400 pounds of light straight-run gasoline (flammable hydrocarbon) occurred within a hydrotreating unit at the Suncor Energy (U.S.A.) Inc. ("Suncor") refinery in Commerce City, Colorado (**Figure 1**). The release formed a vapor cloud that ignited, resulting in an explosion and fire. One Suncor operator was seriously injured due to thermal burns. Suncor estimated $40 million in property damage. In addition, this event contributed to a Refinery shutdown for inspection and repairs until the end of March 2023.

Figure 1. Commerce City refinery on Tuesday, January 3, 2023. (Credit: The Denver Post)

From June 17, 2022, until the day of the incident, a steam turbine-driven pump and the surrounding equipment associated with the unit were a temporary dead-leg (a section of piping with no flow). At this time, the pump was locked out for maintenance by closing the inlet and outlet valves to isolate the equipment and piping from the process flow. As a result, the process fluid (hydrocarbon and water) within this equipment was stagnant for 190 days before the incident.

The chemical release occurred during a partial shutdown of the plant due to the severe cold weather. The ambient temperature dropped below freezing between December 21–24, 2022, freezing the water within the isolated pump's piping (the dead-leg). On December 24, 2022, the daytime temperature increased, and the ice began to melt. At 10:40 a.m., flammable hydrocarbons escaped from the flange of an ice-damaged valve. This release quickly created a flammable vapor cloud, which drifted toward a fired heater (furnace), where it most likely ignited. Simultaneously, two operators, wearing their everyday flame-

resistant coveralls, were performing emergency response tasks in the fired heater area and were engulfed in the colorless and odorless portion of the vapor cloud. The two operators were injured when the vapor cloud exploded.

Probable Cause

Based on Suncor's investigation, the CSB determined that the probable cause of the incident was the release of flammable hydrocarbons through the flange of an ice-damaged valve. A nearby fired heater most likely ignited the flammable hydrocarbon vapor cloud.

Contributing to the incident was Suncor's dead-leg identification and management program, which did not identify and protect the temporary dead-leg created during maintenance activities. As a result, the water in this piping froze and expanded during cold weather.

Also contributing to the severity of the incident was Suncor's emergency response procedure, which allowed the operators to respond to the flammable vapor cloud to "eliminate any source of ignition if it can be done safely." Under these circumstances, the operators relied (in part) on their senses to determine when and where it was safe to perform emergency response tasks near imperceptible portions of the vapor cloud. Suncor could have reduced the severity of the event by establishing clear policies and training its operators to respond to the flammable vapor release without putting themselves in harm's way.

10. Tyson Foods

Perry, Iowa

January 7, 2023

Incident Summary

On January 7, 2023, at approximately 4:55 p.m., about one pound of anhydrous ammonia was released at the Tyson Fresh Meats ("Tyson") facility in Perry, Iowa (**Figure 1**). Exposure to the toxic ammonia gas seriously injured one Tyson employee.

Figure 1. Tyson Foods Facility. (Credit: The Perry News)

At the time of the incident, the Tyson employee was working on an out-of-service ammonia compressor used in Tyson's refrigeration system. The compressor had been previously isolated from the system, and the ammonia was understood to have been removed entirely.

When removing the bolts on the flange connecting the outlet piping to the compressor, a burst of ammonia vapor was released directly into the employee's chest and face. The employee was not wearing respiratory protection because the ammonia compressor was understood to be empty. The injured employee was taken to a hospital for treatment of the ammonia exposure injuries he suffered.

Tyson's investigation found that the company's ammonia removal procedure allowed some ammonia to remain trapped between the compressor's discharge check valve (a valve that only allows for single-direction flow) and an isolation valve. Another valve needed to be opened to remove ammonia from the isolated piping. Tyson determined that this valve had remained closed because the procedure did not include this valve.

Probable Cause

Based on Tyson's investigation, the CSB determined that the probable cause of the anhydrous ammonia release was disconnecting the outlet piping from the ammonia compressor while some ammonia remained within the equipment. Tyson's ammonia removal procedure contributed to the incident because following it did not effectively remove the ammonia from the compressor.

11. Dow St. Charles Operations

January 17, 2023

Hahnville, Louisiana

Incident Summary

On January 17, 2023, at 10:45 p.m., 670 gallons of hot water were accidentally released and pooled at the St. Charles Operations facility in Hahnville, Louisiana. The facility is operated by Union Carbide Corporation, a subsidiary of The Dow Chemical Company ("Dow"). One employee was seriously injured after stepping into the pool of hot water.

Dow's investigation of the events leading up to the incident began on January 9, 2023, when the facility planned maintenance work on a control valve in the boiler feedwater piping system. Operators observed water leaking past two valves in series, upstream of the control valve, when in the closed position. To allow for control valve maintenance, site personnel developed and executed a plan to route leaking boiler feedwater out of the system by opening two bleed valves (in series) between the leaking valves. Site personnel attached a hose to the bleed valve piping to route the leaking hot boiler feedwater to a nearby sump.

On January 17, 2023, after maintenance work on the boiler feedwater control valve was completed, operators were tasked to recommission the control valve. At about 8:00 p.m., operators lined up valves in the piping system so the control valve could be returned to service. The operations personnel did not use the site's operational readiness checklist, which included requirements for personnel to evaluate or "walk down" the piping and valve lineup to ensure correct positioning before startup. As a result, when hot feedwater was re-introduced to the piping, the bleed valves remained open, and the temporary hose remained connected to the piping. Hot boiler feedwater began releasing through the open bleed valves and hose.

Figure 1. Pool of Hot Water. (Credit: Dow)

At 10:46 p.m., the control board operator observed a low boiler feedwater pressure alarm and requested an outside operator to investigate. Personnel identified that the boiler feedwater piping was the source of the low-pressure alarm and, realizing there was a leak, closed an upstream valve to stop the leak. Dow reported that 670 gallons of hot water were released. At about 11:45 p.m., an outside operator attempted to close the two open bleed valves and inadvertently stepped into a pool of the hot boiler feedwater that had accumulated in a depression (**Figure 1**). The high-pressure boiler feedwater release may have created or enlarged this hole. The operator was seriously injured when his lower leg was submerged in the hot water above the top of his rubber boot, and the hot water contacted his lower leg and foot.

Probable Cause

Based on Dow's investigation, the CSB determined that the probable cause of the incident was starting up the boiler feedwater piping system with open bleed valves connected to an open-ended hose, allowing hot water to release and accumulate. An operator subsequently stepped into the pooled hot water, receiving burns to his lower leg and foot. The ineffective application of the operational readiness checklist contributed to the incident by not ensuring that the bleed valves were closed and the hose was removed before the startup.

12. Phillips 66 Refinery

January 17, 2023

Borger, Texas

Incident Summary

On January 17, 2023, natural gas liquid was accidentally released during maintenance of a natural gas liquid storage cavern at the Phillips 66 Borger Refinery ("Phillips 66") tank farm near Borger, Texas. The released natural gas liquid formed a vapor cloud and ignited, causing a large fire (**Figure 1**). The fire fatally injured one contract worker and seriously injured another. Phillips 66 estimated the property damage from the incident to be $3.1 million.

Figure 1. Local emergency response to the incident. (Credit: Phillips 66)

The gas storage cavern was used to store natural gas liquid (a mixture of mostly propane and butane). At the time of the incident, contractors were securing components of the wellhead after a maintenance operation and needed to tighten eight lockdown screws into the wellhead. A contractor used a battery-operated impact wrench, which was inadvertently left in reverse. When the contractor attempted to tighten one of the lockdown screws, the screw was accidentally removed (**Figure 2**), releasing natural gas liquid. This flammable material ignited, injuring the two workers. Both workers were transported to the hospital, where one succumbed to the burn injuries.

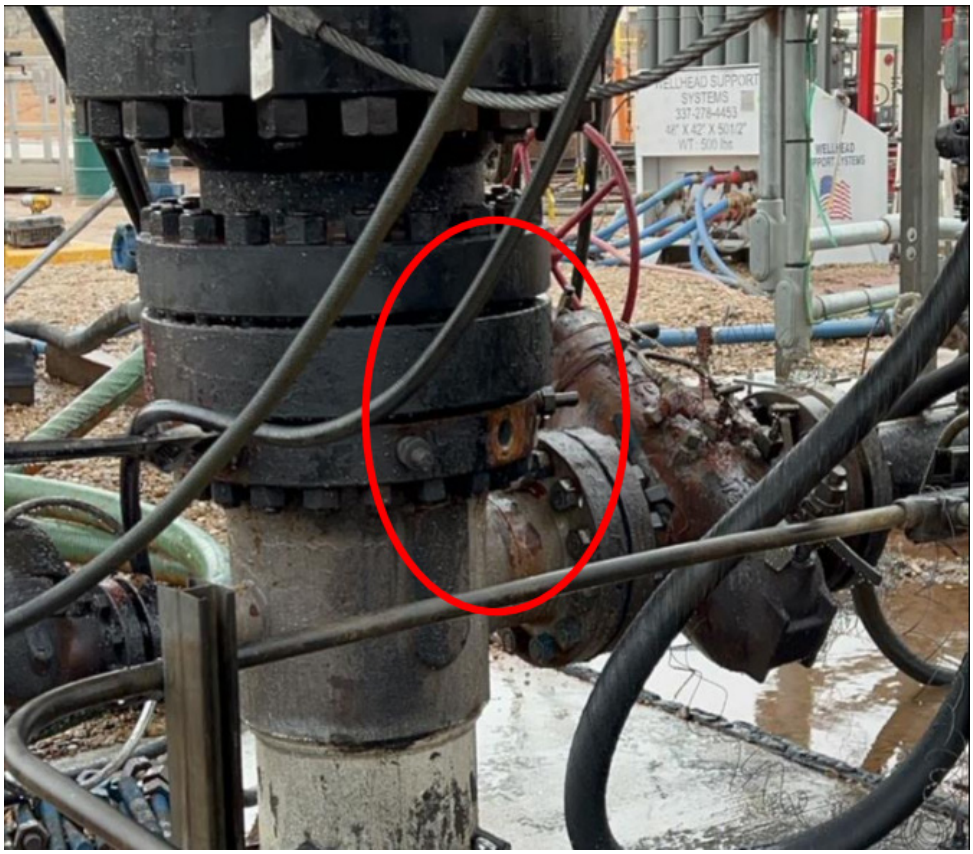

Figure 2. Assembly where lockdown screw was removed. (Credit: Phillips 66)

Cavern seals were in place for the maintenance work, which prevented any release from the cavern itself. When the lockdown pin was removed, the residual natural gas liquid was released from the hydraulic workover unit, referred to as a "snubbing unit," which was being used for the maintenance operation. The pressure in the snubbing unit at the time of the incident was 400 pounds per square inch gauge.

Phillips 66 estimated that 16 barrels of natural gas liquids were released. After the incident, Phillips 66 created action items to require (1) using hand tools to adjust lockdown screws on cavern wellheads and (2) establishing risk management practices to vent pressure from the snubbing unit to the flare system.

Probable Cause

Based on the Phillips 66 investigation and the OSHA inspection, the CSB determined that the probable cause of the accidental release of natural gas liquid was the inadvertent removal of a lockdown screw from the wellhead. Contributing to the incident was the use of a battery-operated impact wrench and the presence of pressurized natural gas liquid in the snubbing unit.

13. Georgia-Pacific

January 19, 2023

Rincon, Georgia

Incident Summary

On January 19, 2023, less than five pounds of hot water and pulp were accidentally released, seriously injuring one employee at the Georgia-Pacific Savannah River LLC ("Georgia-Pacific") mill in Rincon, Georgia, a facility that produces paper products.

The employee had been tasked with inspecting and cleaning a pulp screen. The pulp screen equipment's drain system had plugged (an abnormal condition), causing water and pulp to remain inside the equipment. With the plugged drain, the process conditions allowed the typically warm water to become hot.

When the employee started unbolting the equipment flange to access the screen, hot water and pulp sprayed out of the flange (**Figure 1**), contacting the employee. The employee received thermal burns requiring hospitalization.

Figure 1. Hot water and pulp sprayed out of the pulp screen. (Credit: Georgia-Pacific)

Georgia-Pacific found that miscommunication and ineffective training allowed the worker to open this equipment before it was effectively isolated and de-energized.

After the incident, Georgia-Pacific added safety interlocks to shut down this equipment automatically during certain abnormal conditions.

Probable Cause

Based on Georgia-Pacific's investigation, the CSB determined that the probable cause of the incident was opening equipment that contained pressurized hot water and pulp. Contributing to the incident was ineffective communication and training on the site's procedure to control hazardous energy.

14. CITGO Petroleum Refinery

January 21, 2023

Sulphur, Louisiana

Incident Summary

On January 21, 2023, at 4:30 p.m., 30 pounds of hydrogen gas were accidentally released from a shell-and-tube heat exchanger at the CITGO Petroleum refinery ("CITGO") in Sulphur, Louisiana. The released hydrogen caught fire, leading to an emergency shutdown, and caused over $1.5 million in property damage.

The hydrogen release originated from the flange between the heat exchanger channel and shell and occurred during unit startup (**Figure 1**). The heat exchanger was assembled in 2013 and had undergone 43 thermal cycles. During that time, the bolts had relaxed (a normal event) but had relaxed to the point that the flange could no longer contain the hydrogen within the heat exchanger. CITGO's investigation found that the bolt torque value used to assemble the heat exchanger in 2013 was too low and should have been much higher to prevent leakage.

Figure 1. The Flange Where the Leak Occurred. (Credit: CITGO)

CITGO found that the assembly instructions for both the incident heat exchanger and a nearby similar heat exchanger listed incorrect torque values that were too low, as the instructions listed the wrong bolt sizes. In addition, CITGO suspected that since it is common practice at the site to assemble similar flanges to similar torque values, the incorrect torque instructions from the nearby heat exchanger may

have been applied to the incident heat exchanger. The company determined that the hydrogen may have ignited from contacting an adjacent hot heat exchanger, friction from the release, or a spark.

Probable Cause

Based on CITGO's investigation, the CSB determined that the probable cause of the incident was under-torqued bolts that had relaxed during 43 thermal cycles until the flange could not contain the hydrogen within the heat exchanger. Inaccurate assembly instructions and the likely application of incorrect assembly instructions for another heat exchanger contributed to the incident.

15. Kinder Morgan Gas Plant

January 31, 2023

Snyder, Texas

Incident Summary

On January 31, 2023, at 6:40 a.m., an accidental release of high-pressure carbon dioxide (CO_2) occurred when a vessel overpressured and catastrophically ruptured at a Kinder Morgan CO_2 gas plant in Snyder, Texas. Vessel fragments propelled up to 1,200 feet away and heavily damaged a control room (**Figure 1**). Kinder Morgan estimated the property damage to be over $14 million.

Figure 1. Aftermath of vessel overpressure, vessel location marked with red 'X.' (Credit: Kinder Morgan, annotated by CSB)

The incident occurred in the site's CO_2 compression system. Upstream of each compressor was a vessel called a scrubber that removed liquid from the CO_2 feed stream. Removing liquid from compressor feed streams is critical to preventing compressor damage.

On one of the high-pressure compressor system scrubbers, a liquid level control valve (called a "dump valve") became stuck in the open position, which was common at the site during cold weather. The outside temperature at the time was 22 degrees Fahrenheit (°F). The liquid drained out of the high-pressure scrubber through the stuck-open valve, and then high-pressure CO_2 gas also started flowing out through the stuck-open valve. The high-pressure gas was released into the low-pressure drain system, and as it did, the CO_2 became cold—as low as negative 30 °F (due to the Joule-Thompson effect).

The cold CO_2 caused ice or hydrate to form in a drain system vessel's outlet piping, including the piping to its emergency pressure relief valve. When this happened, the high-pressure CO2 could not vent through the pressure relief valve. The pressure in the drain system vessel continued to build until it reached about 550–700 pounds per square inch gauge (psig) and catastrophically ruptured. The vessel fractured in a brittle mode, producing fragments that flew up to 1,200 feet away.

The ruptured drain system vessel, which was made of carbon steel and measured 15 feet long by 6 feet wide, was rated to a maximum pressure of 125 psig at 650 °F. The blocked pressure relief valve had a set pressure of 15 psig. The scrubbers that drained liquid to the drain system operated at pressures ranging from 450-1,000 psig.

The failed vessel did not have instrumentation installed to allow operators to monitor conditions such as pressure, temperature, or level, and the scrubber liquid level and dump valve position were not recorded. The system's lack of instrumentation prevented operations personnel from identifying the abnormal operating condition and taking corrective action.

In two previous process hazard analysis (PHA) reviews, the company had identified the potential for CO_2 gas to blow through a scrubber dump valve, but this scenario was identified as an operational problem, not a safety problem. The PHAs did not identify the potential for ice or hydrate formation in the drain system due to a stuck-open dump valve. The PHAs also did not include a full review of the downstream closed drain system, as the closed drain system was viewed as a low-pressure utility system with low safety risk.

Kinder Morgan's investigation concluded that the incident resulted from the thermodynamic properties and system pressures not being sufficiently accounted for, resulting in inadequate vessel and piping design, inadequate overpressure protection, and inadequate instrumentation. The investigation recommended, among other corrective action items, that the site create an engineering design standard that addresses hazards associated with introducing high-pressure fluids into drain systems.

Kinder Morgan reported that 5.6 million pounds of carbon dioxide were released. In addition, the company reported that natural gas (111,000 pounds), hydrogen sulfide (2,000 pounds), carbon monoxide (1,400 pounds), sulfur dioxide (1,200 pounds), and nitrogen oxides (NOx) (260 pounds) were also released.

Probable Cause

Based on the Kinder Morgan investigation, the CSB determined that the probable cause of the incident was the overpressure of a drain system vessel after a scrubber dump valve became stuck in the open position. Ice or hydrate formed in the vessel outlet piping, blocking the relief path. Inadequate vessel and drain system design and the lack of needed equipment instrumentation contributed to the incident.

16. Kinder Morgan Crude Oil Production Facility
February 11, 2023
Snyder, Texas

Incident Summary

On February 11, 2023, shortly before 1:00 p.m., a pump failure released hydrocarbons (primarily crude oil) and nitrogen oxide at a Kinder Morgan crude oil production facility in Snyder, Texas. The crude oil released from the failed pump ignited, causing a fire that damaged nearby equipment and led to additional material releases (**Figure 1**). Kinder Morgan estimated the property damage from the incident to be about $1.5 million.

Figure 1. Aerial view of the fire and equipment involved in the incident. (Credit: Kinder Morgan)

Kinder Morgan's investigation found excessive wear and tear on the pump, which led to its failure. The company also found that the pump's bearing lock nut, which holds the bearings in place, was loose. Kinder Morgan concluded that this loose lock nut allowed the pump shaft to move and contact pump components, which caused pump damage that resulted in crude oil being released from the pump into the atmosphere. The company also concluded that heat from metal-to-metal contact in the pump seal area may have provided the ignition source.

During the incident, over 1,500 barrels of hydrocarbons (primarily crude oil) and over 1,200 pounds of nitrogen oxide were released.

Probable Cause

Based on the Kinder Morgan investigation, the CSB determined that the probable cause of the accidental crude oil release and fire was the failure of a crude oil pump. The released crude oil was likely ignited from heat from metal-to-metal contact in the worn pump.

17. Georgia-Pacific

February 21, 2023

La Mirada, California

Incident Summary

On February 21, 2023, at 10:15 p.m., an unknown amount of propane was accidentally released, seriously injuring a temporary employee at the Georgia-Pacific Corrugated, LLC ("Georgia-Pacific") facility in La Mirada, California.

The temporary employee had moved a propane-fueled forklift to the facility's filling station (**Figure 1**) to refuel its tank. He connected the filling station's hose to the forklift's tank and opened the valve to start the propane flow. The hose connection was not secure, and propane immediately discharged into the atmosphere. The employee tried to either tighten or remove the hose during the release. As a result, the cold propane sprayed and cryogenically burned him. The temporary employee was not wearing personal protective equipment (PPE) that could have protected the employee from being exposed to cold propane.

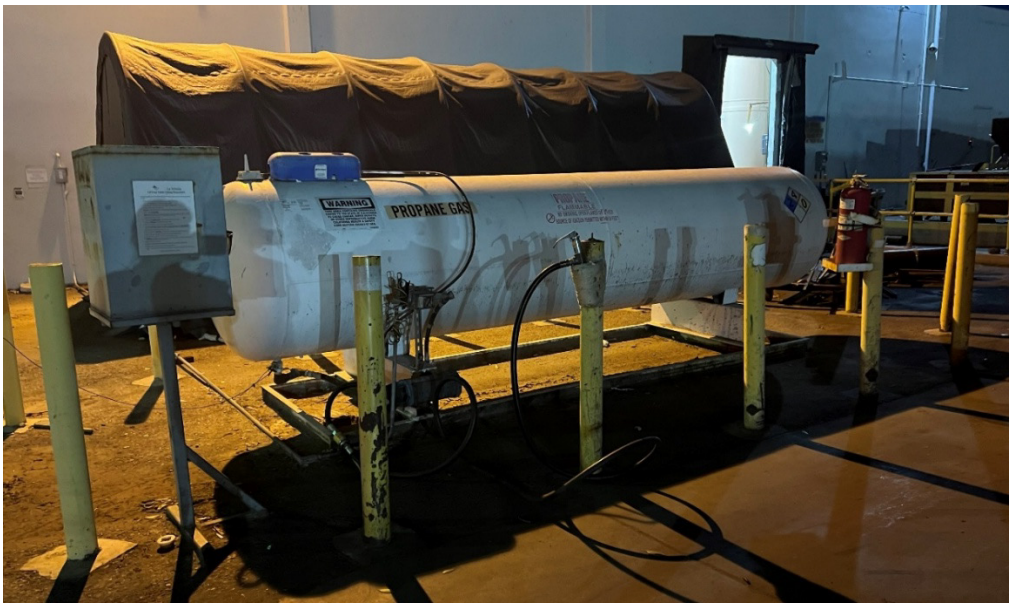

Figure 1. Propane Filling Station. (Credit: Georgia-Pacific Corrugated, LLC)

There was no documentation that the temporary employee had been trained on safely filling propane tanks, although another employee stated that the temporary employee had been trained. Georgia-Pacific's investigation found that site training on refilling propane fuel tanks did not include information on items to inspect before beginning the filling operation.

Probable Cause

Based on Georgia-Pacific's investigation, the CSB determined that the probable cause of the accidental release of propane was not securing the hose connection before starting the filling operation. Not using personal protective equipment that could protect the employee from being exposed to cold propane contributed to the severity of the incident.

18. Pemex Refinery

February 23, 2023

Deer Park, Texas

Incident Summary

On February 23, 2023, at 8:15 p.m., an accidental release of approximately 164 pounds of hydrocarbons (pentane and heavier hydrocarbons) occurred at the PEMEX Deer Park Refinery ("Pemex") in Deer Park, Texas. Deer Park Refining Limited Partnership operates this Pemex refinery. The hydrocarbons were released from an open bleed valve on a crude unit heat exchanger (E-7400) during startup (**Figure 1**). The hot hydrocarbons ignited (autoignition), causing a fire that damaged nearby equipment. Pemex estimated the property damage from the incident to be $2.3 million.

Figure 1. Heat exchangers after the incident. (Credit: Pemex)

On February 12, 2023, the crude unit heat exchangers (E-7400 and E-7401) were shut down for cleaning. Ten days later, on February 22, refinery operators prepared to put the heat exchangers back into service after the cleaning. During the day shift on February 23, they purged air from the heat exchangers to prepare it for startup.

Night shift operators then continued readying the heat exchangers for startup. They obtained the energy isolation drawing, which was used to document which valves had been locked in the open or closed position to allow for safe cleaning of the heat exchangers.

The operators walked down the equipment, removed the locks indicated on the energy isolation drawing, and ensured the valves were lined up in the correct position for startup. The operators believed they had addressed all the valves documented on the energy isolation drawing. Unknown to the operators, however, a bleed valve on top of the heat exchangers remained locked open when the lock should have been removed, and the valve should have been closed. Pemex's investigation report noted that the open bleed valve was not easy to locate visually, and the operators' ability to see it may have been further impaired when it was dark outside.

As the startup sequence progressed, hot hydrocarbons sent to the heat exchangers flowed through the open bleed valve into ambient air and ignited. The material was released at 562 degrees Fahrenheit (°F) and had an autoignition temperature of 482 °F.

Pemex stated that the energy isolation drawing was destroyed in the fire; so it is unknown if the locked open bleed valve was shown on the drawing.

Probable Cause

Based on Pemex's investigation, the CSB determined that the probable cause of the incident was the release and ignition of flammable hydrocarbons when a bleed valve was inadvertently left open during an equipment startup. Contributing to the incident was a lack of a system, such as leak testing, to ensure all valves were in the correct position before the equipment was started up.

19. ConocoPhillips

February 24, 2023

Watford City, North Dakota

Incident Summary

During the morning of February 24, 2023, an unknown amount of hydrocarbons and hydrogen sulfide were accidentally released, fatally injuring an employee inside an enclosed building (**Figure 1**) at a ConocoPhillips oil and gas facility in Watford City, North Dakota. The hydrocarbons and hydrogen sulfide displaced the oxygen in the building, and the employee asphyxiated in the oxygen-deficient atmosphere.

Figure 1. The Enclosed Building. (Credit: ConocoPhillips)

The employee was considered a "lone worker" who operated multiple oil and gas facilities in the local area. Some of the oil and gas equipment was housed inside enclosed, insulated buildings, allowing operators to work in a climate-controlled environment. At the time of the event, it was negative 26 °F outside, and the interior of the building where the incident occurred (approximately 8 feet tall and 90 square feet) was about 65 °F.

A pump inside the building was not operating as designed, causing an adjacent vessel to begin overfilling. To prevent the vessel overfill from causing the facility to shut down, the employee began manually draining the vessel and another nearby vessel, both of which were housed inside the building. To drain the vessel, the employee connected a temporary hose to it and drained its liquid, mostly water and hydrocarbons, into a bucket inside the building. The employee then left the building temporarily to conduct operations at other locations in the facility. During this time, the drained hydrocarbons vaporized inside the enclosed building and displaced oxygen. About twenty minutes later, the employee returned to the insulated building and may have accidentally knocked over the bucket of drained liquid. Additional hydrocarbons and hydrogen sulfide likely vaporized, further displacing the oxygen inside the building. The employee breathed in the oxygen-depleted atmosphere and asphyxiated.

The building where the draining occurred did not have detectors installed to monitor for hazardous gases, and it was not ventilated. The employee had a personal gas detection monitor, but it was turned off and in his truck. No company procedure was in place that provided instructions for safely draining liquids from vessels inside buildings.

After the incident, ConocoPhillips evaluated adding additional engineering controls (for example, hazardous gas detection and alarms, forced ventilation) to its enclosed buildings, developed a written procedure requiring that process fluids be drained outside of buildings, and enhanced training and supervisor verification requirements regarding the use of personal gas monitors.

Probable Cause

Based on ConocoPhillips' investigation, the OSHA inspection, and the local Sheriff's Office investigation, the CSB determined that the probable cause of the incident was the displacement of oxygen inside an enclosed building after an operator drained process liquid into a bucket and the hydrocarbon and hydrogen sulfide components vaporized. Contributing to the incident was the absence of company procedures detailing instructions for safely draining liquids from vessels located inside buildings. Contributing to the severity of the incident was the lack of engineered safeguards (such as installed detectors, alarms, and ventilation) to control or alert of a hazardous atmosphere and an unsuccessful system for ensuring employees wear personal gas monitors.

20. Georgia-Pacific

February 24, 2023

Alcolu, South Carolina

Incident Summary

On February 24, 2023, at 9:20 a.m., an accidental release of approximately two gallons of a sodium hydroxide and water solution ("caustic solution") seriously injured an employee at the Georgia-Pacific Wood Products, LLC ("Georgia-Pacific") facility in Alcolu, South Carolina.

A new pump for unloading caustic solutions from tank trucks was installed at the facility the day before the incident. On the day of the incident, Georgia-Pacific used the new pump for the first time. Employees turned on the pump to begin transferring the caustic solution from a tank truck, but the pump failed to move fluid and leaked. The employees planned to disassemble the pump to identify the operational problem.

Before disassembling the pump, it was decided to flush it out with water from a fire hose (**Figure 1**). This action was taken to prevent employees from getting the caustic solution on their hands when the pump was disassembled. An employee connected a fire hose to the pump and partially opened the valve. The pump could not handle the pressure supplied by the firewater, and the plastic pump casing cracked. Caustic solution and water sprayed out of the pump, seriously injuring one employee.

Figure 1. Caustic Unloading Pump (yellow oval). (Credit: Georgia-Pacific)

After the incident, Georgia-Pacific modified its caustic unloading system, eliminating the need for an unloading pump.

Probable Cause

Based on Georgia-Pacific's investigation, the CSB determined that the probable cause of the incident was the overpressure of a pump casing after pressurized firewater was introduced to the pump.

21. Pemex Refinery

March 14, 2023

Deer Park, Texas

Incident Summary

On March 14, 2023, at 11:40 a.m., approximately 1,000 pounds of flammable hydrocarbons were accidentally released from a pump seal and ignited (autoignition) at the PEMEX Deer Park Refinery ("Pemex") in Deer Park, Texas, causing a fire. Deer Park Refining Limited Partnership operates this Pemex refinery. The company estimated the property damage from the incident to be over $1 million.

Figure 1. Damaged Pump Bearings. (Credit: Pemex)

During the unit startup approximately five days before the incident, the pump (a centrifugal pump) had operated with low suction (inlet) pressure for nearly two hours due to a low liquid level in the upstream equipment. The low suction pressure caused the pump to cavitate, which vibrated the pump and damaged the pump's bearings (**Figure 1**). Five days later, on March 14, the damaged bearings and the resulting stress on the pump's mechanical seal caused the seal to fail. The hot hydrocarbons within the pump were released into the atmosphere and ignited, causing a fire. The material was released at 590 degrees Fahrenheit (°F) and had an autoignition temperature of 484 °F.

During the unit startup, the upstream equipment liquid level fell below its low-level alarm set point eight times, cavitating the pump and triggering alarms on the control room console. In addition, on March 11, two days after the unit startup, vibration from the damaged pump triggered a "High Priority Alarm." The refinery's usual responsive action to high-priority vibration alarms was to switch pumps. However, Pemex did not have another pump available and continued to operate the installed pump, as refinery employees believed the pump was still safe to operate. Employees anticipated that a replacement pump would be available on March 13, but the pump was not replaced before the incident on March 14.

Although the pump vibrations continued and worsened, they never triggered the "Critical High High" vibration alarm threshold because the alarm was programmed incorrectly. Had the vibration alarm been programmed correctly, the "Critical High High" alarm should have activated on March 12, two days before the incident.

Pemex's investigation found that the refinery operators mistrusted the pump vibration alarms due to past nuisance alarms, causing employees to normalize these alarms.

Probable Cause

Based on Pemex's investigation, the CSB determined that the probable cause of the incident was the release and ignition of hydrocarbons from a failed pump that had been damaged after it cavitated during a unit startup. Contributing to the incident were unit startup conditions that damaged the pump, incorrectly programmed alarms, and employee mistrust of alarms.

22. Domtar Paper Mill

March 29, 2023

Hawesville, Kentucky

Incident Summary

On March 29, 2023, at approximately 5:05 p.m., toxic hydrogen sulfide gas was accidentally released at Domtar Paper Company, LLC's ("Domtar") paper mill in Hawesville, Kentucky. Exposure to the hydrogen sulfide gas seriously injured one Domtar operator and injured two other Domtar operators.

At the time of the incident, three Domtar operators were tasked with circulating an acid-cleaning solution through process equipment to remove the buildup of solids impairing its performance. This task required an operator to stand directly over a tank and pour solid sulfamic acid powder into its opening.

When these operators added the sulfamic acid powder, the tank should have contained water, but a valve had been left open. This allowed a "weak wash" process stream to enter the tank before the operators added the solid sulfamic acid. The weak wash contained sodium sulfide, which reacted with the sulfamic acid, generating the toxic hydrogen sulfide gas.

Operator 1, who was standing directly over the tank opening (**Figure 1**), lost consciousness from exposure to the hydrogen sulfide gas that evolved from the tank. Operator 3 was able to call for help over the plant radio system but lost consciousness soon after. Operator 2 was seriously injured after losing consciousness (while trying to help Operator 1), falling to the floor, rolling through a guardrail system, and falling about 11 feet to a lower area of the structure.

Figure 1. The Tank. The red arrows show the approximate locations of two of the operators. (Credit: Domtar)

Two other Domtar employees heard the distress call and entered the room to help the operators. All three operators regained consciousness. Operator 1 and Operator 3 were able to walk outside without assistance. Emergency responders transported Operator 2 to a hospital for treatment.

Domtar reported that about 25 pounds of hydrogen sulfide were released.

Probable Cause

Based on Domtar's investigation, the CSB determined that the probable cause of the hydrogen sulfide release was the reaction between the added sulfamic acid and the sodium sulfide in the tank. Domtar's procedures did not indicate that the weak wash valve should be closed during normal operation, which contributed to the incident. Had the weak wash valve remained closed (or more robustly isolated), sodium sulfide could have been kept out of the tank, preventing the reaction that generated the toxic hydrogen sulfide.

23. Flint Hills Resources Refinery

April 8, 2023

Rosemount, Minnesota

Incident Summary

On April 8, 2023, at about 7:45 a.m., hydrogen sulfide and sulfur dioxide were released from the sulfur recovery unit at the Flint Hills Resources Pine Bend Refinery, LLC ("FHR") in Rosemount, Minnesota (**Figure 1**). This event resulted in $2.235 million in property damage.

Figure 1. FHR Pine Bend Refinery. (Credit: FHR)

FHR determined that the accidental release resulted from a ruptured tube within the waste heat boiler of the sulfur recovery reaction furnace (**Figure 2**). The tube rupture was caused by a damage mechanism known as sulfidation corrosion (also known as high-temperature sulfidic corrosion). Under certain temperature conditions, sulfidation corrosion causes thinning in iron-containing materials over time due to a reaction between sulfur compounds and iron.

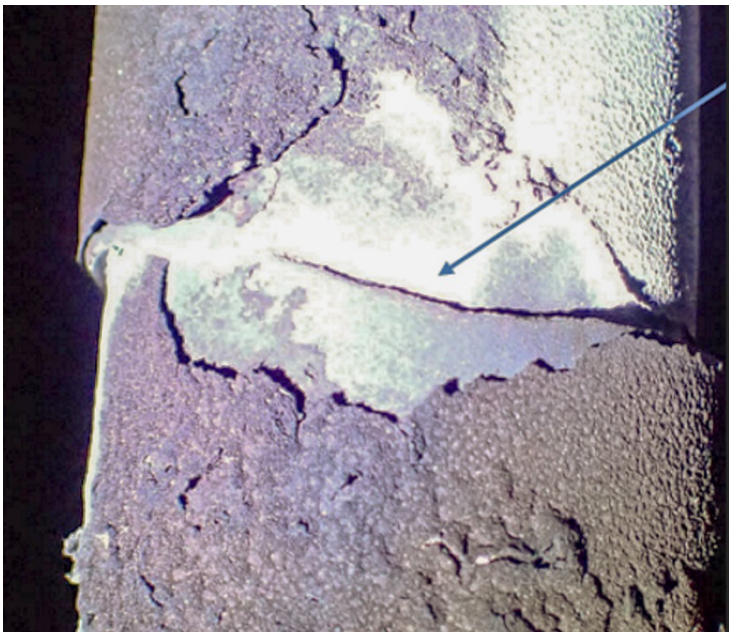

Figure 2: Ruptured Tube. (Credit: FHR)

The FHR investigation also found fouling (hydrocarbon solids), which had formed on the outside of some tube wall surfaces, resulted in higher tube wall temperatures and areas of increased metal loss from sulfidation corrosion. The investigation also found that the hydrocarbons were in the boiler feed water. This indicates that the boiler feed water was not being effectively monitored, which allowed the hydrocarbon contamination to remain undetected.

FHR reported that approximately 68 pounds of hydrogen sulfide and 999 pounds of sulfur dioxide were released.

FHR now monitors and controls boiler feedwater quality with in-line analyzers. The analyzers continuously sample boiler feedwater and strip any hydrocarbons from the sample. A carrier air then sweeps the hydrocarbons to a metal-oxide sensor for quantitative analysis. The in-line sample results provide FHR with the opportunity to evaluate hydrocarbon presence in near real-time. This allows for identification when boiler feedwater does not achieve American Society of Mechanical Engineers ("ASME") recommendations based on hydrocarbon measurement and implementation of prompt corrective measures as necessary.

Probable Cause

Based on FHR's investigation, the CSB determined that the probable cause of the accidental hydrogen sulfide and sulfur dioxide release was a tube rupture in the waste heat boiler. The tube had thinned over time from sulfidation corrosion. Contributing to this event was hydrocarbon contamination in the boiler feed water that was not being effectively monitored and controlled, resulting in localized tube fouling that led to increased tube wall temperatures and thinning from the sulfidation corrosion damage mechanism.

24. Polycarbon Industries

May 4, 2023

Newburyport, Massachusetts

Incident Summary

On May 4, 2023, at about 12:40 a.m., a pressure Nutsche filter vessel ("vessel") exploded at the Polycarbon Industries, Inc. ("PCI") facility in Newburyport, Massachusetts. The explosion and fire fatally injured one PCI operator and caused approximately $48 million in loss from property damage, which led to the permanent closure of the facility (**Figure 1**).

Figure 1. Damages After Explosion at PCI. (Credit: The Salem News)

At the time of the incident, PCI was producing a substance called Dekon 139 ("Dekon"). The Dekon had already been synthesized, and excess liquid from the production process had been removed from the solid product ("cake") within the nitrogen-inerted vessel. PCI used an agitator to smooth the cake and remove lumps that formed during drying to remove the liquid from the cake.

In post-incident testing, PCI determined that Dekon could undergo exothermic, self-accelerating decomposition when heated to 280 degrees Fahrenheit. PCI learned that Dekon decomposition releases flammable gases, including hydrogen, methane, and carbon monoxide.

In its incident investigation, PCI determined that leading up to the incident, the agitator had loosened and was rubbing a plate at the bottom of the filter dryer vessel, generating heat from friction. The friction likely caused an area of high temperature ("hot spot") in the Dekon, which likely reached the temperature

necessary for the Dekon to begin decomposition. The decomposition reaction released energy, which increased the temperature of the material in the vessel and caused more Dekon to decompose.

The gases produced by the reaction rapidly increased the pressure within the vessel, causing the vessel's discharge door to open. The released flammable materials (gas and Dekon dust) mixed with atmospheric oxygen and ignited, causing an initial weak explosion. Shortly after that, the vessel's rupture disc opened, and a second larger explosion occurred when the vessel failed.

One PCI operator was unable to escape the area and was fatally injured.

The CSB estimated that approximately 600 pounds of Dekon decomposed into flammable gases that were consumed during the incident.

Probable Cause

Based on PCI's investigation, the CSB determined that the probable cause of the explosion and fire was a self-accelerating decomposition reaction of Dekon, which produced flammable gases and released combustible Dekon dust that ignited upon release. Contributing to the incident was PCI's incomplete knowledge of the hazards associated with Dekon, including its ability to undergo a self-accelerating decomposition reaction capable of rupturing the reaction vessel.

25. Darling Ingredients

June 22, 2023

Wadesboro, North Carolina

Incident Summary

On June 22, 2023, at about 9:10 p.m., a 5,200-gallon polyethylene storage tank ("tank") ruptured at the Darling Ingredients ("Darling") facility in Wadesboro, North Carolina. The rupture fatally injured one Darling employee.

At the time of the incident, the tank needed to be refilled with aluminum chloride; however, sulfuric acid was added instead. Approximately 80 gallons of 93 percent sulfuric acid were added to the 60 gallons of aluminum chloride remaining in the tank, resulting in a reaction that caused the tank to rupture. The tank rupture fatally injured the employee who was refilling the aluminum chloride tank.

Darling's investigation appeared to focus on the incorrect reaction rather than a reaction scenario consistent with the available evidence. Darling's research materials pointed to the reaction between sulfuric acid and aluminum metal that generated hydrogen gas. The company concluded that the hydrogen gas was released at its autoignition temperature (over 1,000 degrees Fahrenheit (°F)) and ignited, triggering an explosion. Post-incident photographs of the damaged tank do not appear to support a scenario where the internal tank temperature reached 1,000 °F, however (**Figure 1**). The melting temperature of the polyethylene is approximately 260 °F. Therefore, the company's reaction scenario appears inconsistent with the available evidence.

Figure 1. Ruptured Polyethylene Tank at Darling. (Credit: Darling)

The CSB concluded that the reaction most likely generated hydrogen chloride vapors. The more likely scenario was that the reaction between aluminum chloride and sulfuric acid produced enough hydrogen

chloride vapor to increase the pressure within the polyethylene tank, likely resulting in an overpressure that separated the tank's body from its base.

The CSB estimated that approximately 130 pounds of hydrogen chloride vapors were accidentally released.

Probable Cause

Based on the factual information from Darling's investigation, the CSB determined that the probable cause of the overpressure was the increase in the tank's internal pressure resulting from the hydrogen chloride vapors created by the reaction between sulfuric acid and aluminum chloride.

26. BASF TOTALEnergies

September 5, 2023

Port Arthur, Texas

Incident Summary

On September 5, 2023, at 11:50 a.m., a distillation tower ("Tower") collapsed (**Figure 1**) at the BASF TOTALEnergies Petrochemical, LLC ("BTP") facility in Port Arthur, Texas. The collapse was the result of a fire inside the distillation tower. The incident resulted in approximately $194 million in property damage.

Figure 1. Collapsed Distillation Tower at BTP. (Credit: BTP)

A few weeks before the incident, BTP shut down its Pyrolysis Gasoline unit, including its extractive Tower. BTP followed its procedure to remove solvent and hydrocarbons from within the Tower to prepare for maintenance work. On the day of the incident, a maintenance crew began opening manways to prepare the Tower for entry. At 9:30 a.m., temperatures with the Tower's stainless steel structured packing beds began to rise. BTP sounded an emergency alarm at 10:44 a.m. after smoke and flames showed a fire within the Tower. Personnel were evacuated after adding nitrogen and trying to stop air from entering the Tower. At 11:53 a.m., the Tower folded over (collapsed).

BTP's investigation found that the Tower fire resulted from a chain of undesired reactions. About a month before the unit shut down, equipment leaks in another area of the process allowed water to enter the extractive distillation unit, leading to internal corrosion that removed iron from the metal walls. This iron formed iron sulfide (a pyrophoric material) from hydrogen sulfide that is usually present in the process equipment. When the Tower's manways were opened, oxygen (air) entered the Tower, starting an exothermic iron sulfide oxidation reaction. BTP concluded that the heat from this iron sulfide oxidation

reaction resulted in localized heating (1,300 to 1,800 degrees Fahrenheit) within the structured packing that weakened the Tower's walls and ultimately caused the Tower to collapse.

In addition, BTP's investigation found that a 2016 incident had revealed the potential for iron sulfide to accumulate within the Tower. The investigation team determined that this knowledge had not been effectively transferred to the existing site personnel. Had the site's operations team known about the potential for iron sulfide within the Tower, changes to the procedure to remove solvent and hydrocarbon could have been made to mitigate the heating from the iron sulfide oxidation.

During the incident, approximately 160 pounds of sulfur dioxide and an unknown amount of other reaction and combustion products were accidentally released.

Probable Cause

Based on BTP's investigation, the CSB determined that the probable cause of the fire was smoldering iron sulfide oxidation within the structured packing of the Tower. Contributing to the incident was that BTP did not effectively maintain its knowledge from its 2016 incident finding that iron sulfide could accumulate within the Tower.

U.S. Chemical Safety and Hazard Investigation Board