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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 25 accidental release events in 14 states. These events resulted in 7 fatalities, 23 serious injuries, and approximately $1 billion in property damage.

Accidental Release Events							
Number	Incident Date	Company	City	State	Fatality	Serious Injury	Substantial Property Damage ($ Million)
1	2020-05-10	Cynaco	Winnemucca	Nevada		1	
2	2020-10-01	BASF	Geismar	Louisiana		1	
3	2021-02-15	Chevron Phillips Chemical	Port Arthur	Texas			5.8
4	2021-02-15	Chevron Phillips Chemical	Sweeny	Texas			2.5
5	2021-07-02	Daikin	Decatur	Alabama	2	1	
6	2022-07-29	W.S. Red Hancock	Canton	Mississippi	1	5	
7	2022-08-19	Valero	Texas City	Texas			10
8	2022-09-22	Rubicon	Geismar	Louisiana		1	
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10	2022-12-23	Delek	El Dorado	Arkansas			36
11	2023-01-21	PBF Energy	Chalmette	Louisiana			34.1
12	2023-02-03	Dow	Hahnville	Louisiana		4	
13	2023-02-18	Cleveland-Cliffs	Warren	Ohio			1
14	2023-04-03	IMTT	St. Rose	Louisiana		2	15
15	2023-05-04	Marathon Petroleum	Wilmington	California		1	
16	2023-05-15	Marathon Petroleum	Texas City	Texas	1		829
17	2023-05-23	CVR Energy	Wynnewood	Oklahoma	1	1	8
18	2023-09-05	SABIC	Ottawa	Illinois		1	
19	2023-10-13	Hornady	Alda	Nebraska	1		
20	2023-12-29	Tradebe	Bridgeport	Connecticut		1	6
21	2024-02-14	Tronox	Hamilton	Mississippi		2	
22	2024-03-17	ExxonMobil	Baytown	Texas			32
23	2024-05-29	Western Sugar Cooperative	Fort Morgan	Colorado	1	1	
24	2024-07-12	LyondellBasell	Channelview	Texas			9.8
25	2024-08-29	LyondellBasell	Houston	Texas			16.8
				Total	**7**	**23**	**1,006**

1. Cyanco

May 10, 2020

Winnemucca, Nevada

Incident Summary

On May 10, 2020, at 11:30 p.m., hydrogen cyanide vapor was accidentally released at the Cyanco facility in Winnemucca, Nevada, which produces sodium cyanide (**Figure 1**). Exposure to the toxic vapor seriously injured one Cyanco employee.

Figure 1. Cyanco Facility in Winnemucca, Nevada (Credit: Cyanco)

At the time of the incident, an operator who was preparing to wash equipment in a process building within the solid sodium cyanide plant felt vapors on their face as they walked over a floor drain and noticed a strong "almond" odor characteristic of hydrogen cyanide, a highly toxic substance used in the production of sodium cyanide. The operator's gas detector sounded its alarm and briefly displayed a high concentration of hydrogen cyanide. The operator was not wearing respiratory protection. Shortly thereafter, the operator began to experience shortness of breath. After taking a short break, the operator's symptoms worsened, including headache, nausea, and fatigue, which along with shortness of breath, are symptoms of cyanide poisoning that can occur rapidly following exposure to hydrogen cyanide. Emergency responders transported the operator to a hospital, where medical professionals admitted the operator and diagnosed cyanide exposure. The operator was successfully treated with cyanide antidote therapy.

Cyanco's investigation did not identify a specific source for the accidental release of hydrogen cyanide. The company examined the floor drain and the equipment near the exposure location but did not identify a release point or develop a plausible scenario for how the release of hydrogen cyanide occurred. In addition, the investigation revealed that although Cyanco workers had assessed the potential hazards related to the planned equipment washing operation before commencing work, they had concluded that the operators did not need respiratory protection because the risk of hydrogen cyanide exposure was low. This led to the operator not wearing protective respiratory equipment at the time of the incident.

Probable Cause

Based on Cyanco's investigation, the CSB determined that the probable cause of the incident was exposure to hydrogen cyanide vapors from an unknown source. Contributing to the severity of this incident was that the operator's personal protective equipment (PPE) did not include respiratory equipment that could have protected the operator from hydrogen cyanide exposure. Had the operator been wearing appropriate protective respiratory equipment, the operator likely would have not been exposed to highly toxic hydrogen cyanide.

2. BASF

October 1, 2020

Geismar, Louisiana

Incident Summary

On October 1, 2020, at approximately 9:00 a.m., approximately 554 pounds of chlorine gas were accidentally released at the BASF facility in Geismar, Louisiana. Exposure to the toxic chlorine vapors seriously injured one BASF employee.

At the time of the incident, four workers (two BASF employees and two contractors) were trying to stop a chlorine leak (described by BASF as a fugitive emission) from a drain valve in the company's methyl diisocyanate production plant. Because a chlorine leak was detected, BASF assumed that at least one of the drain valve's connections in its flanges or bonnet was loose.

The four workers had a safe work permit to retighten the bolts using hand tools. However, the leak persisted after the bolts were retightened by hand. One of the contractors then tried to retighten the bolts using an impact wrench, a power tool designed to tighten and loosen bolts with short bursts of high torque. The vibrations from the impact wrench caused the connections on the drain valve's bonnet to fail catastrophically, forcefully disconnecting the top half of the drain valve (closing element, stem, and handle) from the bottom half (body and seat) and releasing the toxic chlorine vapors.

The workers were wearing supplied air respirators to perform the job. After the chlorine release, they evacuated the area. However, one BASF employee did not switch to the "escape bottle" for their respirator before detaching the respirator from the stationary air supply source during the evacuation. The subsequent lack of supplied airflow in the respirator caused the employee to remove their respirator mask during the evacuation, resulting in the employee being exposed to the toxic chlorine vapors. The employee was transported and admitted to a hospital for medical treatment.

BASF's investigation found that the drain valve was severely corroded. Over time, chlorine being released from the drain valve had reacted with condensed water that had accumulated in the piping system's insulation blanket, creating hydrochloric acid that had corroded the valve and deteriorated the bolts in the valve's bonnet (**Figure 1**). After the incident, BASF discovered that three other valves were similarly corroded.

Figure 1. Corroded drain valve's bonnet and bolts. (Credit: BASF)

BASF's investigation also revealed that one of the contractors tried to use their stop work authority after seeing the dilapidated valve. The contractor brought concerns to one of the BASF employees. While the BASF employee went to get a supervisor's opinion, there was a miscommunication between the two parties about whether or not to continue working on the corroded valve. As a result, the work continued, ultimately leading to the chlorine gas release.

Probable Cause

Based on BASF's investigation, the CSB determined that the probable cause of the incident was the catastrophic failure of corroded bolts in the drain valve's bonnet. The corrosion was caused by prolonged exposure to hydrochloric acid, created by the reaction between chlorine and condensed water.

Contributing to the incident was BASF's mechanical integrity program. Had BASF inspected the valve before authorizing this job, the extent of the corrosion could have been identified, and a shutdown could have been initiated to replace the drain valve instead of attempts to repair it. Contributing to the severity of the incident was BASF's respiratory protection program, which did not ensure its workers could effectively transition to the escape bottle during an emergency. Had BASF effectively trained its workers to switch to their escape bottles during an emergency, the employee should have not been exposed to the chlorine.

3. Chevron Phillips

February 15, 2021

Port Arthur, Texas

Incident Summary

On February 15, 2021, at 9:53 p.m., a hydrogen and hydrocarbon gas mixture was accidentally released into the firebox of a fired heater, where it ignited, creating a fire at the Chevron Phillips Chemical Company ("Chevron Phillips") facility in Port Arthur, Texas (**Figure 1**). Chevron Phillips estimated that the property damage from the incident was $5.8 million.

Figure 2. The Chevron Phillips facility in Port Arthur, Texas. (Credit: Google Maps)

Chevron Phillips' investigation determined that freeze-related operational issues due to extreme cold weather from Winter Storm Uri caused the facility's boiler units to shut down. This shutdown decreased the supply of steam and water to an ethylene unit at the facility. A safety system automatically shut the fired heater down due to insufficient steam and water flow. Although the automatic valves closed to prevent feed from entering the tubes, the fired heater's fuel gas isolation valve failed to close as intended. This failure allowed the burners to continue operating. Without any flow through the tubes to remove heat from their walls, the tubes in the fired heater reached excessively high temperatures. Some tubes ruptured, likely due to short-term overheating, but a metallurgical analysis was not performed to confirm the cause of the tube failures (**Figure 2**). When the tubes ruptured, hydrocarbons downstream from the fired heater were released through the broken tubes and ignited by the burner flames inside the firebox, causing a fire.

Figure 3. Failed fired heater tubes. (Credit: Chevron-Phillips)

During post-incident testing by Chevron Phillips in temperatures above freezing, the fuel gas isolation valve successfully closed as designed. Chevron Phillips' investigation concluded that the fuel gas isolation valve did not close because water in the instrument air supply had frozen or ice formed on the external actuator components (related to inadequate winterization), preventing the isolation valve from closing.

Probable Cause

Based on Chevron Phillips's investigation, the CSB determined that the probable cause of the incident was the rupture of fired heater tubes from short-term overheating. When the tubes were broken, a hydrogen and hydrocarbon gas mixture flowed from downstream equipment into the firebox. Flames from the burners ignited the flammable materials, resulting in the fire. Inadequate winterization of flow control equipment contributed to the incident.

4. Chevron Phillips

February 15, 2021

Sweeny, Texas

Incident Summary

On February 15, 2021, at 3:05 p.m., a hydrogen and hydrocarbon gas mixture was accidentally released into the firebox of a fired heater, where it ignited and exploded at the Chevron Phillips Chemical Company ("Chevron Phillips") facility in Sweeny, Texas (**Figure 1**). Chevron Phillips estimated the incident resulted in $2.5 million in property damage.

Figure 4. The Chevron Phillips facility in Sweeny, Texas. (Credit: Google Maps)

Chevron Phillips' investigation found that the facility shut down multiple fired heaters when extreme cold weather from Winter Storm Uri caused several freeze-related operational issues. Due to emergency conditions that included utility losses and supplier-driven gas shortages, Chevron Phillips shut down its fired heaters without removing the solidified carbon deposits on the interior walls of the heater tubes (decoking).

Chevron Phillips' investigation revealed that further utility upsets caused the facility to stop all fuel gas supply and fully shut down the remaining fired heaters. During the shutdown, a valve between one of the ethylene unit's fired heaters and downstream equipment remained open. The open valve allowed downstream flammable hydrogen and hydrocarbon gas to flow backward into the fired heater tubes. Approximately 30 minutes after this happened, a tube within the fired heater ruptured, allowing the flammable gas to enter the firebox. The gas accumulated, ignited, and exploded, causing extensive damage to the fired heater (**Figure 2**).

Figure 5. Fired heater explosion damage. The left image shows the broken tube and walls, and the right image shows a fan. (Credit: Chevron Phillips)

Chevron Phillips' investigation determined that the tube failure likely occurred because the fired heater tubes were shut down without decoking. Coke fouling can insulate the tube surface, resulting in local hotspots and increasing the risk of thermal shock and tube failure in fired heaters. These conditions stressed the tube's walls when the metal cooled faster than the internal coke, breaking the tube. Chevron Phillips' investigation concluded that hot insulation inside the firebox likely ignited the gas (autoignition).

Probable Cause

Based on Chevron Phillips's investigation, the CSB determined that the probable cause of the incident was a fired heater tube failure from thermal stress due to the rapid shutdown. When the tube broke, a hydrogen and hydrocarbon gas mixture from downstream equipment flowed into the firebox. Hot insulation within the firebox likely ignited the flammable gas, resulting in an explosion. Inadequate winterization of multiple valves, instruments, and control systems contributed to the incident.

5. Daikin

July 2, 2021

Decatur, Alabama

Incident Summary

On July 2, 2021, at approximately 9:15 p.m., approximately 700 pounds of a mixture of vapors, including chlorodifluoromethane ("R22") and perfluoroisobutene ("PFIB"), were released at the Daikin America, Inc. ("Daikin") facility in Decatur, Alabama (**Figure 1**). Exposure to the toxic mixture of vapors fatally injured two Daikin operators and seriously injured another Daikin operator.

Figure 1. Daikin Facility. (Credit: al.com)

Daikin was returning a drying tower to service after it had been offline for maintenance. After the maintenance activity, this equipment contained air, and Daikin's procedure included steps to remove this air and replace it with R22. To accomplish this, the company used a two-step purge process. First, nitrogen was added to sweep out the air, and second, R22 was added to sweep out the nitrogen. The displaced vapors were released into the ambient air from an open valve about six feet above the ground for each step. The valve was aimed vertically downward, resulting in the vapors being released in a downward direction toward the area where the operators were working.

Daikin's procedure did not specify the source of the R22 material used in this purging operation. The R22 was taken from another process vessel that contained other chemicals, including PFIB. As Daikin's operators performed this purging, PFIB was released into the ambient air from the open valve, exposing three operators to this toxic vapor. The operators did not immediately report any adverse effects from the exposure and went home at the end of their shift. Approximately two days later, two of the operators became ill and were admitted to the hospital. The next day, the third operator was hospitalized. Two of the operators later succumbed to their respiratory injuries. One operator died on August 10, 2021, and the second operator passed away on September 28, 2021.

After the incident, Daikin updated its procedure to warn that toxic vapors may be present and to require that its operators use supplied air respirators. In addition, the company now directs the purge vapors to an incinerator. The procedures were also updated to specify that only high-purity (non-toxic) R22 can be used in the purging procedure.

Probable Cause

Based on Daikin's investigation and an investigation by the federal Occupational Safety and Health Administration (OSHA), the CSB determined that the toxic PFIB vapors were likely released with R22, which was purged from equipment into the ambient air to remove nitrogen. Daikin's safety management systems, which allowed the discharging of R22, PFIB, and other byproducts into a work area, contributed to the severity of the incident. Had Daikin ensured that the release of these hazardous vapors was avoided or discharged to a safe location, the incident could have been prevented.

6. W.S. Red Hancock

July 29, 2022

Canton, Mississippi

Incident Summary

On July 29, 2022, at 7:45 a.m., an explosion and fire occurred at the W.S. Red Hancock ("Red Hancock") facility in Canton, Mississippi. The explosion and subsequent fire fatally injured one employee and seriously injured five other employees (**Figure 1**).

Figure 1. News report image after the explosion at Red Hancock. (Credit: WLBT News)

The Red Hancock facility separates crude oil condensate (flammable liquid hydrocarbon) from salt water through a series of four tanks. After the crude oil condensate is recovered, the saltwater waste is pumped into a saltwater disposal well. Two of the tanks used in Red Hancock's disposal process were replaced with new tanks shortly before the incident occurred, but two tanks were not replaced.

Red Hancock's investigation found that although most of the liquid was removed from the two tanks that were not replaced, some salt water, residual hydrocarbon material, and air remained inside these tanks. At the time of the incident, seven Red Hancock employees were completing the tank replacement work, which included installing an elevated walkway between the tanks and finishing piping and structural connections. While welding piping between the two middle tanks, one of the employees opened a valve (**Figure 2**) to the older tank that contained residual crude condensate material, likely releasing some hydrocarbon vapors into the new piping being welded. The flammable vapor ignited, and flames traveled back into the

Figure 2. Open valve between new piping (left) and an old tank (right). (Credit: Red Hancock)

tank, resulting in an explosion and fire that ejected the top of the tank. In addition, the blast launched and forcefully propelled an adjacent tank approximately 80 feet into the woods (**Figure 3**).

Figure 3. This post-incident photo shows the location of the welding activity that triggered the explosion (gold star) and the pre-incident location of the fourth tank, which was launched by the blast and propelled into the woods shown in the background. (Credit: Red Hancock with annotations by CSB)

As a result of the explosion and fire, six of the employees were transported and admitted to the hospital, where they received treatment for their burn injuries. One of these employees died at the hospital six days later.

Red Hancock's investigation found that no work permits were written for the welding work associated with the tank replacement task. An investigation by the federal Occupational Safety and Health Administration (OSHA) found that the tanks involved in the explosion had not been thoroughly cleaned, which allowed flammable material to remain near the welding activity at the time of the incident.

Probable Cause

Based on Red Hancock's and OSHA's investigations, the CSB determined that the probable cause of the incident was the presence of flammable vapors near a welding activity being performed. Not thoroughly draining, cleaning, and purging the tanks to remove the flammable material before starting construction contributed to the incident. Had the tanks been thoroughly drained, cleaned, and purged prior to the commencement of construction, this incident likely could have been prevented.

7. Valero

August 19, 2022

Texas City, Texas

Incident Summary

On August 19, 2022, at approximately 3:45 a.m., about 4,000 pounds of a hydrogen and hydrocarbon mixture was accidentally released into the firebox of a fired heater, where it ignited, creating a large fire at Valero Refining-Texas, L.P.'s ("Valero") refinery in Texas City, Texas (**Figure 1**). Valero estimated that the property damage from the incident was $10 million.

Figure 6. The Valero refinery in Texas City, Texas. (Credit: Google Maps)

On the morning of the incident, Valero restarted a fired heater that had been offline for approximately 12 hours due to a compressor shutdown caused by a malfunction of a pressure transmitter in the lube oil system. During the startup, it was essential to flow process feed through all four passes of the fired heater's tube system. However, only two of the four passes in the tube system had sufficient flow through them when the burners were ignited. Although the minimum flow was eventually established in another tube pass, there was no flow through the fourth pass.

Valero's investigation of the incident found that without the fluid flowing through the fourth pass to remove heat, the tube's metal wall temperature reached 1,500 degrees Fahrenheit (°F), which exceeded the design temperature limit. After the operations supervisor noticed the high temperature, field operators were sent to inspect the heater tubes. The field operators reported that some tubes were "glowing red hot," and consequently they manually turned off two of the fired heater's eight burners. The field operators then reduced the flow through the first three passes to help drive feed material into the fourth pass. Although operators reported hearing material flowing in the fourth pass, the meter indicated no flow. The Valero operations team concluded that the flow meter was malfunctioning.

Less than an hour later, a convection section tube in the fourth pass ruptured due to short-term overheating (**Figure 2**), releasing a flammable mixture of hydrogen and hydrocarbons into the firebox. Flames from the gas-fired burners ignited the mixture, resulting in a large fire.

Figure 7. Ruptured fired heater tubing. (Credit: Valero)

During its investigation, Valero discovered that the startup procedure for the fired heater, which required maintaining a steady flow through all four tube passes before lighting the burners, was not used. This procedure was "conditional," however, and was only necessary if the firebox temperature had cooled below 400°F. At the time when the burners were lit, this temperature was slightly below 400°F.

Additionally, Valero found that the fired heater lacked engineered safeguards to prevent the burners from being lit before establishing flow in each of the four passes. In response to the incident, Valero modified its automated burner controls to help ensure that the flow rate through every pass exceeds a predetermined minimum flow rate before operators can ignite a burner.

Probable Cause

Based on Valero's investigation, the CSB determined that the probable cause of the incident was a ruptured fired heater tube from short-term overheating. Flames from the fired heater's gas-fired burners ignited these flammable chemicals, resulting in the fire. The lack of automated safeguards that did not prevent the burners from being ignited before the minimum flow was established through each of the four tube passes contributed to the incident. Had Valero had such automated safeguards in place, this incident likely could have been prevented.

8. Rubicon

September 22, 2022

Geismar, Louisiana

Incident Summary

On September 22, 2022, at approximately 9:00 a.m., a liquid mixture comprised of aniline, formalin, and hydrochloric acid was accidentally released, seriously injuring one contractor at the Rubicon chemical manufacturing facility ("Rubicon") in Geismar, Louisiana (**Figure 1**). Rubicon is a joint venture between Huntsman and Lanxess.

Figure 1. Rubicon chemical manufacturing facility in Geismar, Louisiana. (Credit: Rubicon)

On September 20, 2022, two days before the incident, an off-site power outage caused an immediate loss of process flow in Rubicon's methyl diamine unit. The lack of flow allowed solids to form throughout a piping system. Rubicon personnel were clearing the solids from this piping on September 22 when the incident occurred.

At approximately 9:00 a.m. on September 22, two contract workers began opening a flange connection in the piping system. After the flanged connection was fully opened, an amount (approximately 28 ounces) of toxic and corrosive liquid containing aniline, formalin, and hydrochloric acid sprayed from the open-ended piping. Some of the released liquid contacted the face and neck of a third contract worker ("hot zone attendant"). The hot zone attendant was present to monitor the safety of workers inside the "hot zone"—a 30-foot diameter area marked by red barricade tape—and to help decontaminate any workers leaving the hot zone. While the workers inside the barricade were wearing personal protective equipment ("PPE") that included chemical suits with hoods and full-face supplied air respirator masks, the hot zone attendant wore a chemical suit and hood but was not wearing face protection.

After being sprayed with the toxic and corrosive liquid, the hot zone attendant first showered in the unit and then again at the site's medical facility. The hot zone attendant was then transported to a hospital, admitted for inpatient care, and successfully treated for exposure to aniline.

Rubicon's investigation found that the hot zone attendant did not wear face protection because the operations team did not recognize the potential for pressurized liquid aniline to remain in the piping system. Energy isolation work (often referred to as line breaks) performed after the power outage involved opening multiple other piping connections, including a valve at the high point in the piping system. Rubicon's operations team believed that this work had removed pressure from the system. A post-incident review of the process data, however, showed that pressure remained in some areas of the piping system. The company's energy isolation plan did not include a review of the available local or computer control system data to ensure that the piping was not under pressure.

Probable Cause

Based on Rubicon's investigation, the CSB determined that the probable cause of the accidental release was the opening of the flange connection while portions of the piping contained pressurized liquid. Rubicon's energy isolation plan contributed to the incident by not ensuring the piping was depressured before workers began disassembling the flange connection. Allowing a worker near this equipment opening activity who was not wearing protective equipment that could shield the worker's face from being sprayed with the toxic and corrosive process liquid contributed to the severity of the incident. Had the worker been wearing protective equipment with a face shield, this incident likely could have been prevented. Additionally, reviewing available local or computer control system data prior to the work to ensure that the piping was not under pressure could have helped prevent this incident.

9. ExxonMobil

October 11, 2022

Carlsbad, New Mexico

Incident Summary

On October 11, 2022, at approximately 2:00 p.m., 2,200 cubic feet of natural gas under high pressure were released from a 20-inch gas pipeline at the XTO Energy ("XTO") facility, a subsidiary of ExxonMobil, in Carlsbad, New Mexico. The high-pressure natural gas forcefully impacted a contractor, resulting in one serious injury.

On the day of the incident, an XTO employee and a contractor were tasked with passing a large-diameter cleaning tool (called a "pig") through the 20-inch pipeline. This "pigging" procedure involved sending a pig with a diameter slightly larger than the pipe to clean and displace fluids within the pipeline. High pressure pushes the pig through the piping, ending in a section (called a "receiver") designed to capture and hold the pig until removal. The receiver was newly installed and being used for the first time at the time of the incident.

When the two workers went to remove the pig from the receiver, the pressure in the receiver was above 1,150 pounds per square inch ("psi"). To safely remove the pig, the pressure needed to be reduced by relieving it through a vent valve located at the top of the receiver. The contractor initially tried to remove the plug from the vent valve to relieve the pressure but found that the plug could not be removed with hand tools. This indicated that there could be pressure between the valve and the plug, forcing the threads tightly against each other. The contractor concluded that the vent valve might be leaking and decided to relieve the pressure inside the receiver using the drain valve instead, which was located at the bottom of the receiver (**Figure 1**).

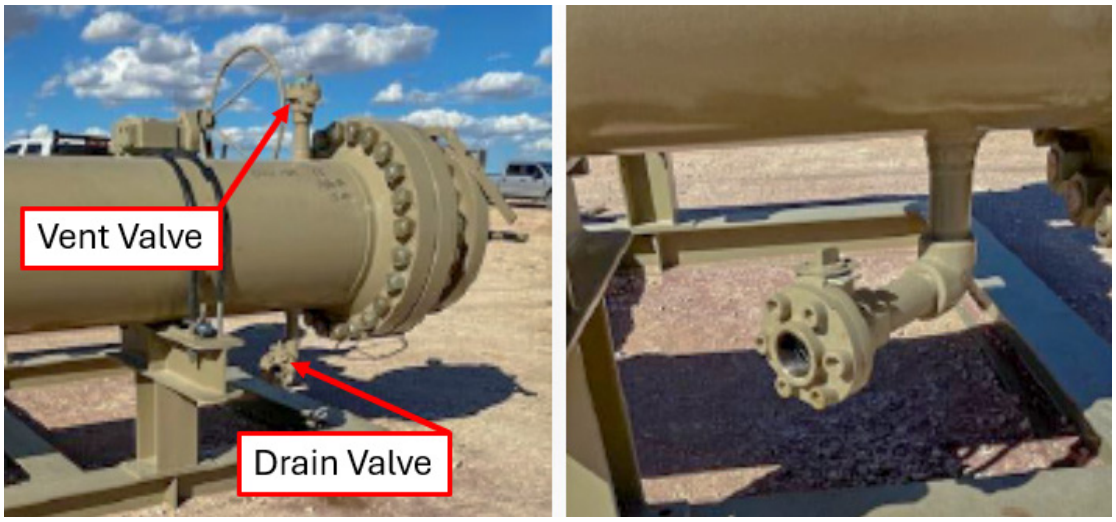

Figure 1. Orientation of the vent valve and drain valve (left) and post-incident position of the drain piping after opening the valve (right). (Credit: XTO, edited by the CSB)

XTO's investigation of the incident found that the 90-degree fitting (elbow) shown in Figure 1 was not properly tightened, allowing it to turn freely. Because the elbow was not properly tightened, when the contractor applied a wrench to the valve stem and began opening the 2-inch ball valve on the drain

piping, the valve rotated to the left and fully opened. The 1,150-psi natural gas forcibly discharged toward the contractor's left leg, launching the contractor approximately 50 feet away from the source of the release, resulting in a serious injury. The contractor was transported by helicopter and admitted to a hospital for medical treatment.

Probable Cause

Based on XTO's investigation, the CSB determined that the probable cause of the incident was the insufficient tightening of the 90-degree fitting, which resulted in the full opening of the drain valve and the rapid and forcible release of natural gas from the receiver. The leaking vent valve at the top of the receiver also contributed to the incident. The non-welded drain piping, which was able to turn freely when the valve was opened, contributed to the severity of the incident.

10. Delek

El Dorado, Arkansas

December 23, 2022

Incident Summary

On December 23, 2022, at about 4:08 a.m., approximately 1,800 gallons of naphtha were accidentally released into the firebox of a fired heater, where it ignited, resulting in a serious fire at the Delek US Holdings, Inc.'s ("Delek") Lion Oil Refinery in El Dorado, Arkansas (**Figure 1**). Delek estimated that the property damage from the incident was $36 million.

Figure 8. The Delek refinery in El Dorado, Arkansas. (Credit: Google Earth)

Delek's investigation identified that ambient temperatures at the facility dropped to 12 degrees Fahrenheit by 11:00 p.m. on the night of the incident. This cold weather caused operational issues with some instruments and controls, leading to low hydrocarbon flow through the tubes of a fired heater. The decreased flow resulted in reduced heat transfer, which likely caused the metal temperatures in the tubes to rise significantly. This high-temperature condition ultimately caused a tube to rupture (**Figure 2**), releasing flammable hydrocarbons into the firebox, where the existing burner flame ignited them. Delek commissioned a metallurgical examination and found that the tube ruptured due to creep damage (which results from prolonged exposure to stress at elevated temperatures) and short-term overheating.

Figure 9. The ruptured tube within the fired heater (left) and after removal (right). (Credit: Delek)

Delek's investigation found that some instruments and controls were not effectively winterized for cold weather conditions, which impacted their performance. As a result, some controls were put in manual mode, and some alarms were interpreted by Delek employees as unreliable, leading to reduced hydrocarbon flow through the tubes and elevated tube wall temperatures. Additionally, the fired heater was not equipped with instrumentation to measure the tube's metal wall temperatures. Delek's investigation further revealed that Delek's process hazard analysis for this fired heater relied on safeguards that were insufficient or not in place to prevent low tube pass flow conditions. In addition, a low-flow safety interlock did not work because it was improperly set.

Probable Cause

Based on Delek's investigation, the CSB determined that the probable cause of the naphtha release was a tube rupture, which resulted from creep damage and short-term overheating. Flames from the fired heater's burners ignited the flammable hydrocarbons, resulting in the fire. Fired heater safeguards that were not in place or improperly set, in addition to inadequate winterization of flow control equipment, contributed to the incident. Had the fired heater been equipped with instrumentation to measure the tube's metal wall temperatures and other safeguards been in place, this incident likely could have been prevented.

11. PBF Energy

January 21, 2023

Chalmette, Louisiana

Incident Summary

On January 21, 2023, at 1:58 p.m., a mixture of hydrogen and hydrocarbons was accidentally released into the firebox of a fired heater, where it ignited, resulting in a large fire at the Chalmette Refining, L.L.C.'s refinery in Chalmette, Louisiana, a subsidiary of the PBF Holding Company LLC ("PBF Energy") (**Figure 1**). PBF Energy estimated the property damage from the incident to be approximately $34.1 million.

Figure 10. The PBF Energy refinery in Chalmette, Louisiana. (Credit: PBF Energy)

According to PBF Energy's investigation, four months before the incident, a contractor performed an infrared ("IR") scan of the fired heater and found elevated temperatures in the heater, with one tube section operating above 1,300 degrees Fahrenheit (°F). At the time, the contractor concluded that the high temperatures were measurements of the scale and oxidation on the outside surface of the tubes, not the tube's metal wall temperature. After the incident, PBF Energy determined that the IR temperature measurements taken before the incident were likely accurate, but they had been misinterpreted. As a result, the infrared temperature data was not used to adjust the operating conditions of the fired heater, which could have lowered the tube temperature within the design limit.

PBF Energy's investigation determined that on the day of the incident, the fired heater's tubes experienced another high-temperature event, leading to a tube rupture. The unit had automatically shut down due to a problem in another part of the process. During this shutdown, the hydrogen and hydrocarbons flowing through the fired heater's tubes stopped, but the burners continued operating because the fuel gas control valve did not fully close. Without fluid flow through the tubes to remove heat, the tube's temperature exceeded 1,400°F. Operating at this temperature caused short-term overheating, further degrading the tubes' integrity. As the fired heater was restarted, a tube ruptured (**Figure 2**), releasing a flammable mixture of hydrogen and hydrocarbons into the firebox, where flames from the gas-fired burners ignited it and resulted in a fire at the facility. The investigation concluded that

the tube failure was likely the result of a combination of localized creep damage (which results from prolonged exposure to stress at elevated temperatures) and short-term overheating.

Figure 11. Ruptured tube. (Credit: PBF Energy)

The company estimated that about 51,000 pounds of diesel, 160 pounds of hydrogen, and 560 pounds of methane were released. After the incident, PBF Energy installed larger fired heater viewports to allow for improved infrared scans of the tubes and installed instrumentation to monitor temperature.

Probable Cause

Based on PBF Energy's investigation, the CSB determined that the probable cause of the incident was a fired heater tube rupture from a combination of creep damage and short-term overheating. Flames from the fired heater's burners ignited the released flammable mixture of hydrogen and hydrocarbons, resulting in the fire. Insufficient temperature instrumentation and an inadequate infrared scanning program contributed to the incident.

12. Dow

February 3, 2023

Hahnville, Louisiana

Incident Summary

On Friday, February 3, 2023, at approximately 10:46 p.m., a flash fire was accidentally released from a product purge vessel ("vessel") flange during planned maintenance activities at a facility operated by Union Carbide Corporation ("Union Carbide") in Hahnville, Louisiana (**Figure 1**). Union Carbide is a subsidiary of The Dow Chemical Company ("Dow"). The fire seriously injured four contract workers.

Figure 1. Saint Charles Operations in Hahnville, Louisiana. (Credit: Dow)

On January 29, 2023, the facility shut down its polyethylene unit for planned maintenance. Following the shutdown procedure, operators purged and isolated the vessel in preparation for maintenance. The facility hired a contractor company to support the planned maintenance activities, which included replacing internal filter elements. The maintenance activity involved hot work, an operation that uses flames or can produce sparks.

On February 3, 2023, Dow issued a safe work permit to remove bolts from the top head of the vessel (**Figure 2**). Most bolts were removed using tools that the company considers low-energy hot work tools. However, the remaining bolts could not be removed with these tools. As a result, a safe work permit to perform high-energy hot work was issued to remove the remaining bolts with a grinder (a high-energy hot work tool).

Figure 2. Top head of incident vessel. (Credit: Dow)

The vessel is connected to a flare system to vent unreacted gases. At the time of the incident, a series of valves were available to isolate the vessel from the flare system, but only one valve

was closed to isolate the flare. While the valve was closed, it did not fully prevent flammable gas from flowing from the flare system into the vessel. In addition, air was also present within the vessel. The flammable gas mixed with air, creating a flammable atmosphere inside the vessel.

Dow's investigation found that not all of its hot work policy requirements were met before using the grinder to cut the remaining bolts, such as isolating the vessel through blinding or air gapping (the company's preferred method) and using an inert gas (such as nitrogen) to purge residual materials from the system. Although Dow conducted atmospheric monitoring outside the vessel, which showed a zero percent lower explosive limit (indicating that the atmosphere was free of explosive and flammable gases), no combustible gas monitoring of the atmosphere inside the vessel was performed where the bolts were removed.

Hot metal fragments from grinding the bolts ignited the flammable vapor within the vessel, resulting in a flash fire that exited from the vessel's flange, seriously injuring four contract workers. The injured contract workers were transported to a hospital and admitted for medical treatment.

Dow reported that a small quantity of flammable chemicals (less than 10 pounds) had entered the vessel. These chemicals likely included a mixture of hydrogen, methane, ethane, ethylene, isopentane, hexane, hexene, and nitrogen. When these chemicals ignited, the flash fire erupted from the vessel flange with an unknown fraction of the combustion products.

Probable Cause

Based on Dow's investigation, the CSB determined that the probable cause of the flash fire was performing hot work (grinding) to cut flange bolts on a pressure vessel containing a flammable atmosphere. The ineffective application of the hot work policy contributed to the incident by relying on a single isolation valve to prevent flammables from entering the vessel from the flare system and not performing combustible gas testing of the flammable atmosphere within the vessel before permitting this work. Had combustible gas testing of the atmosphere within the vessel been conducted before permitting the work, this incident likely could have been prevented.

13. Cleveland-Cliffs

February 18, 2023

Warren, Ohio

Incident Summary

On February 18, 2023, at 2:50 p.m., flammable fuel gas ignited, resulting in an explosion of a boiler at the Cleveland-Cliffs Cleveland Works LLC Warren Coke Plant ("Cleveland-Cliffs") in Warren, Ohio (**Figure 1**). Cleveland-Cliffs estimated that the property damage was approximately $1 million.

Figure 1. Emergency response after the explosion. (Credit: Cleveland 19 News)

On the day of the incident, tubes inside the boiler were carrying water, and a burner inside the structure heated the water to produce steam. The boiler's burner was combusting fuel gas (composed of natural gas and coke oven gas) to heat the water to produce steam. The forced draft fan that introduced air to the burner unexpectedly shut down, and without air being fed to the burner, the burner flame went out. Flammable fuel gas continued to enter and accumulate in the boiler, however, and about ten minutes later, the accumulated flammable gas ignited, resulting in an explosion. The company determined that the oxygen analyzer installed in the boiler was the source of ignition. The explosion caused extensive damage to the boiler and ductwork.

Cleveland-Cliffs' investigation found insufficient alarms to alert operators that the forced draft fan had shut down. A visual alarm signaling loss of air had activated on a control room screen, but the operator was looking at a different screen at the time of the incident and did not see the alarm. In addition, there were no cameras installed to monitor the burner flame and no dedicated video monitor for operators to view the boiler exhaust, which could have indicated an operational problem with the boiler. After the incident, the company's corrective actions included installing audible alarms for the boiler fans, cameras on the burners, and a dedicated video monitor for the boiler exhaust.

Cleveland-Cliffs did not determine the amount of the combustion products accidentally released, but the company estimated that approximately 28,000 cubic feet of fuel gas had accumulated before the explosion.

Probable Cause

Based on the Cleveland-Cliffs' investigation, the probable cause of the incident was the ignition and explosion of accumulated flammable fuel gas inside a boiler. The flammable fuel gas accumulated in the boiler after the air flowing to the boiler's burner stopped, and the burner flame went out. Insufficient safeguards to prevent fuel gas from flowing to the boiler when the burner flame went out contributed to the incident.

14. IMTT

April 3, 2023

St. Rose, Louisiana

Incident Summary

On April 3, 2023, at approximately 1:45 p.m., flammable vapor within a storage tank ignited, resulting in an explosion and a major fire at the International-Matex Tank Terminals ("IMTT") facility in St. Rose, Louisiana (**Figure 1**). The incident seriously injured two contractors and caused over $15 million in property damage.

Figure 12. The IMTT facility in St. Rose, Louisiana. (Credit: Jeffrey Dubinsky / Louisiana Environmental Action Network)

IMTT provides storage tanks for customers to store liquids in large quantities. IMTT's investigation found that before the incident, one of the company's 8.4-million-gallon storage tanks ("tank") contained natural gas condensate that was drained from the tank in 2021. After removing the flammable liquid, the tank's manways were opened for several weeks for maintenance work inside the tank.

On August 29, 2021, Hurricane Ida made landfall south of the IMTT facility as a Category 4 hurricane with maximum sustained winds of 150 miles per hour. After the hurricane, IMTT discovered that a hatch covering the opening for the ladder to access the tanks' internal floating roof had broken off.

In 2023, IMTT hired a contractor to weld a new hatch cover onto the tank. As two contractor employees were working on top of the tank, flammable vapor inside the tank exploded, seriously injuring both workers. The two contractor workers were transported by helicopter and admitted to a hospital for treatment of their severe burn injuries while other emergency responders fought the resulting tank fire

(**Figure 2**). Flammable hydrocarbon liquid burned in the tank for about nine hours before emergency responders extinguished the fire.

Figure 13. Post-incident photo of the damaged tank (left, Credit: IMTT) and the emergency response to the tank fire (right, Credit: WWL-TV).

IMTT's investigation revealed that the company issued a hot work permit for the grinding and welding to install the new hatch cover. IMTT's air monitoring conducted around the access ladder opening and up to two feet inside the tank's opening showed no flammable vapors. IMTT also issued a work permit that required the contractor workers to cover the opening with a fire blanket and to perform continuous air monitoring on the tank's roof.

Before issuing these permits, IMTT workers reviewed the facility's storage tank inventory records, which indicated that the tank was empty. However, the tank's piping was not locked out, and no manways were opened to confirm that the tank contained no residual flammable liquid. As a result of the incident, IMTT created a tank database showing the operational state of each tank, identifying whether the tank is in service, cleaned, degassed, or gas-free.

Probable Cause

Based on IMTT's investigation, the CSB determined that the probable cause of the incident was the presence of flammable hydrocarbon vapors inside the tank while hot work (grinding or welding) was being performed on the tank's roof. Not thoroughly draining, cleaning, and purging the tanks to remove the flammable material before starting the hot work contributed to the incident. Additionally, ineffective air monitoring practices to identify the presence of flammable hydrocarbon vapor contributed to the incident.

15. Marathon Petroleum

May 4, 2023

Wilmington, California

Incident Summary

On May 4, 2023, at 6:25 a.m., approximately 790 pounds of a hydrocarbon mixture containing about 7,000 parts per million (ppm) of hydrogen sulfide were accidentally released at the Marathon Petroleum Corporation ("Marathon) Los Angeles Refinery in Wilmington, California. Exposure to the toxic hydrogen sulfide vapor seriously injured one Marathon employee.

Marathon's investigation found that on the day of the incident pressure within a distillation column at the facility began to increase significantly. Three field operators worked to open a valve to bypass flow around the distillation column's overhead accumulator ("drum") to reduce the pressure. While opening the bypass valve, the operators found that the indication on the field pressure gauge did not align with the value that the pressure transmitter reported to the computer control system. When there is this kind of instrumentation discrepancy, Marathon expects its operators to replace field gauges during normal troubleshooting activities. To that end, a fourth operator brought a new pressure gauge to the top of the deck to replace the existing gauge.

Per the facility's gauge replacement procedure, the operators closed two valves to isolate the pressure gauge from the process (**Figure 1**). Additionally, the operators discovered a note on the pressure gauge that stated "Valve Issue" with an arrow pointing to the two valves on the drum. One of the valves was used to isolate the pressure gauge (blue rectangle) and the other valve was used to isolate the drum (blue oval). Because the valve used to isolate the drum was visibly broken, the operators assumed that the note referred to it. However, unknown to the operators, the valve used to isolate the pressure gauge could not fully close due to an internal obstruction.

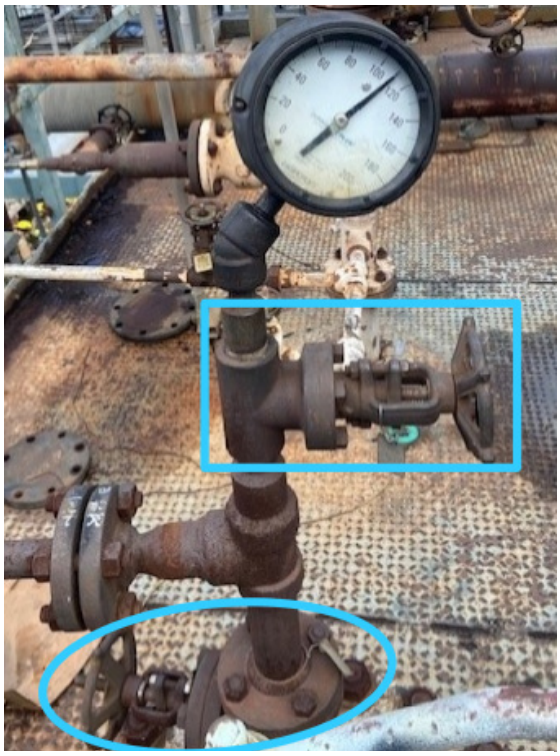

Figure 1. Photo of the pressure gauge and valves involved in the incident. (Credit: Marathon, annotations by CSB)

With the valve isolating the pressure gauge appearing to be closed, one of the operators began unscrewing the pressure gauge to relieve any residual pressure. The operator did not identify a potential leak as there was no indication of residual pressure while unscrewing the last threads of the pressure gauge. After the gauge was removed, however, the process pressure likely dislodged debris in the piping, causing the process stream to discharge into the atmosphere. This released flammable hydrocarbons containing hydrogen sulfide, exposing all four operators to the toxic hydrogen sulfide. Post-incident, Marathon found that the pressure gauge was plugged (**Figure 2**).

Figure 2. Pressure gauge involved in the incident.
(Credit: Marathon)

Marathon's investigation also revealed that none of the operators wore respirators to protect themselves from inhaling the hydrogen sulfide vapor. As a result, exposure to the toxic hydrogen sulfide caused the four operators to lose consciousness. Three operators regained consciousness and climbed down from the drum deck. Emergency responders rescued the unconscious operator. The operator was transported and admitted to a hospital for medical treatment. Emergency responders also reinstalled the pressure gauge to stop the release. The investigation did not identify who wrote the note or find any work order to repair either valve.

Probable Cause

Based on Marathon's investigation, the CSB determined that the accidental release was caused by Marathon's failure to effectively isolate the piping before removing the pressure gauge. Not using PPE that could protect the workers from exposure to hydrogen sulfide contributed to the severity of the incident. Marathon's mechanical integrity program, which did not replace the broken valve after it was identified in the field, also contributed to the incident.

16. Marathon Petroleum

May 15, 2023

Texas City, Texas

Incident Summary

On May 15, 2023, at 9:32 a.m., an accidental release of naphtha caught fire, fatally injuring one worker at the Marathon Petroleum Corporation ("Marathon") Galveston Bay Refinery in Texas City, Texas. Marathon estimated that this event resulted in $829 million in property damage.

On the morning of the incident, two Marathon employees were completing an equipment oil change on an elevated platform above a pump that was supplying naphtha to downstream equipment. The pump's coupling failed, reducing outlet flow and creating high vibration that broke a small bore (¾-inch) piping section, releasing flammable naphtha. Employee 1 was on the platform cleaning up the work area while Employee 2 was carrying a bucket of oil down the stairs from the platform. Employee 2 smelled the released hydrocarbon and saw what looked like a steam cloud. Within minutes of the release, the flammable vapor ignited (**Figure 1**).

Figure 14. Fire from breached piping. (Credit: Marathon)

The heat from the fire ruptured piping and damaged other equipment (**Figure 2**). Employee 2 was able to exit the unit before the flammable naphtha ignited. Employee 1 did not escape from the elevated platform and was fatally injured by the fire.

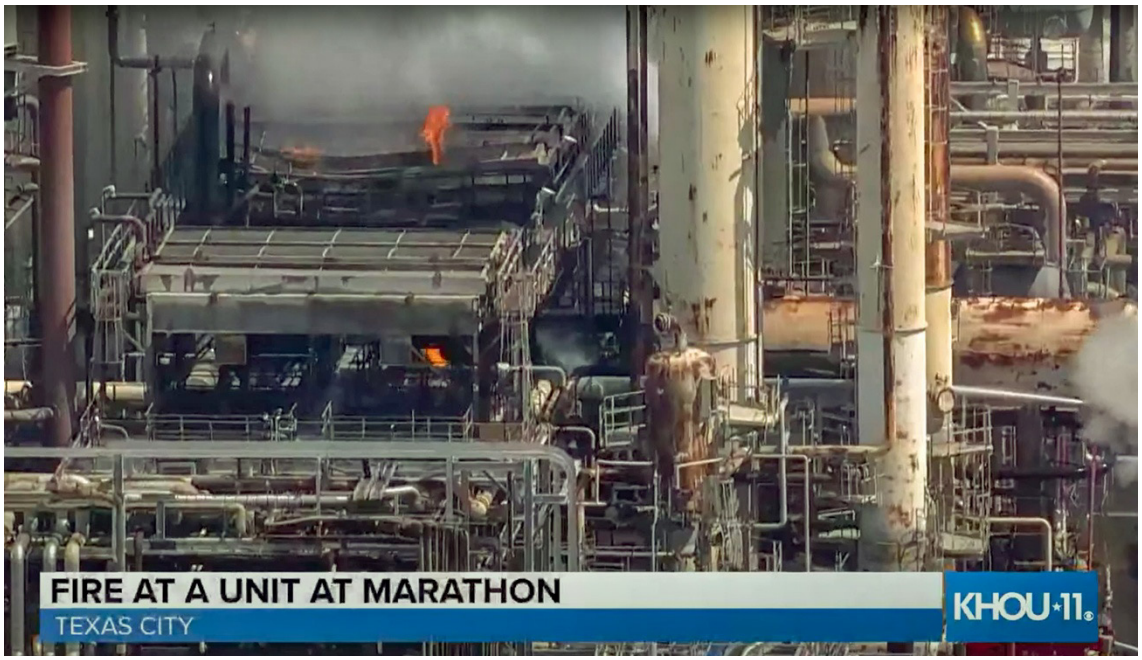

Figure 15. Fire impacting elevated platforms. (Credit: KHOU 11 News)

Marathon's investigation found that a pump inspection in June 2022 had identified damage to the coupling of the pump but did not recommend any repairs. During the release in this incident, the pump's motor continued to operate and spin the damaged coupling. The heat generated by the friction ignited some of the released naphtha, resulting in the fire. Marathon's investigation also found that according to the company's mechanical integrity program, vibration analysis should be performed every two months to predict pump failures, including coupling failures. The last vibration analysis test on the pump was completed in October 2022, seven months before the incident. Marathon reported that approximately 102,000 pounds of naphtha and light hydrocarbons were released.

Probable Cause

Based on Marathon's investigation, the CSB determined that the probable cause of the incident was a pump coupling failure that created high vibration, breaking a section of small-bore piping and releasing flammable naphtha. With the pump's motor continuing to operate, the coupling failure also created enough heat (friction) to ignite some of the released naphtha vapor, creating the fire.

Marathon's mechanical integrity program contributed to the incident by not repairing the damaged coupling identified by the inspection. Additionally, Marathon did not perform its required vibration analysis on the pump, which could have predicted the coupling failure. Marathon could have prevented the incident by performing the required vibration analysis on the pump and repairing the damaged pump coupling.

17. CVR Energy

May 23, 2023

Wynnewood, Oklahoma

Incident Summary

On May 23, 2023, at about 8:20 a.m., approximately 60,000 pounds of naphtha were accidentally released at the CVR Energy, LLC Wynnewood Refinery ("CVR Energy") in Wynnewood, Oklahoma. The released naphtha vaporized and ignited within seconds of the initial release. The fire fatally injured one CVR Energy employee and seriously injured another CVR Energy employee (**Figure 1**). CVR Energy estimated that the incident resulted in approximately $8 million in property damage.

Figure 1. Emergency response to the fatal fire. (Credit: News 9)

CVR Energy's investigation found that a flow control valve ("control valve") in the naphtha hydrotreating unit was malfunctioning. On May 22, 2023, the day before the incident, two maintenance employees were assigned to troubleshoot the control valve. The maintenance team conducted a walkthrough with an operator, who issued them a safe work permit. Operators bypassed flow around the control valve to maintain the desired flow rate to downstream equipment. An operator also closed the isolation valve upstream of the control valve. The isolation valve downstream of the control valve remained open, however, and the drain valves on each side of the control valve remained closed. As a result, the equipment contained flammable liquid naphtha, which the company did not isolate, lock out, or otherwise prepare for equipment opening work.

The control valve was opened from its closed to its fully open position, and the maintenance employees concluded that it was "hung up" and not working correctly. The maintenance employees planned to disassemble the valve and confirmed that there was a gasket set for it. With the workday nearing its end, CVR Energy personnel decided that the control valve work could continue the next workday while the control valve remained bypassed overnight.

On the day of the incident, the same maintenance employees returned to continue working on the control valve. A different operator authorized the maintenance employees to use the same safe work permit from the previous day. The operator understood that the scope of work was limited to troubleshooting the

control valve. Consequently, no field review of the job took place. About 15 minutes after the maintenance employees returned to the work location, naphtha began releasing from the control valve's bonnet flange (**Figure 2**).

The flame in a nearby fired heater likely ignited the flammable hydrocarbon vapor. The fire engulfed the two maintenance workers, but they escaped the area. Emergency responders transported the two workers to hospitals by helicopter, where they were admitted for treatment of their serious burn injuries. Three days later, on May 26, 2023, one of the workers succumbed to their injuries and died.

The investigation revealed that six of the eight nuts had been removed from the control valve's bonnet flange, which was the typical practice at the refinery when preparing to access the internal components. The control valve's bonnet flange had been partially disassembled while its downstream isolation valve was open, and it contained naphtha at 250 pounds per square inch gauge pressure and 425 degrees Fahrenheit. It is unknown whether the maintenance employees thought the system was safe to disassemble the control valve or did not recognize the hazard of disassembling the pressure-retaining components.

Figure 2. Naphtha release point (gold arrows). (Credit: CVR Energy with annotations by CSB)

Probable Cause

Based on CVR Energy's investigation, the CSB determined that the cause of the incident was disassembling a control valve's pressure-retaining bonnet flange during a maintenance activity. The control valve was not isolated from the operating process before performing this work.

Miscommunicating the scope of the work or not recognizing the hazards of disassembling the control valve's pressure-retaining components led to safe work (energy isolation) practices not being performed, which contributed to the incident.

18. SABIC

Ottawa, Illinois

September 5, 2023

Incident Summary

On September 5, 2023, at approximately 7:30 p.m., an accidental release of butadiene vapor occurred inside a decanting tank ("tank") at the SABIC Innovative Plastics, LLC ("SABIC") facility in Ottawa, Illinois. The butadiene vapors ignited, resulting in a fire that seriously injured one SABIC employee.

The incident occurred in SABIC's latex production area during a maintenance shutdown. Employees were tasked with removing an internal part (a "baffle") at the back of the horizontal tank (which was approximately five feet in diameter and nine feet in length). SABIC's procedure stated that the tank should be cleaned using high-pressure water to remove any accumulated solids before entry. However, this procedure was not followed, and residual solids remained in the tank and potentially contained some butadiene (**Figure 1**). The work inside the tank disturbed these solids, which likely released about two pounds of butadiene vapor, creating a flammable atmosphere within a portion of the tank. In addition, while continual monitoring of the confined space was taking place during the entry, the end of the air monitor hose was not near the bottom of the tank where the solids were located, and this likely prevented the 5-gas detector from identifying the presence of flammable butadiene vapor.

Figure 1. Tank Containing Solids at SABIC. (Credit: SABIC)

Leading up to the incident, two workers received a confined space permit and a safe work permit to remove the baffle with hand tools after the area was monitored with a gas detector. One of the workers entered the tank ("entrant") while the other attended the confined space entry ("attendant"). The entrant could not remove the bolts holding the baffle in place with hand tools and switched to a battery-powered

tool, which likely ignited residual butadiene vapors and created a fire. The entrant suffered burn injuries from the fire but was able to escape and was escorted to a safe area by the attendant. The injured worker was transported and admitted to a hospital for medical treatment. Two other SABIC employees were able to put out the fire.

Probable Cause

Based on SABIC's investigation, the CSB determined that the probable cause of the incident was performing work in a confined space containing a flammable atmosphere. Inadequate flammable gas monitoring, the use of a battery-powered tool, and employees' being unaware that SABIC had a procedure requiring the tank to be cleaned before entry contributed to the incident.

19. Hornady

Alda, Nebraska

October 13, 2023

Incident Summary

On October 13, 2023, at approximately 9:45 a.m., a mixture containing tetrazine and lead styphnate detonated at the Hornady Manufacturing Company's ("Hornady") facility in Alda, Nebraska (**Figure 1**). The explosion fatally injured one Hornady operator.

Figure 1. Hornady Facility. (Credit: Omaha World Herald)

At the time of the incident, Hornady was producing priming compound, the ignition component used in firearm ammunition. The priming compound had already completed the first mixing cycle, and the operator was scraping the partially mixed priming compound off the mixer blade and the sides of the mixing bowl with a silicone spatula. While performing this task, the priming compound detonated and fatally injured the operator.

Hornady's investigation evaluated the possibility that the explosion was ignited by static electricity. The explosive material's moisture content was within the proper range, and the spatula, the room floor, and the operator's shoes passed a conductivity check before the incident occurred. Hornady's investigation concluded that these conditions showed that the explosive material should have been adequately desensitized, making static electricity an improbable ignition source. Instead, Hornady's investigation concluded that the detonation was most likely ignited by the energy applied from mixing a dry area of explosive mixture with the silicone spatula.

After the incident, Hornady eliminated the need for operators to scrape the bowl and mixer blade until the entire mixing stage was completed, limiting the time that an operator was near the unmixed explosive components.

Probable Cause

Based on Hornady's investigation, the CSB determined that the probable cause of the detonation was the energy applied by manual mixing to the explosive mixture.

20. Tradebe

December 29, 2023

Bridgeport, Connecticut

Incident Summary

On December 29, 2023, at 1:45 p.m., a storage tank exploded, creating a fire at the Tradebe Environmental Services ("Tradebe") facility in Bridgeport, Connecticut (**Figure 1**). The explosion and fire seriously injured one contractor. Tradebe estimated the property damage to be approximately $5.8 million.

Figure 1. The tank that exploded (left). A portion of the tank after the explosion (right) (Credit: Tradebe, annotated by the CSB).

Tradebe's investigation found that a 10,000-gallon epoxy-lined steel storage tank exploded from a chemical reaction inside the tank. At about 1:00 p.m. on the day of the incident, Tradebe workers finished transferring about 4,000 gallons of organic material containing methylene chloride, tetrahydrofuran, toluene, xylenes, trimethylbenzene, and naphthalene into the storage tank from another vessel at the facility. Chemical compatibility testing was not performed before making this transfer. Tradebe's investigation concluded that adding 4,000 gallons of material to the storage tank agitated the existing 6,000 gallons of sludge already inside the tank, starting an unintended chemical reaction.

The sludge contained hydrogen peroxide, organic peroxides, and metal ions, including cobalt, iron, nickel, and chromium. Agitating this material likely started a chemical decomposition reaction between the organic and peroxide components in the presence of metals. This reaction produced vapor (including oxygen gas) and generated heat. At 1:45 p.m., the flammable vapor within the hot tank ignited (autoignition), and the storage tank exploded. The explosion created a fire that seriously injured a truck driver who was at the facility to make a chemical delivery into a different tank.

Tradebe did not estimate the amount of combustion products released when the storage tank exploded. To prevent a similar incident, Tradebe stated that the company plans to stop handling oxidizers in this equipment, perform compatibility testing before transferring materials, and routinely clean its tanks.

Probable Cause

Based on Tradebe's investigation, the CSB determined that the probable cause of the incident was the mixing of reactive chemicals within a storage tank, which generated heat and oxygen. The heat from the reaction ignited the flammable vapor in the tank (autoignition), resulting in the explosion. The failure to confirm chemical compatibility before transferring material into the storage tank contributed to the incident.

21. Tronox

February 14, 2024

Hamilton, Mississippi

Incident Summary

On February 13, 2024, at 11:59 p.m., a titanium tetrachloride and hydrogen chloride vapor mixture was accidentally released at the Tronox Hamilton facility ("Tronox") in Hamilton, Mississippi (**Figure 1**). Two Tronox employees were seriously injured when they inhaled some of this toxic vapor.

Figure 1. The Tronox facility in Hamilton, Mississippi. (Credit: Monroe Chamber of Commerce)

At Tronox, a process stream containing titanium tetrachloride and solids is sent through a cyclone for separation. The separated solids fall through piping directly connected to a tank filled with water ("water tank") to cool them. Over time, this piping regularly plugs with solids, and Tronox workers periodically unblock it in order to continue operations.

Before the incident, two Tronox employees were clearing the piping when the pressure in the water tank increased, causing a separate pipe connecting the water tank to a scrubber to break. Approximately 280 cubic feet of a mixture of titanium tetrachloride and hydrogen chloride escaped from the broken piping, exposing the two workers to the toxic vapor. After inhaling this vapor, the workers experienced respiratory problems, which worsened over the next few hours. Both employees were transported to a hospital, where they were admitted for treatment.

Tronox's investigation determined that the high-pressure condition inside the water tank was created by a violent chemical reaction between titanium tetrachloride and water that generated hydrogen chloride vapor and heat. Liquid titanium tetrachloride had accumulated within the plugged piping from an upstream spray injection system. When the workers cleared the solids from the piping into the water tank, the liquid titanium chloride also entered the water tank, triggering the chemical reaction. Although the water tank was equipped with a rupture disc to protect the equipment from high-pressure conditions, the rupture disc did not activate during the incident because its inlet piping was blocked with solids (**Figure 2**). The investigation also found that although previous high-pressure events had occurred, Tronox's employees were not required to wear respiratory protection for the pipe-clearing activity.

Figure 2. Solids in the rupture disc inlet piping. (Credit: Tronox)

Probable Cause

Based on Tronox's investigation, the CSB determined that the probable cause of the incident was a reaction between titanium tetrachloride and water, which generated hydrogen chloride vapors. High-pressure conditions developed in the system and broke the piping connected to the water tank, releasing toxic vapor into the surrounding air, which seriously injured two Tronox employees. The water tank's rupture disc did not activate because its inlet piping was plugged with solids, contributing to the incident. Not wearing respiratory protection during the pipe-clearing work contributed to the severity of the incident.

22. ExxonMobil

March 17, 2024

Baytown, Texas

Incident Summary

On March 17, 2024, at approximately 12:50 p.m., about 250,000 pounds of hydrogen and naphtha mixture were accidentally released into the firebox of a fired heater, where it ignited, creating a major fire at the ExxonMobil Corporation Refinery ("ExxonMobil") in Baytown, Texas (**Figure 1**). ExxonMobil estimated that the property damage from the incident was $32 million.

Figure 16. The ExxonMobil facility in Baytown, Texas. (Credit: CNBC)

ExxonMobil's investigation revealed that three days before the incident, on March 14, 2024, the temperature of the tubes in the fired heater exceeded 1,200 degrees Fahrenheit, the heater's operating limit. When the alarms indicated that the temperature exceeded the operating limit, operators at the facility lowered the temperature in the fired heater by reducing the fuel gas flow to the heater's burners.

On March 17, 2024, the day of the incident, the same fired heater reached similar high temperatures, prompting operators to respond again. The situation escalated when two tubes within the fired heater ruptured, releasing hydrogen and naphtha into the firebox. The existing burner flame ignited these flammable hydrocarbons, resulting in a major fire.

ExxonMobil's investigation found that fire blankets and insulation material ("debris") were present inside the failed tubes (**Figure 2**). ExxonMobil determined that this debris was likely left inside the equipment after the conclusion of maintenance work (turnaround) that had been done three weeks earlier. This debris restricted the flow through the tubes, causing an increase in the temperature of the metal walls and ultimately leading to the tube failures. Additionally, the fired heater was not equipped with individual pass flow instrumentation. ExxonMobil's metallurgical examination determined that the

tubes ruptured because of a combination of creep damage (which results from prolonged exposure to stress at elevated temperatures) and short-term overheating.

Figure 17. Failed fired heater tubes (left) and debris removed post-incident (center and right). (Credit: ExxonMobil)

ExxonMobil's investigation revealed that the refinery's process for ensuring that equipment was clean before resuming operations did not include checks of piping or fired heater tubes. Additionally, ExxonMobil determined that its operational readiness programs assessed only the external status of piping and valves and did not evaluate their internal condition.

Probable Cause

Based on ExxonMobil's investigation, the CSB determined that the probable cause of the hydrogen and naphtha release was that tubes in the fired heater ruptured due to a combination of creep damage and short-term overheating. Flames from the fired heater's burners ignited these flammable materials, resulting in the fire. Reduced flow through the fired heater's tubes, caused by debris left inside the equipment after maintenance, contributed to the incident.

23. Western Sugar Cooperative

May 29, 2024

Fort Morgan, Colorado

Incident Summary

On May 29, 2024, at about 3:15 p.m., several pounds of hydrogen sulfide and carbon monoxide gas were released at the Western Sugar Cooperative ("Western Sugar") facility in Fort Morgan, Colorado (**Figure 1**). As a result of the release, one Western Sugar employee was fatally injured and another Western Sugar employee was seriously injured due to inhalation of the gases.

Figure 1. Western Sugar Facility. (Credit: Google Maps)

Western Sugar's investigation found that at the time of the incident, two Western Sugar employees were performing maintenance work on a pump at the facility. The workers closed an isolation valve and removed approximately half of the bolts on the connection before water began leaking from the flange onto the floor. The workers and their supervisor determined that the isolation valve was not properly seated. The two workers left the pump house to get a tool to help close the valve. While the workers were gone, hydrogen sulfide and carbon monoxide gas began releasing into the pump house (which was approximately 400 square feet and 8 feet tall).

When the workers reentered the pump house, they experienced symptoms consistent with toxic gas exposure. One of the workers lost consciousness ("Worker One") when trying to escape up a ladder. The other worker ("Worker Two") escaped the pump house. Worker Two explained the situation to another supervisor, and emergency responders were contacted. A third supervisor and two other employees attempted to rescue Worker One, but they realized that the area was dangerous and tried to escape. During the escape, one of the attempted rescuers ("Rescuer One") fell, appeared to be unconscious, and could not self-rescue. An air monitoring device that was lowered into the pump house sounded an alarm for both hydrogen sulfide and carbon monoxide, indicating the concentrations of the gases were above 20 and 35 parts per million, respectively. Because of the high concentrations of the gases, Western Sugar employees halted their rescue attempts and waited for emergency responders to arrive.

Emergency responders with self-contained breathing apparatuses were able to rescue the two employees from the lower pump house and transport them to a local hospital for medical treatment. Rescuer One died at the hospital later that day. Worker One survived and was released from the hospital after a few

days. After the incident, Western Sugar classified the lower pump house as a confined space and installed continuous air monitoring equipment.

Probable Cause

Based on Western Sugar's investigation, the CSB determined that the probable cause of the incident was the pump's leaking isolation valve that allowed hydrogen sulfide and carbon monoxide gas to enter the pump house when the flange was opened. Not identifying or controlling these toxic gases from being released in this part of the process contributed to the incident. Contributing to the severity of the incident was that the lower pump house was not classified as a confined space, which allowed employees to enter without safeguards such as respiratory protection, air monitoring, attendants, or a rescue plan.

24. LyondellBasell

July 12, 2024

Channelview, Texas

Incident Summary

On July 12, 2024, at 7:00 p.m., a mixture of nitrogen and benzene was accidentally released into the firebox of a fired heater. The benzene ignited, causing a fire at the LyondellBasell Industries ("LyondellBasell") facility in Channelview, Texas (**Figure 1**). Lyondell Chemical Company operates this LyondellBasell facility. The company estimated that the incident resulted in $9.8 million in property damage.

Figure 18. The LyondellBasell facility in Channelview, Texas. (Credit: Google Maps (left), The Center for Land Use Interpretation (right))

The incident occurred while LyondellBasell employees were restarting the fired heater after Hurricane Beryl damaged offsite power systems, disrupting water availability and causing a shutdown of the facility on July 8, 2024. Process fluid should circulate through the fired heater's tubes during the unit startup. LyondellBasell's investigation found that the process flow through the fired heater was reduced because two misaligned valves (open valves that should have been closed) allowed some of the flow to bypass the heater.

Without enough fluid flow to remove heat, the tubes reached temperatures as high as 1,900 degrees Fahrenheit, far above the safe operating temperature. The high-temperature condition weakened the tubes in the upper portion of the fired heater and caused some of them to rupture, likely from short-term overheating (**Figure 2**).

Figure 19. Broken fired heater tubes. (Credit: LyondellBasell)

LyondellBasell reported that the ruptured tubes released approximately 16,000 pounds of nitrogen and 630 pounds of benzene into the firebox. The operating burner flames ignited the flammable benzene, resulting in a fire.

LyondellBasell's investigation reviewed the company's process hazard analysis and determined that the existing instrumentation safeguards did not protect against low-flow or high-temperature conditions in the fired heater during startup. The investigation also found that human factors caused valve alignment errors that allowed some process flow to bypass the furnace. These included vague radio communications, multitasking due to a high startup workload, stress from the major hurricane, perceived time pressure from delays, and implementing an unfamiliar startup, which was infrequently conducted.

After the incident, LyondellBasell provided its operations team with fired heater startup simulator training and improved the company's instrumented safeguards for the fired heater. These instrumentation upgrades included an alarm and a safety interlock to protect the equipment when the temperature difference between any individual tube pass temperature and the combined process fluid temperature exiting the furnace indicates that there is insufficient process flow through the tubes.

Probable Cause

Based on LyondellBasell's investigation, the CSB determined that the probable cause of the incident was ruptured process tubes in a fired heater. Short-term overheating likely resulted in the tubes rupture, releasing nitrogen and benzene into the firebox. The flames from the fired heater's operating burners likely ignited the benzene. Human factors resulted in two valve misalignments that contributed to the incident by creating a low-flow condition through the tubes, which increased the temperature in the tubes. A lack of instrumentation safeguards to protect the fired heater from low-flow and high-temperature conditions also contributed to the incident.

25. LyondellBasell

August 29, 2024

Houston, TX

Incident Summary

On August 29, 2024, at 6:45 p.m., flammable vapors were accidentally released from a reactor at the LyondellBasell Industries ("LyondellBasell") refinery in Houston, Texas, resulting in a fire at the facility. Houston Refining LP owns and operates this LyondellBasell facility. The incident resulted in $16.8 million in property damage.

At the time of the incident, employees noticed flames coming from the head of a reactor in the fluidized catalytic cracking unit ("FCCU") (**Figure 1**). The flammable vapor released from the reactor likely caught fire from autoignition because the reactor operated at 960 degrees Fahrenheit (°F), which is above the autoignition temperature for most of the hydrocarbons released. Unit operators put out the flames with a fire extinguisher. LyondellBasell reported that over 400 pounds of flammable vapors were released during this incident.

Figure 1: The FCCU at LyondellBasell. (Credit: Google Earth)

LyondellBasell's investigation determined that the flammable chemicals were released through an 8-inch crack in the wall at the top (head) of the reactor (**Figure 2**). Additionally, LyondellBasell found other

cracks in the reactor that were up to 67 percent of the wall thickness. The cracks were created by a damage mechanism known as corrosion fatigue. Corrosion fatigue is caused by cyclically applied stress under corrosive conditions. Internal cracks formed at the top of the reactor, an area that was consistently exposed to sulfur-containing chemicals commonly found in petroleum refining. This sulfidation corrosion was coupled with temperature swings over 200°F, which applied stress to the vessel through expansion and contractions of the metal with the temperature changes. LyondellBasell found that there had been more than 50 temperature cycles since 2011. Additionally, platform supports were added to the reactor head in 2001, contributing to the cracking by increasing the stress exerted on the vessel. Stress-assisted preferential sulfur penetration is the specific type of corrosion fatigue responsible for the 8-inch crack.

Figure 2. One of the cracks in the reactor's head. (Credit: LyondellBasell, edited by the CSB)

The investigation also revealed that LyondellBasell was not inspecting the reactor's walls for cracking because the site's mechanical integrity program did not identify corrosion fatigue as a potential damage mechanism. The company attributed this gap to following industry standards that did not identify corrosion fatigue as a common FCCU reactor damage mechanism.

Probable Cause

Based on LyondellBasell's investigation, the CSB determined that the probable cause of the accidental release was an 8-inch corrosion fatigue crack through the wall at the top of the reactor. Adding platform supports to the top of the reactor contributed to the incident by increasing the stress exerted on the vessel during the temperature changes. LyondellBasell's mechanical integrity program contributed to the incident by not identifying corrosion fatigue as a potential damage mechanism for its FCCU reactor.

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U.S. Chemical Safety and Hazard Investigation Board