2024

Calendar

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A year of process safety incident case studies

Forget not those
who were needlessly killed and injured
in the process safety incidents described herein.

This calendar of process safety incident case studies was prepared by Peter Davern, Department of Chemical Sciences, University of Limerick, Ireland.

All case study descriptions were drafted with reference to the publicly available final investigation reports, case study reports, safety bulletins, investigation digests and/or videos released by the U.S. Chemical Safety and Hazard Investigation Board (CSB): https://www.csb.gov/investigations/completed-investigations/?Type=2.

JANUARY – WATSON GRINDING AND MANUFACTURING CO.

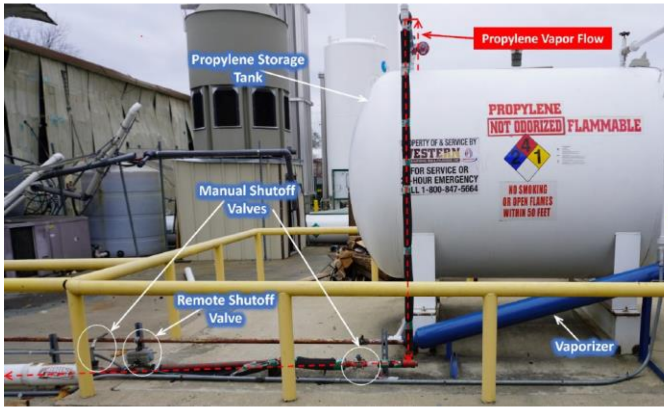

Figure 1: Post-incident photo of the propylene storage tank

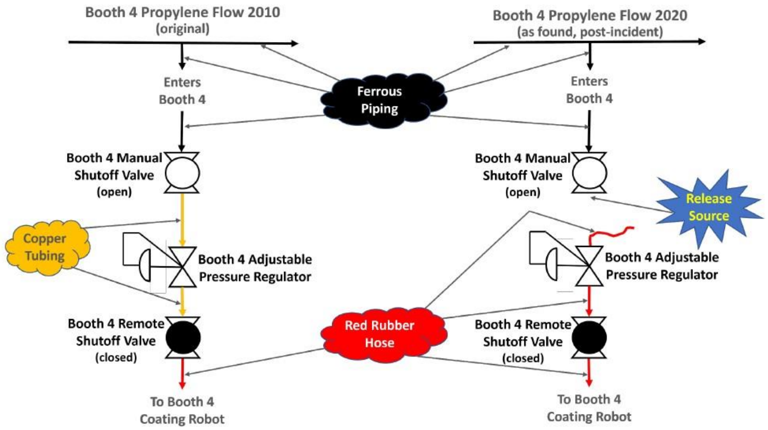

Figure 2: Simplified propylene flow diagram of the Booth 4 gas equipment as originally installed in 2010 (left), and as found, post-incident (right)

Incident type: Propylene release and explosion

Time, day, date: Shortly before 4:30 a.m., Friday, 24 January 2020

Location: Houston, Texas, U.S.

Industrial sector: Specialty grinding, machining and thermal spray coating services

Substance(s) involved: Propylene

Number killed: 3 **Number injured:** 2

Organisation: Watson Grinding and Manufacturing Co.

Description:

Watson Grinding and Manufacturing Co. (Watson) was a specialty grinding and machining service provider that also specialized in thermal spray coating, particularly High Velocity Oxygen Fuel (HVOF) coating. The company serviced parts for a variety of industries. In the HVOF coating process, propylene and oxygen gases were fed into the combustion chamber of a spray gun, combusted under pressure, and the resulting high-velocity flame accelerated through a water-cooled nozzle. Pure metals, ceramics, metallic alloys, or composites in powder form were entrained in the flame and thus deposited in successive layers on the surface of the item being coated. The thermal spray coating operations were conducted in a number of self-contained coating booths, each staffed with a coating booth operator. A propylene storage tank (Figure 1) supplied propylene vapour to the coating booths through pipework fitted with two manual valves and one remote shut-off valve. Operators performed the HVOF coating both manually and by using industrial robotic arms. Figure 3, a pre-incident photo, shows the interior of a HVOF coating booth during the spray coating of a ball valve component. A number of the booths were equipped with a gas detector, similar to that shown in Figure 3. The purpose of the gas detection system was to continually monitor the propylene and oxygen concentrations inside the coating booths and, in instances of dangerous concentrations, do the following: (1) activate local alarms when the prescribed parameters were exceeded, (2) start up the booth's exhaust fan (if not already operating), and (3) stop the flow of these gases, both locally in the booth and remotely at the propylene and oxygen storage tanks outside the coating building. Watson used daily leak tests (including visual inspections and spraying soapy water onto fittings) and employees' sense of smell to detect propylene leaks. If leaks were detected, one of the two manual valves on the propylene storage tank's supply line could be closed, or one of the coating building's emergency gas shutoff buttons (E-Stops) could be activated to close the supply line's remote shutoff valve. At the end of the workday, at least one of the two manual shutoff valves on the propylene storage tank could be closed; this practice was informal, however, and not always performed because to do so might slow down the next morning's startup. Around 4:00 a.m. on the morning of the incident, two employees arrived outside the facility, smelled and heard what they believed was a propylene gas leak, and notified management. Management did not direct them to evacuate the facility. It went unrecognised by all concerned that an explosive concentration of propylene had accumulated inside the coating building because a propylene supply hose had become disconnected from its fitting inside a coating booth (Booth 4) sometime overnight. When another employee arrived, entered the building and turned on the lights, the propylene vapour ignited, resulting in an explosion. The explosion fatally injured two employees and injured two additional employees. A nearby resident died two weeks later due to injuries sustained in his house caused by the explosion. The explosion damaged hundreds of nearby structures, including homes and several businesses. On February 6, 2020, the company (which had approximately 130 employees) filed for bankruptcy. It is no longer in business.

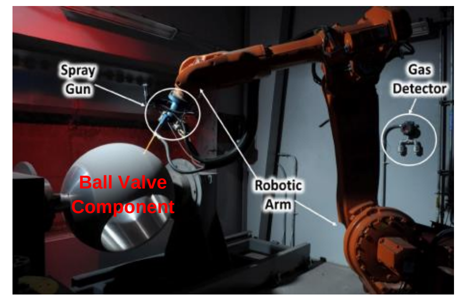

Figure 3: A HVOF coating booth interior

Contributing factors:

● None of the propylene supply line's three shutoff valves had been isolated on the evening before the incident, nor was there an established procedure to do so. ● The lights in the coating building's common area were not designed to be safe in a flammable atmosphere, making them a potential ignition source if activated. ● The automated system of gas detection, alarm, exhaust fan startup, and gas shutoff was not maintained, and Booth 4's system was not functional at the time of the propylene leak. ● There was no management of change review of the decision to change the rigid copper tubing on Booth 4's gas equipment to a flexible red rubber hose (Figure 2). ● The red rubber hose was not suitable for propylene service and had therefore degraded. Also, Watson had stopped using factory-crimped hosing in favour of hoses being crimped by the coating booth operators, and the red rubber hose was found to be poorly crimped, post-incident. ● The absence of an emergency response plan to evacuate the facility, prevent others from entering, and contact emergency responders for help.

Some lessons learned:

The importance of having (i) an effective process safety management system in facilities that handle hazardous materials, (ii) well-maintained and reliable gas detection, alarm, exhaust and shutdown systems, and (iii) a comprehensive and effectively implemented emergency response plan.

JANUARY

2024

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24 2020: Propylene release & explosion, Watson	25	26	27	28
29	30	31				

FEBRUARY – PACKAGING CORPORATION OF AMERICA (PCA) PAPER MILL

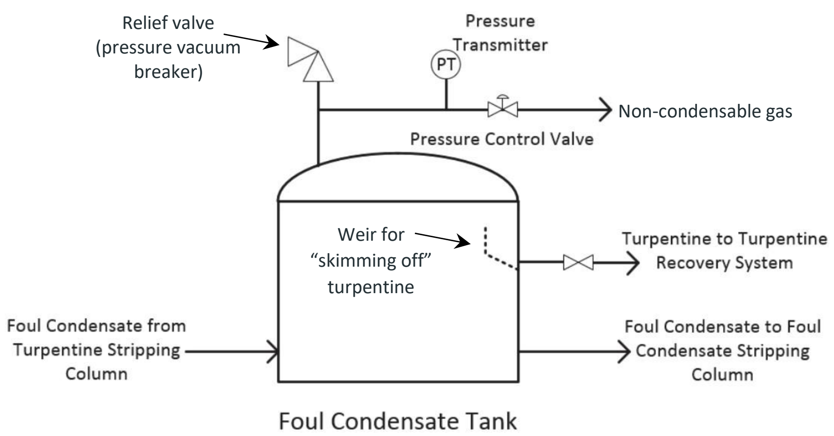

Figure 1: Simplified drawing of the foul condensate tank. The top of the weir (dotted line) sits approximately 6 meters from the base of the tank. As the liquid inside the tank rises above 6 meters, liquid is "skimmed" into the weir and sent to a turpentine recovery system.

Figure 2: A computer-generated image depicting the hot work being performed on the pipework above the foul condensate tank

Incident type: Non-condensable gas system explosion

Time, day, date: approximately 11:05 a.m., Wednesday, 08 February 2017

Location: DeRidder, Louisiana, U.S.

Industrial sector: Pulp and paper

Substance(s) involved: Non-condensable gas

Number killed: 3 **Number injured:** 7

Organisation: Packaging Corporation of America (PCA)

Description:

The Packaging Corporation of America's (PCA) DeRidder, Louisiana pulp and paper mill produces containerboard used in products such as boxes and cardboard displays. The containerboard is made from pulp produced at the mill. During the process of creating pulp, vapours are generated. These vapours, which contain turpentine, water, and other non-condensable gases (including sulfur compounds), are collected and separated. To separate the vapours, they first enter a turpentine-stripping column. There, most of the turpentine is removed and sent to a condenser. The remaining vapours condense to a liquid (known as "foul condensate") containing mostly water but also residual amounts of sulfur compounds and turpentine. The foul condensate is sent from the stripping column to an approximately 380,000 liter-capacity atmospheric storage tank, used to store the liquid at, or close to, ambient pressure. This foul condensate tank is primarily used to regulate the flow of liquid between the turpentine-stripping column upstream and a downstream unit that removes the remaining sulfur components from the water. At the time of the incident, the mill was undergoing its annual shutdown. One of the shutdown tasks was to repair water piping located above, and connected to, the foul condensate tank; the piping had shifted and cracked months earlier. The repair required welding to be done on the piping. To prepare for this hot work, valves were closed leading into and out of the tank and the piping was separated from the tank, while 3 meters of liquid remained inside. The liquid was left within the tank, partly because there were no plans to work directly on the tank. The company also assumed that the tank contained mostly water, was sealed off from the atmosphere, and thus did not pose a safety risk. Residual turpentine, normally present in foul condensate, collected on top of the liquid in the tank due to its density. The tank was equipped with a weir to skim turpentine off the surface of the foul condensate liquid once the liquid had reached a height of 6 meters (Figure 1). The skimmed turpentine was sent to a turpentine recovery system. But in the months before the incident the turpentine was not removed due to confusion as to who at the mill was responsible for operating the tank. Due to this confusion, a valve designed to direct skimmed turpentine to the mill's turpentine recovery system remained closed for months. Thus, leading up to the incident, there was more flammable turpentine in the tank than anyone expected. In addition, there are normally vapours in the tank's headspace. Although these vapours can become flammable, they are supposed to be kept at a concentration too rich to burn. However, due to the non-routine conditions experienced during the annual shutdown, the tank's contents likely cooled, creating low pressure within it. This most likely triggered a relief valve on the tank's roof to draw in more air to avoid damaging the tank from the vacuum created by low pressure, thus creating an explosive atmosphere. Ahead of the hot work, in addition to the process isolations, a mill employee used a gas detector to check for a flammable atmosphere in and around the water piping, and found none. As a result, the company issued a hot work permit for the welding work. But even though a flammable atmosphere was not present outside the tank, a flammable atmosphere existed inside the tank. Without knowing that the tank posed a serious hazard, three contract workers began welding on the water piping located above it (Figure 2). Though it was not possible to confirm, it is likely that sparks or molten slag from the hot work landed on or near the tank, heating up the tank wall or otherwise igniting the contents inside. Alternatively, it may be that the hot work was complete but as the tools were lowered, a welding torch fell and created an electric arc on the tank or its vent piping. Regardless, the hot work activities likely ignited the flammable vapours and liquid turpentine inside the tank resulting in a large explosion. The tank separated from its base and launched up and over a six-storey structure, landing approximately 114 meters away. Three people were killed and seven were injured; all were contract employees working near the tank.

Contributing factors:

● PCA did not voluntarily apply its process safety management system, required by OSHA elsewhere in the mill, to the non-condensable gas system that included the foul condensate tank. Thus, no process hazard analysis was ever done that could have identified and then defined safeguards to address the scenario of a flammable atmosphere arising inside the foul condensate tank, especially when planning hot work. ● It was unclear who was responsible for the foul condensate tank. Over time, this led to few workers knowing much about the tank, its contents, and its explosion potential. ● The tank's design did not adequately address the scenario of a flammable atmosphere developing within. It could have been (i) fitted with a low-pressure alarm to alert that the vacuum relief valve may open, allowing air in, (ii) fitted with an oxygen analyser to alert workers and trigger a nitrogen inertion step, or (iii) vacuum-rated to avoid the need for a vacuum relief valve entirely.

Some lessons learned:

The importance of (i) applying a process safety management system thoroughly, (ii) clearly defining roles and responsibilities, and (iii) the inherently safer design of tanks containing flammables.

FEBRUARY

2024

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
			1	2	3	4
5	6	7	8 2017: **Non-condensable gas system explosion, PCA DeRidder**	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29			

MARCH – INTERCONTINENTAL TEREMINALS COMPANY, LLC

Figure 1: Plume of black smoke rising from ITC's tank farm fire

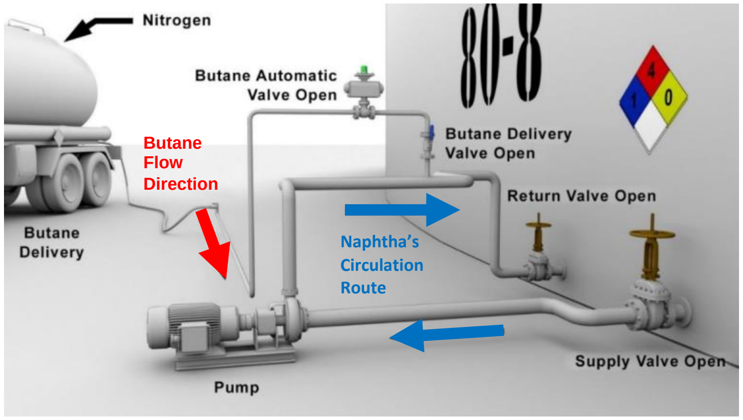

Figure 2: Schematic of ITC's Truck Butane Injection System prior to 2016

Incident type: Storage tank release and fire

Time, day, date: approximately 10:00 a.m., Sunday, 17 March 2019

Location: Deer Park, Texas, U.S.

Industrial sector: Petrochemicals storage

Substance(s) involved: Butane-enriched naphtha

Number killed: 0 **Number injured:** 0

Organisation: Intercontinental Terminals Company, LLC (ITC)

Description:

At the time of the incident Intercontinental Terminals Company, LLC (ITC) was a terminal and storage facility operator that had been servicing the petrochemical industry for over five decades. ITC's facility at Deer Park, Texas was situated on an inlet in the Houston Ship Channel. It housed 242 fixed storage tanks whose capacities ranged from 8,000 to 160,000 barrels (1,272,000 to 25,440,000 liters). The terminal was separated into various tank farms, each containing multiple tanks within a common secondary containment area intended to capture the entire contents of the largest tank in the containment area in the event of a leak or spill. The tanks stored petrochemical liquids and gases, fuel oil, bunker oil, and distillates for various oil and chemical companies that leased the tanks from ITC. One such tank, Tank 80-8, was an 80,000-barrel aboveground atmospheric storage tank that held flammable butane-enriched naphtha; naphtha is a complex mixture of petroleum hydrocarbons in the C4–C10 range. It was equipped with a Truck Butane Injection System to boost the naphtha's octane level by allowing butane to be unloaded from a truck under nitrogen pressure into the tank, via pipework connected to the tank's external naphtha circulation loop (Figure 2). On the evening before the incident, two butane truck deliveries were unloaded into Tank 80-8 over an approximately three-hour period. The tank's circulation pump was started before unloading began. It remained on during the unloading process, and stayed running through the night and into the following morning to mix the roughly 70,300 barrels of butane-enriched naphtha within the tank. At around 9:30 a.m. on the following morning, the pump's mechanical seal failed and butane-enriched naphtha began releasing to the atmosphere. Between 9:30 and 10:00 a.m., Tank 80-8's volume decreased by more than 177 barrels as the butane-enriched naphtha continued to release from the failed (though still running) pump. At 10:00:46 a.m., the released product ignited. After the fire had started, ITC was unable to isolate or stop the release. As a result, the fire burned, intensified, and spread to the other 14 tanks located in the same containment area. The fire burned for three days before being extinguished. The fire caused substantial property damage at the terminal, including the destruction of fifteen 80,000-barrel aboveground atmospheric storage tanks and their contents. The incident also significantly impacted the environment. A containment wall around the tanks breached and released an estimated 470,000–523,000 barrels of hydrocarbon and petrochemical products, firefighting aqueous film forming foam, and contaminated water into the nearby waterways, sediments, and habitats, ultimately reaching the Houston Ship Channel and surrounding waters. An approximately 11-kilometer stretch of the Houston Ship Channel was closed, as were several waterfront parks in the vicinity, due to the contamination. The incident did not result in any injuries or fatalities; however, the local community experienced serious disruptions, including several shelter-in-place orders because of benzene-related air quality concerns. The estimated property damage from the incident exceeded $150 million.

Contributing factors:

● ITC did not have a formal mechanical integrity procedure in place to cover Tank 80-8 and its associated equipment, including the circulation pump. The investigation concluded that the pump continued circulating butane-enriched naphtha despite failure of its outboard bearing. The bearing failure likely led to significant pump vibration, which loosened the gland nuts that secured the mechanical seal in place, causing the seal to separate and allow the release of the flammable mixture. ● Tank 80-8 was not equipped with a flammable gas detection system to warn personnel of a hazardous atmosphere resulting from loss of containment from the tank or its associated equipment. A 2014 hazard review recommended the addition of flammable gas detection systems near Tank 80-8; however, this was never done. ● Tank 80-8 and the other storage tanks nearby were not equipped with remotely operated emergency isolation valves designed to mitigate process releases remotely from a safe location. ● Although mostly designed to the relevant standards when built, parts of the tank farm design (e.g., tank spacing, subdivisions, engineering controls for pumps, and drainage systems) made it hard for emergency responders to slow or prevent the initial fire's spread, thus the fire spread to other tanks in the tank farm. The resulting accumulation of hydrocarbon and petrochemical products, firefighting foam, and contaminated water in the secondary containment area ultimately contributed to a breach of the containment wall and a release of materials to the local waterways. ● Tank 80-8 was not covered under OSHA's Process Safety Management Standard or the U.S. EPA's Risk Management Program Rule. Thus, no process safety management program was applied to it.

Some lessons learned:

For companies that handle large volumes of flammable or highly hazardous substances, the importance of (i) having multiple preventive and mitigation safeguards in place such that a single safeguard failure does not result in a catastrophic event, (ii) strategically located gas detection systems, (iii) appropriate remote isolation capability, (iv) considering more robust tank farm design criteria, and (v) applying a process safety management program even when not a regulatory requirement.

MARCH

2024

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17 2019: Storage tank release & fire, Intercontinental Terminals Company
18	19	20	21	22	23	24
25	26	27	28	29	30	31

APRIL – LOY-LANGE BOX COMPANY

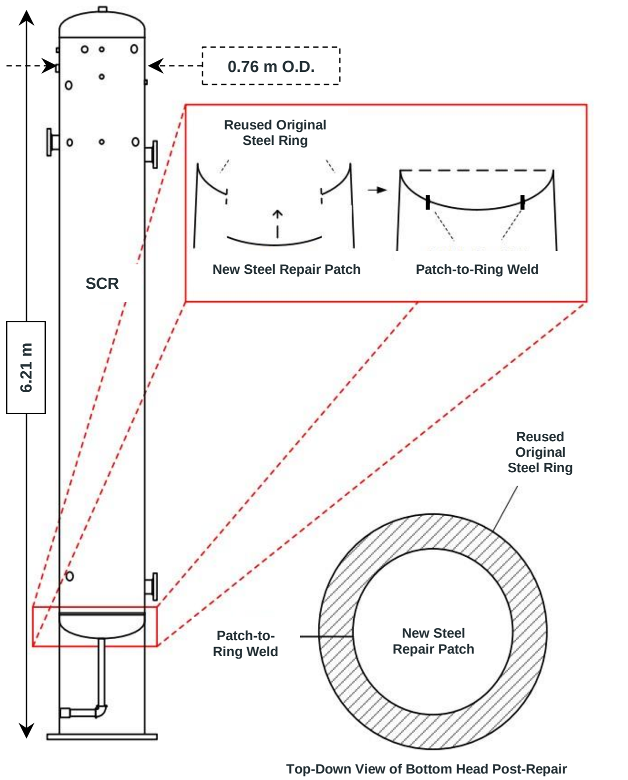

Figure 1: Diagram of repair made to SCR bottom head in 2012

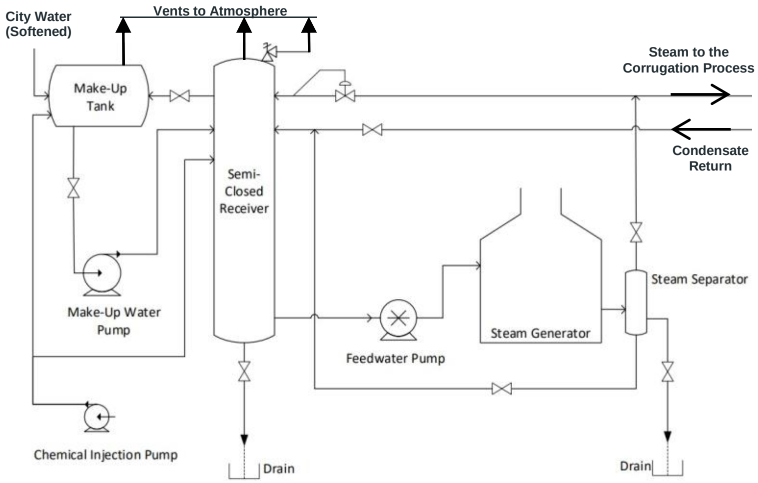

Figure 2: A diagram showing part of the Loy-Lange steam generation system

Incident type: A steam BLEVE

Time, day, date: approximately 7:20 a.m., Monday, 03 April 2017

Location: St. Louis, Missouri, U.S.

Industrial sector: Corrugated cardboard manufacturing

Substance(s) involved: Steam

Number killed: 4 **Number injured:** 0

Organisation: Loy-Lange Box Company

Description: Loy-Lange Box Company manufactured corrugated cardboard for use in products such as boxes. Making corrugated cardboard involved heating paper using a steam generation system (Figure 2). The steam generation system used municipal water fed into a make-up tank. There, the water was treated with chemicals and heated to around 93 °C to remove dissolved gases including oxygen, because oxygenated water is corrosive to steel. The water then flowed from the make-up tank into a larger pressure vessel called the semi-closed receiver (SCR). The SCR had a long cylindrical center and two end pieces called heads, all of which were made of steel and thus susceptible to oxygen corrosion. The SCR was kept under pressure to allow the water inside retain more heat than at atmospheric pressure. From the SCR, the water was pumped to a generator that converted it to the steam used to heat the paper. Having heated the paper, the steam condensed back into hot water, which was routed back to the SCR. At the end of the workday, operators shut down the steam generation system leaving the SCR filled with warm water. The next workday, they would restart the steam generation system. During the daily startup, operators would initially block the flow of water into the SCR from both the make-up tank and the condensed steam return line, and the water remaining in the SCR from the day before was pumped to the steam generator. As a result, the SCR's water level would drop from its normal height of about 4.3 meters to about 0.6 meters. When the SCR was nearly empty, operators would then allow water to flow into it from the make-up tank, and the restarted steam generator was then used to heat the water in the make-up tank. But at this point in the startup process, the water in the make-up tank may not have been effectively heated to around 93 °C, so not all of the dissolved oxygen in the water was removed. Therefore, during startup, oxygenated water entered the SCR instead of the heated oxygen-free water used during normal operation; this presented a serious corrosion hazard within the steel SCR. Eventually, hot condensed steam returning from the corrugation process was available and operators opened a valve to allow it to flow into the SCR, reducing demand for water from the make-up tank. The SCR's design meant that water did not exit easily from its bottom head. Operators could achieve flow in the bottom head by opening a manual valve and draining water from the SCR - a procedure known as a blowdown. But between blowdowns, a small volume of oxygenated water would remain trapped in the bottom head, and over time the oxygenated water corroded the steel. The potential for corrosion was known; during its time operating the SCR, Loy-Lange experienced at least three leaks due to corrosion. In response to a 2012 leak, a repair company removed most of the bottom head. The repair company patched the hole with new steel, but left the remainder of the bottom head in place (Figure 1). However, this original ring of steel in the bottom head was also thinned from corrosion; it continued to degrade and eventually started to leak in 2017. The Friday before the incident, operators noticed a leak appearing to come from underneath the SCR. A welding company was due to assess the SCR, but was unavailable until the following Monday. Loy-Lange continued operating the leaking pressure vessel throughout the remainder of Friday, and shut down the steam generation system as normal that evening. The following Monday, an operator began the regular startup process around 6 a.m. At approximately 7:20 a.m., the SCR's bottom head catastrophically failed. The water within, now suddenly exposed to atmospheric pressure, flashed into steam, greatly expanding in volume. The result was a boiling liquid expanding vapour explosion (BLEVE). The explosion launched the SCR from Loy-Lange's building and into the air. It travelled about 159 meters, crashing through the roof of the nearby Faultless Healthcare Linen company. One Loy-Lange operator and three Faultless Healthcare Linen employees were fatally injured.

Contributing factors:

● There was a history of equipment failures at Loy-Lange caused by oxygen corrosion in the steam system. ● The SCR's bottom head repair in 2012 left a corroded steel ring in the vessel that continued to corrode for five years until it failed on the day of the incident. ● The pressure vessel never underwent an annual regulatory inspection because Loy-Lange failed to register it with the relevant local regulatory authority. ● When addressing the risks associated with corrosion in its steam system, Loy-Lange did not employ sound safety management principles like mechanical integrity and incident investigation.

Some lessons learned:

The importance of having a safety management system that is effective enough to recognise and, thereafter, address corrosion as a potentially catastrophic failure mode for pressure vessels.

APRIL

2024

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	2	3 2017: Steam BLEVE, Loy-Lange Box Co.	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

MAY – KURARAY AMERICA, INC.

Figure 1: A computer-generated image depicting the horizontal release of ethylene vapour from EVAL Reactor 2's emergency pressure relief system

Figure 2: The welding machine on the back of the pickup truck, post-incident

Incident type: Ethylene release and fire

Time, day, date: 10:28 a.m., Saturday, 19 May 2018

Location: Pasadena, Texas, U.S.

Industrial sector: Polymer production

Substance(s) involved: Ethylene

Number killed: 0 **Number injured:** 23

Organisation: Kuraray America, Inc.

Description:

Kuraray America, Inc. manufactures EVAL, a copolymer made from ethylene and vinyl alcohol, which is used in food packaging and storage containers. Leading up to the incident, operations personnel were taking steps to bring one of four reactors (EVAL Reactor 2) back online following a weeks-long, scheduled, plant-wide shutdown for maintenance and equipment upgrades. All four reactors looked similar but EVAL Reactor 2 had a lower maximum design pressure (740 psi) than the other three (1,150 psi). EVAL Reactor 2 already contained liquid methanol and ethylene vapour as operators began incrementally raising the reactor's pressure by adding more ethylene vapour. This was done to reach the target pressure for reaction start up, while also checking for leaks. Meanwhile, chilled liquid (from a newly commissioned refrigeration system) was unnecessarily circulating through the reactor's heat exchanger. After 11:20 p.m. on the night before the incident, the combination of reactor pressure and the low temperature from the chilled liquid caused ethylene vapour to condense in the reactor. This caused the reactor temperature to decrease. Around 7 a.m. on the morning of the incident, a supervisor noticed the reactor's low temperature and instructed operators to stop circulating the chilled liquid through the heat exchanger and to periodically added steam to the reactor's water-filled jacket. As the reactor temperature increased with each injection of steam to the jacket, some liquid ethylene inside the reactor vapourised, thus raising the reactor pressure. By about 8:45 a.m., the reactor's pressure had reached the operating target of nearly 600 psi but was still increasing. Around 9 a.m., the pressure reached 640 psi and the high-pressure alarm went off. A board operator responded by periodically opening a pressure control valve (PCV) to send some of the vapour inside the reactor to a flare. However, being concerned about exceeding the flare's environmental emissions limits, he did not fully open the pressure control valve. He was also focused on other startup activities and did not realise the valve was not open enough to bring the pressure under control. The pressure inside the reactor continued to rise. Despite this, shortly after 10 a.m., operators initiated the next step in the startup. At that time, a new board operator took over and noticed the reactor pressure was over 700 psi. But he did not recall the reactor's maximum design pressure of 740 psi and thought it could withstand a higher pressure, like the other three reactors. Similar to the first board operator, the new operator only partially opened the pressure control valve, not realising how dangerously close the pressure was to the reactor's limit. But the control valve was not open enough to relieve the reactor's pressure. At 10:28 a.m., the reactor's emergency pressure relief system activated. High-pressure ethylene vapour discharged from the reactor into the atmosphere. It was released horizontally toward an area where contractors were working, rather than vertically to a safe location (Figure 1). Soon after, a welding machine operating nearby on a pickup truck (Figure 2) likely ignited the vapour. A large fire erupted. 23 people were injured, many as they urgently tried to evacuate. The ethylene-fuelled fire stopped after about three minutes when the spring-loaded emergency relief valve closed as the reactor's pressure normalized. In total, around 1,000 kg of ethylene was ejected to the atmosphere.

Contributing factors:

● Kuraray's long-standing design of its emergency pressure-relief systems deviated from industry standards by discharging flammable ethylene vapour through horizontally-aimed piping into the air, near workers. ● The decision to design EVAL Reactor 2 with a lower maximum design pressure than the other three EVAL reactors. ● Operators were not provided with specific warnings about EVAL Reactor 2's lower maximum design pressure, nor were they trained on alarm set-points or how to respond to high-pressure scenarios. ● A high-high-pressure safety interlock, designed to automatically relieve excess ethylene pressure via the PCV to the flare, had been disabled earlier in the startup when troubleshooting an issue with a misaligned valve. ● An emergency open valve (EOV), designed to relieve excess ethylene pressure to the flare, was not used because written supervisor approval was needed to physically unlock and thereafter activate its control room switch. ● A 2015 Kuraray Process Hazard Analysis team recommended upgrading the EOV to allow it to be taken over by the control system and fully opened at pressures above the high-high-pressure alarm; however, this recommendation's implementation had been pushed out to 2019. ● The presence of non-essential workers, i.e., contractors, during startup and upset conditions. ● The control system that flooded the operators with about 160 alarms per hour on the morning of the incident. ● Kuraray's failure to identify weaknesses in its process safety management (PSM) systems during periodic self-audits.

Some lessons learned:

The importance of (i) abiding by recognized and generally accepted good engineering practices (RAGAGEP), and (ii) fully implementing the management system elements within PSM systems.

MAY

2024

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19 2018: Ethylene release and fire, Kuraray America, Inc.
20	21	22	23	24	25	26
27	28	29	30	31		

JUNE – THE GOODYEAR TIRE & RUBBER COMPANY

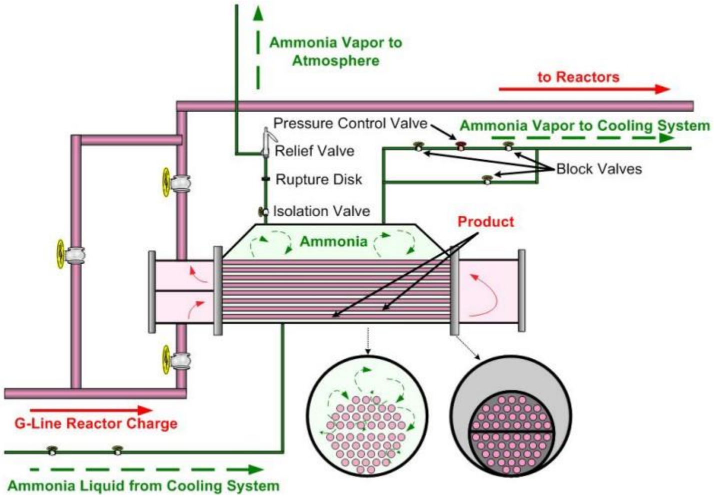

Figure 1: A diagram of the ammonia heat exchanger


Figure 2: The remains of the ammonia heat exchanger, post-incident

Incident type: Heat exchanger rupture and ammonia release

Time, day, date: about 07:30 a.m., Wednesday, 11 June 2008

Location: Houston, Texas, U.S.

Industrial sector: Tyre and rubber manufacturing

Substance(s) involved: Ammonia

Number killed: 1 **Number injured:** 6

Organisation: The Goodyear Tire and Rubber Company

Description:

At the time of the incident, the Goodyear Tire and Rubber Company's Houston facility produced synthetic rubber in several process lines. In the production area, a series of reactor vessels processed chemicals, including styrene and butadiene. Shell-and-tube heat exchangers in the reactor process line used pressurised anhydrous liquid ammonia to cool process chemicals en route to the reactors (Figure 1). As the ammonia absorbed heat from the process chemical flowing through tubes in the centre of the heat exchanger, the ammonia boiled to vapour in the heat exchanger shell. A pressure control valve in the ammonia vapour return line maintained the ammonia pressure at 150 psig in the heat exchanger. Ammonia vapour returned to the ammonia cooling system where it was pressurized and cooled, liquefying the ammonia for re-use in the cooling system. Process chemicals exiting the heat exchanger flowed to the reactors. Each heat exchanger was equipped with a rupture disk in series with a pressure relief valve (both set at 300 psig) to protect the heat exchanger from excessive pressure. The relief system was designed to vent ammonia vapour through the roof to atmosphere. The day before the incident, Goodyear operators closed an isolation valve on one of these heat exchangers between its shell (ammonia cooling side) and its pressure relief valve, ahead of maintenance work to replace the burst rupture disk under the relief valve. Maintenance workers replaced the rupture disk on that day; however, the closed isolation valve was not re-opened. On the morning of the incident, an operator closed a block valve isolating the ammonia pressure control valve from the heat exchanger. The operator then connected a steam line to the process line to clean the piping. The steam flowed through the heat exchanger tubes, heated the liquid ammonia in the exchanger shell, and increased the pressure in the shell. The isolation valve and block valve, both closed, prevented the increasing ammonia pressure from safely venting through either the ammonia pressure control valve or the rupture disk and relief valve. The pressure in the heat exchanger shell continued climbing until it violently ruptured at about 7:30 a.m. The catastrophic rupture released ammonia, exposing five nearby workers to the chemical; ammonia vapour irritates the eyes and respiratory system and makes breathing difficult. One additional worker was injured while exiting the area. Immediately after the rupture and resulting ammonia release, Goodyear evacuated the plant, and medical responders removed the six injured workers. Management declared the incident over later that morning, although debris blocked access to the area immediately surrounding the heat exchanger. Plant responders managed the clean-up while other areas of the facility resumed operations. Several hours later, after plant operations had resumed, a supervisor assessing damage in the immediate incident area discovered the body of a Goodyear employee located under debris in a dimly lit area. The employee had been fatally injured by flying debris while she walked through the heat exchanger area when it ruptured catastrophically.

Contributing factors:

● There was evidence of breakdowns in the work order and Lockout/Tagout programs used for equipment undergoing maintenance insofar as maintenance workers did not always obtain the necessary production operators' signatures before and after maintenance work, and the progress and status of maintenance work were not documented by operators. Goodyear was unable to produce a signed copy of the work order to replace the rupture disk, and information about the safety relief vent's isolation valve remaining closed and locked-out was limited to a handwritten note. ● A malfunction in the computerized electronic badge-in/badge-out system meant that all workers were not properly accounted for during the plant evacuation. As a result, Goodyear management believed all workers had safely evacuated the affected area. However, the fatally injured employee's absence had not been noted due to a gap in training and drills on worker headcounts among the supervisors and security employees who conducted the headcount; and since the fatally injured employee was a member of the emergency response team, her absence from the muster point was not considered unusual. ● Workers stated that plant-wide evacuation and shelter-in-place drills had not been conducted in the four years prior to the incident, and some employees had not been fully trained on the related procedures.

Some lessons learned:

The importance of (i) ensuring effective control over maintenance activities, and (ii) having an appropriate level of emergency response training and drills.

JUNE

2024

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
					1	2
3	4	5	6	7	8	9
10	11 2008: Heat exchange rupture & ammonia release, Goodyear	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

JULY – LYONDELLBASELL LA PORTE COMPLEX

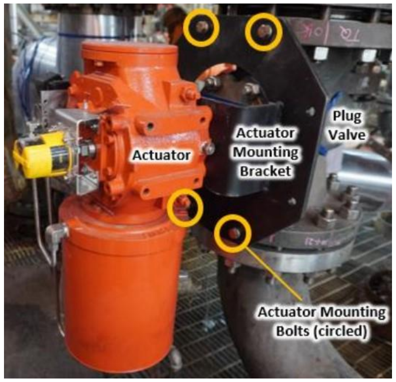

Figure 2: The incident valve with the four actuator mounting bolts circled

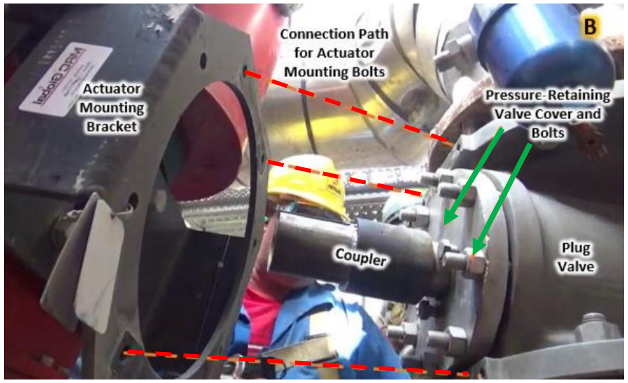

Figure 3: Exemplar pressure-retaining valve cover and bolts

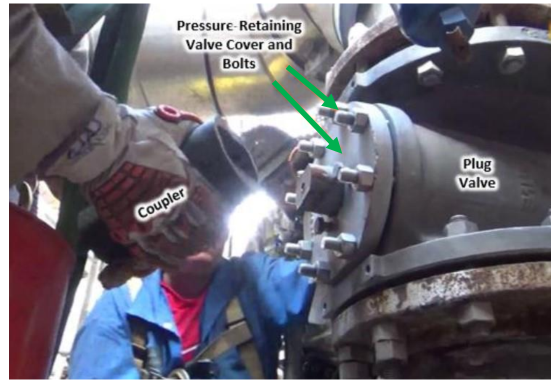

Figure 4: An exemplar valve with its coupler removed

Incident type: Release of acetic acid and methyl iodide mixture

Time, day, date: after 6:45 p.m., Tuesday, 27 July 2021

Location: La Porte, Texas, U.S.

Industrial sector: Chemicals

Substance(s) involved: Acetic acid and methyl iodide

Number killed: 2
Number injured: 1

Organisation: LyondellBasell

Description:

LyondellBasell's La Porte complex is the world's third largest producer of acetic acid. Prior to the incident, the company decided to avail of an acetic acid unit shutdown to remove and repair a portion of leaking methanol piping located beneath and attached to the unit's acetic acid reactor (Figure 1). To isolate the piping, which contained methanol and acetic acid, company personnel chose to use the valve located between the leaking piping and the acetic acid reactor – a pneumatically actuated eight-inch plug valve – as an isolation device. To do so, the personnel decided they would remove the actuator connected to the plug valve (including its coupler) and install a 'pipe tee' over the valve stem. The pipe tee would then be physically locked in place using a chain and padlock arrangement, in compliance with the company's energy isolation procedure. LyondellBasell directed its third-party contractor, Turn2, to perform the actuator removal task. Turn2 confirmed that it had a night crew that was qualified and available to remove the actuator. LyondellBasell issued the work permit for the task, and a Turn2 foreman and two Turn2 pipefitters began work to remove the plug valve actuator. At the time, the acetic acid reactor contained about 75,000 kg of a 61.7% acetic acid mixture (which included methyl iodide) at 130 psi and 114 °C. The Turn2 workers removed the insulation material from around the plug valve, and then began to remove the bracket mounting bolts located on the exterior of the actuator mounting bracket (Figure 2). But before removing all of the bracket mounting bolts, the Turn2 workers determined that they also needed to remove the valve cover nuts shown in Figure 3. They did not know that removing these nuts was not necessary to remove the actuator; nor did they know that the nuts were pressure-retaining, holding the valve cover in place. The Turn2 workers removed all of the pressure-retaining nuts, not recognising that they had compromised the pressure integrity of the valve. They then finished removing all of the bracket mounting bolts shown in Figure 2. Once done, they removed the actuator and its mounting bracket from the plug valve. Once the actuator was removed, the Turn2 workers noticed that the coupler was still seated in its designated slot on the top of the valve stem (Figures 3 and 4). They attempted to slide the coupler from the valve stem, but it was too tight to remove by hand, so they used a crow bar to remove it. While doing so, the combination of forces from the crow bar and the process fluid pressure inside the plug valve caused the unfastened valve cover and the plug to eject from the plug valve body, and acetic acid rapidly released from the open plug valve. The entire contents of the acetic acid reactor, about 75,000 kg of acetic acid mixture at 114 °C, emptied from the reactor via the open, unplugged valve. The releasing acetic acid mixture sprayed all three Turn2 workers. The Turn2 foreman and one pipefitter were fatally injured from chemical burns and inhalation of the released acetic acid and methyl iodide, and the second pipefitter was seriously injured from acid exposure.

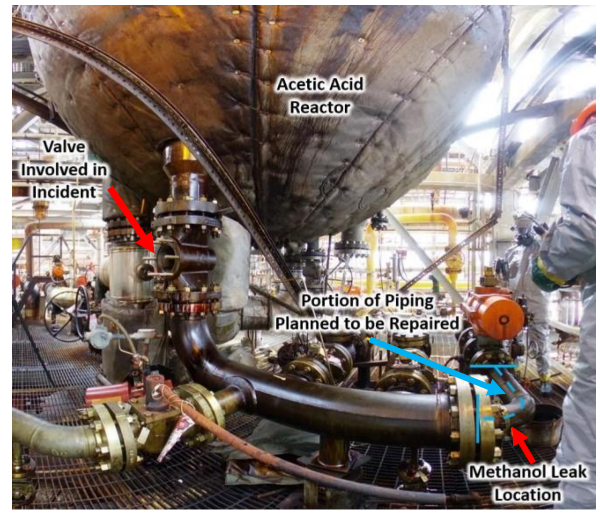

Figure 1: The acetic acid reactor, post-incident, showing the methanol leak location, the portion of the piping for repair, and the location of the plug valve involved in the incident

Contributing factors:

● Previous similar incidents have led to plug valves coming apart, releasing hazardous materials, and causing serious injuries and/or fatalities, e.g., Puebla, Mexico, 1977; US Amoco, 1980; AkzoNobel Polymer Chemicals, La Porte, 2013; ExxonMobil Baton Rouge Refinery, 2016. ● LyondellBasell had no procedure detailing how to remove the actuator, and the company failed to oversee adequately the work being done. ● Neither LyondellBasell nor Turn2 trained the Turn2 work crew on how to remove the actuator. ● The plug valve's design did not include any markings or warning labels to alert anyone attempting to remove the actuator that the valve cover's nuts and bolts were pressure-retaining components.

Some lessons learned:

In light of the incidents at LyondellBasell and elsewhere, the importance of (i) thoroughly risk assessing all plug valve actuator removal work, and (ii) having the pressure-retaining components on plug valves clearly marked (e.g., with colour-coding and/or warning labels/signs) – if not done by the valve's designer, then done by the valve owner.

JULY

2024

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27 2021: Acetic acid & methyl iodide release, LyondellBasell	28
29	30	31				

AUGUST – BIO-LAB, INC.

Figure 1: TCCA bags stacked three-pallets high as a precaution from floodwater

Figure 2: TCCA decomposition gases, including toxic chlorine, released from Bio-Lab Plant 4 after the building was severely damaged during Hurricane Laura and rainwater contacted the stored TCCA

Incident type: Toxic gas release and fire

Time, day, date: after 8:30 a.m., Thursday, 27 August 2020

Location: Westlake, Louisiana, U.S.

Industrial sector: Chemicals manufacturing and supply

Substance(s) involved: Trichloro-isocyanuric acid (TCCA)

Number killed: 0 **Number injured:** 0

Organisation: Bio-Lab, Inc.

Description:

Bio-Lab, Inc. manufactures and supplies sanitising chemicals, including trichloroisocyanuric acid, TCCA. TCCA (a white solid) is a chlorinating agent often used as a sanitiser to kill algae and bacteria in large volumes of water, mostly swimming pools and hot tubs. In large bodies of water, TCCA is soluble and reacts in a controlled manner, producing hypochlorous acid (an active form of chlorine in water) to sanitise contaminants. However, when TCCA is either wetted or moistened by a small amount of water yet fails to dissolve, it can undergo a chemical reaction capable of liberating enough heat to decompose the chemical, thus producing toxic chlorine gas (and possibly explosive nitrogen trichloride). Three days before the incident, Bio-Lab activated its Hurricane Plan to prepare for the forecasted imminent arrival of Hurricane Laura. The plan included obtaining trucks to transport chemicals, including TCCA, from the facility before Hurricane Laura made landfall. Bio-Lab successfully transported about 375,000 kg of TCCA from the facility to another Bio-Lab facility in Georgia. However, two additional scheduled trucks never arrived, leaving over 450,000 kg of TCCA on-site as the hurricane approached. To protect the remaining TCCA and other products from potential floodwater, employees raised the materials 38–53 cm above floor level by placing them on triple-stacked pallets (Figure 1). The day before the incident, all employees evacuated the facility. The morning of the incident, winds from Hurricane Laura caused parts of the roof to be torn from the facility's Plant 4 building, which housed an estimated 32,000–45,000 kg of TCCA. By 8:30 a.m., rainwater from Hurricane Laura had contacted the TCCA. This initiated the chemical reaction that led to TCCA's decomposition, releasing toxic chlorine gas and causing a fire. The decomposition and fire created a massive plume of toxic gas and smoke that travelled over the local community (Figure 2), prompting the local authority to issue a shelter-in-place order. Bio-Lab's fire protection system included using two electric and two diesel-powered firewater pumps to pressurise water for use via hose stations, fire hydrants, and fire monitors. In addition, Bio-Lab had rented a back-up generator to operate the two electric firewater pumps in case Hurricane Laura caused a power outage. The anticipated power outage duly occurred, but Bio-Lab personnel did not have the rental generator's operating manual and were unable to activate the generator in a timely enough manner. Also, one of the diesel-powered firewater pumps was non-functional; according to a Bio-Lab manager after the incident, the pump "didn't work and it hadn't for some years". The remaining diesel-powered firewater pump could not achieve adequate pressure to apply the volume of water needed to saturate the decomposing TCCA enough to reduce and/or control the decomposition reaction. As such, the incident could not be controlled until contracted third-party emergency responders arrived, set up their equipment, and successfully flowed sufficient water to saturate the decomposing TCCA. Later that same day and into the following day, incident responders successfully dealt with another TCCA decomposition event in the Finished Goods Warehouse, which Hurricane Laura's wind had also severely damaged. After the incident, Bio-Lab invested approximately $250 million to reconstruct the damaged facility, and resumed production operations around March 2023. There were no reported injuries from the incident.

Contributing factors:

● Bio-Lab did not implement the revised industry guidance for extreme weather preparation published after the 2017 Arkema incident (Texas), when extensive flooding from Category 4 Hurricane Harvey caused an organic peroxide decomposition and fire at the Arkema facility. As a result, Bio-Lab was unprepared for the winds produced by Category 4 Hurricane Laura. ● Bio-Lab's building roofs were not built to current wind design standards. ● Bio-Lab chose not to implement a 2010 Process Hazard Analysis recommendation to "consider evaluating warehouse roof structure for hurricane conditions; verify warehouse is built to withstand high winds." ● Bio-Lab's fire protection system was inadequate and largely non-functional, causing a lengthy delay of around 5½ hours before productive emergency response operations began. During this delay, TCCA continued to decompose, releasing large clouds of decomposition products, including toxic chlorine gas. ● The Bio-Lab facility is 'grandfathered' to the state-adopted codes and standards at the time of its construction (1979), meaning it was not required to have automatic extinguishing systems. ● TCCA can decompose and release toxic chlorine gas, yet it is not regulated under OSHA's Process Safety Management (PSM) Standard or the U.S. EPA's Risk Management Program Rule.

Some lessons learned:

The importance of (a) evaluating the hazards to processes of extreme weather and implementing safeguards to protect from those hazards, (b) having fully operational emergency response equipment that can function when needed during emergencies, and (c) applying a PSM program for substances with known reactive hazards even when not a regulatory requirement.

AUGUST

2024

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27 2020: Toxic gas release & fire, Bio-Lab, Inc.	28	29	30	31	

SEPTEMBER – EVERGREEN PACKAGING

Figure 1: A typical bleach reaction stage at Evergreen showing the two connected process vessels called the upflow tower and the downflow tower

Figure 2: Electric heat gun recovered from the scene of the incident

Incident type: A hot work initiated confined space fire

Time, day, date: 5:15 a.m., Monday, 21 September 2020

Location: Canton, North Carolina, U.S.

Industrial sector: Paper mill

Substance(s) involved: Epoxy vinyl ester resin

Number killed: 2 **Number injured:** 0

Organisation: Evergreen Packaging

Description:

The paper mill operated by Evergreen Packaging (Evergreen) was undergoing a planned shutdown, and associated maintenance and capital project work were ongoing throughout the facility. In one of Evergreen's pulp bleaching units, two contract companies (Universal Blastco, or "Blastco," and Rimcor) were independently performing simultaneous maintenance work inside two process vessels called an "upflow tower" (35 m high, 2.6 m diameter) and a "downflow tower" (33.5 m high, 6.7 m diameter). A crossover line, as shown in Figure 1, connected the vessels. The pulp bleaching process is corrosive by design, and the upflow and downflow towers were constructed of corrosion-resistant materials. However, due to the corrosive nature of the process, the upflow and downflow towers required periodic maintenance to their inside surfaces. The upflow tower was constructed of fibre-reinforced plastic, and Blastco's repair work in the upflow tower required applying flammable epoxy vinyl ester resin and sheets of fiberglass to the inside walls of the vessel. However, cool ambient temperatures in the area on the night of the incident caused the resin to harden slower than the Blastco workers anticipated, resulting in the newly applied resin and fiberglass sliding down the inside walls of the vessel. The Blastco workers attempted several means of addressing the issue but were ultimately unsuccessful. Two Blastco workers resorted to using a portable, electric heat gun (Figure 2) to warm the resin, enabling it to harden faster. The Blastco crew did not warn of or otherwise communicate to Evergreen or Rimcor its use of the heat gun, which was an ignition source in the presence of the flammable resin. At approximately 5:15 a.m., a fire started inside the upflow tower when the heat gun fell into a five-gallon bucket containing flammable resin. The Blastco workers inside the upflow tower successfully escaped the fire and evacuated the vessel. However, smoke and flames quickly spread via the crossover line to the connected downflow tower, fatally injuring two Rimcor workers there.

Contributing factors:

● Blastco's failure to recognise the use of the heat gun as hot work and to inform Evergreen and Rimor accordingly. ● The cool weather on the night of the incident. Blastco could have delayed lamination work to day shifts when temperatures in the area were 15 – 20 °C. ● The ineffective nature of the pre-job planning, which overlooked the potential for poor performance of the resin in cold temperatures and how to overcome this safely. ● Blastco's failure to adequately evaluate or control the hazards associated with introducing a flammable liquid into a permit-required confined space. ● The failure to recognise that the vessels and crossover line constituted a single confined space, which would have compelled Blastco and Rimcor to coordinate their simultaneous jobs. ● Blastco's failure to activate properly Evergreen's emergency services when the fire started. ● The combustible nature of the upflow tower and crossover line's materials of construction which enabled the fire to spread quickly.

Some lessons learned:

● Hot work encompasses <u>any</u> method of work that can ignite a fire, not just spark- or flame-producing work methods. ● The particular need when undertaking work in confined spaces to evaluate the hazards that can arise directly from the work activities themselves. ● The involvement of emergency response personnel in the planning and coordination of confined space work in which flammable materials are used, in particular confined spaces made from combustible materials of construction; and the stationing of trained and equipped emergency response personnel directly outside a confined space in which flammable materials are used. ● The need to assess, oversee and coordinate adequately simultaneous jobs being undertaken (same time and location), in particular those of a non-routine nature.

SEPTEMBER

2024

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21 <u>2020:</u> Hot work initiated confined space fire, Evergreen Packaging	22
23	24	25	26	27	28	29
30						

OCTOBER – AGHORN OPERATING INC.

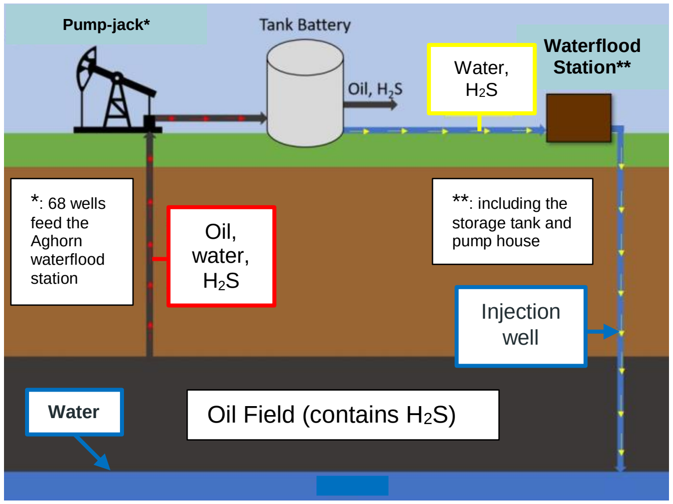

Figure 1: An illustration of the Aghorn waterflooding process

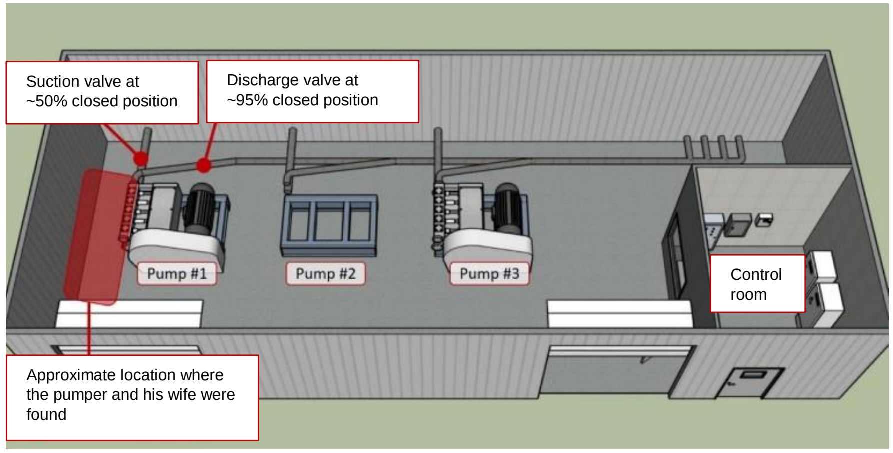

Figure 2: An illustration of the pump house at the waterflood station, showing the control room, Pump #1's suction and discharge valve positions, and the approximate location where the pumper and his wife were found

Incident type: Toxic gas release

Time, day, date: the evening of Saturday, 26 October 2019

Location: Odessa, Texas, U.S.

Industrial sector: Oil extraction

Substance(s) involved: Hydrogen sulfide (H_2S)

Number killed: 2
Number injured: 0

Organisation: Aghorn Operating Inc.

Description:

Aghorn Operating Inc.'s oil extraction process starts at an oil well where pump-jacks lift oil from underground reservoirs (Figure 1). The extracted oil contains hydrogen sulphide (H_2S, a toxic gas) and some water. To remove the water, the extracted oil is fed to a tank battery where, on settling, the water separates from the oil. The oil is then transported for further processing, while the water is pumped through pipelines to the waterflood station. It is now called 'produced water' because it can contain residual oil and other contaminants, including H_2S gas. At the waterflood station, the produced water flows into a large storage tank. From there it enters the pump house. Here, pumps pressurise the produced water and inject it back into the oil field through injection wells. The injected water increases the reservoir pressure and displaces the oil, thus allowing a larger quantity of oil to be extracted. At the time of the incident, the pump house contained two pumps and a control room. Typically, the station is not continuously occupied. Instead, an Aghorn employee, called a 'pumper', visits twice per day to record meter readings and inspect equipment. When an equipment problem occurs in their absence, an alarm system triggers an automated phone call to the pumper. The pumper should then acknowledge the alarm and go to the station to investigate. The station was also equipped with a H_2S detection and alarm system that would trigger a separate automated phone call to the pumper if it detected dangerous levels of the toxic gas, and would also illuminate a rotating red beacon light on top of the pump house. On the evening of the incident, the phone system called an Aghorn pumper alerting him to a pump malfunction of some kind. The pumper drove to the waterflood station. The H_2S beacon light was not illuminated when the pumper arrived at the waterflood station nor at any time for the rest of the night. The pumper parked near the waterflood station leaving his personal H_2S monitor inside his truck. He went into the control room where the control system indicated an oil level alarm for Pump #1. Pump #1, which could automatically start when enough water was available to pump to the injection wells, was still connected to its power source. The pumper did not de-energize Pump #1 before approaching it. He closed Pump #1's discharge valve and partially closed its intake valve (Figure 2). While the pumper was near the pump, he was overcome and fatally injured by toxic H_2S gas. The post-incident investigation found that a plunger on the pump had shattered; this allowed water containing H_2S to escape from the pump into the pump house where the pumper was working. The investigation was unable to determine whether the pump failure and water release occurred before the pumper arrived at the facility, or if the pump automatically turned on while the pumper was closing valves. After several hours when the pumper did not return home, his wife drove with their two children (aged 6 and 9 years) to the facility to check on him. En route, she phoned an off-duty pumper (on vacation at that time) who advised her of her husband's likely whereabouts at the facility. She entered the waterflood station and soon found him on the floor in the pump house. She then was also overcome and fatally injured by the toxic H_2S gas. The off-duty pumper lost phone contact with her and initiated an emergency response. A short time later, emergency responders approached the pump house and detected a very strong smell of H_2S. This required them to set up their command post outside the front gate of the facility and wear self-contained breathing apparatus. They found the pumper and his wife deceased inside the pump house and water spilling from Pump #1. The responders rescued the two children who were inside their mother's car, still alive. Working with Aghorn employees, the responders were able to stop the water release the following morning.

Contributing factors:

● Aghorn's failure to enforce operator use of personal H_2S monitors when in the vicinity of equipment or facilities with the potential to release H_2S. ● Aghorn's failure to develop, train on, and enforce Lockout/Tagout procedures that led to the pumper performing work on Pump #1 while it was still energized. ● The physical and operational design of Aghorn's facility, which did not allow for adequate ventilation of the toxic H_2S gas inside the pump house. ● Aghorn's deficient safety management program. ● Aghorn's failure to maintain and properly configure the site's H_2S detection and alarm system – the post-incident investigation found that this critical system was not functional on the night of the incident. ● Aghorn's poor site security that allowed the pumper's wife to gain access to the facility.

Some lessons learned:

At facilities handling toxic gases, the importance of (a) training in and enforcement of the use of personal toxic gas monitors and Lockout/Tagout procedures, (b) adequately designed, maintained, tested and functioning toxic gas detection and alarm systems, and building ventilation systems, and (c) effective site security to prevent non-employees from accessing hazardous areas.

OCTOBER

2024

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26 2019: Toxic gas release, Aghorn Operating Inc.	27
28	29	30	31			

NOVEMBER – WACKER POLYSILICON NORTH AMERICA LLC

Figure 1: The start of the HCl release

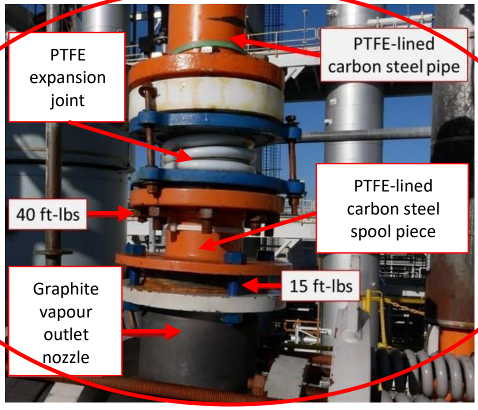

Figure 2: HCl vapour outlet piping on the heat exchanger's graphite vapour outlet nozzle

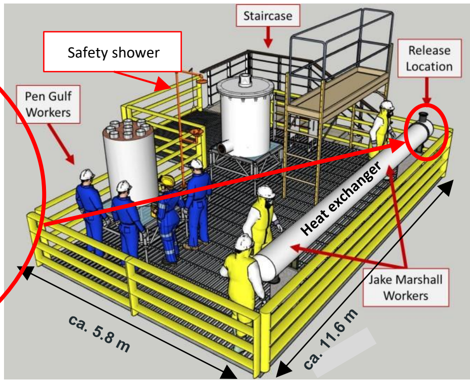

Figure 3: A general spatial representation (not to scale) of the location of the four Pen Gulf and three Jake Marshall workers and the equipment

Incident type: Hydrogen chloride release

Time, day, date: 10:04 a.m., Friday, 13 November 2020

Location: Charleston, Tennessee, U.S.

Industrial sector: Silicones, Polysilicon

Substance(s) involved: Hydrogen chloride

Number killed: 1 **Number injured:** 2

Organisation: Wacker Polysilicon North America LLC

Description:

Wacker Polysilicon North America LLC manufactures silicones, polycrystalline silicon (polysilicon) and pyrogenic silica. At the time of the incident, Wacker was nearing the end of a two-week shutdown of its hydrogen chloride (HCl) regeneration unit, which included replacing segments of a graphite heat exchanger located on a fifth-floor platform (Figure 1). The night before the incident, Wacker operators re-introduced acid into the regeneration unit and brought the unit to operating temperatures and pressures. By early the next morning, the unit had reached normal operating conditions. Later that morning, Wacker issued a permit to Jake Marshall, LLC (a piping contractor) to check the torque on all the bolts on the graphite heat exchanger's vapour outlet piping. The manufacturer of this outlet piping recommended a torque value of 40 foot-pounds (ft-lbs) for bolts on the PTFE-to-PTFE connections (Figure 2) and 15 ft-lbs for bolts connected to the graphite heat exchanger nozzle (Figure 2, blue-coloured bolts). The Wacker permit authoriser and the Jake Marshall foreman toured the work area, and reviewed the permit and equipment to be torqued. Before leaving the area, the Wacker permit authoriser provided the Jake Marshall foreman with an information packet containing the piping installation and operation manual, which included the manufacturer-recommended torque values for PTFE-to-PTFE piping connections, but not for graphite connections like those on the graphite heat exchanger nozzle. Thereafter, the Jake Marshall foreman reviewed the work area with three of his workers, provided verbal instructions, and left. The workers then returned to ground level to prepare for the work. Meanwhile, four workers from Pen Gulf Inc. (an insulation contractor) accessed the fifth floor and began preparing for insulation activities. Unaware of the planned permitted torquing work, the Pen Gulf workers were wearing the minimum personal protective equipment (PPE) required by Wacker: flame-resistant clothing, steel-toe safety boots, and hard hats; they also possessed escape respirators, safety harnesses, safety glasses and gloves. The three Jake Marshall workers returned to the fifth floor wearing full-body chemical-resistant suits, rubber boots and gloves, and full-face respirators with acid-gas cartridges as required by a Jake Marshall policy covering work done on piping containing hazardous chemicals. The Jake Marshall lead-worker provided one of his colleagues with a torque wrench set to 40 ft-lbs. When the Pen Gulf workers saw the Jake Marshall workers wearing chemical protective clothing and respirators, they asked whether they (the Pen Gulf workers) were allowed to be in the area. A Jake Marshall worker said they could stay since the Jake Marshall workers were not working with chemicals (Figure 3). A Jake Marshall worker used the torque wrench set at 40 ft-lbs to check the torque on the 15 ft-lbs blue-coloured bolts. The excess torque applied to these bolts caused the graphite heat exchanger to crack, releasing gaseous HCl. A white gaseous HCl cloud filled the area within 15 seconds (Figure 1), obscuring the platform workers' view of their surroundings. When the Jake Marshall torque worker attempted to evade the release, he snagged his chemical suit, which tore, and bumped into equipment, which knocked off his respirator. Due to the breach of his PPE and location of the release, the torque worker was unable to access the platform's sole exit staircase. He moved to the opposite side of the platform towards the rest of the workers (Figure 3). Jake Marshall workers placed him in a safety shower to protect him from the release. Three of the four Pen Gulf workers put on their escape respirators. Realising they would have to walk through the HCl release to access the platform's only exit staircase, they began climbing down piping on the side of the structure, ca. 21.3 m above the ground. While climbing down, all three workers fell to the ground. One worker was fatally injured from the fall, and two sustained serious injuries. The remaining Pen Gulf worker received help putting on her escape respirator from a Jake Marshall worker, who, wearing chemical-resistant PPE, also attempted to shield her from the release. The release continued for about three minutes, until all gaseous HCl had escaped from the system. After the release stopped, the three Jake Marshall workers and one Pen Gulf worker evacuated via the staircase and reached the ground.

Contributing factors:

● The absence of guidance on the torqueing requirement for the bolts on the graphite heat exchanger nozzle. ● Wacker did not treat the torqueing work on the live HCl-containing heat exchanger as a line break nor as an activity that required isolation of hazardous energy since it did not involve the intentional opening of a line; thus no risk assessment of the work was performed. ● Wacker did not assess the risks associated with two independent parties engaged in simultaneous work tasks (same time and location). ● Three months before the incident, a Process Hazard Analysis (PHA) team recommended installing a ladder with an enclosed cage as a secondary means of emergency escape from the fifth-floor platform, but this was not done by the date of the incident.

Some lessons learned:

During maintenance work, the importance of (a) clear, comprehensive written procedures, (b) the control of hazardous energy, and (c) considering the impact of simultaneous operations. Also, the importance of closing out PHA recommended action items in an appropriate timely manner.

NOVEMBER 2024

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
				1	2	3
4	5	6	7	8	9	10
11	12	13 **2020:** Hydrogen chloride release, Wacker Poly-silicon N. America	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

DECEMBER – OPTIMA BELLE LLC

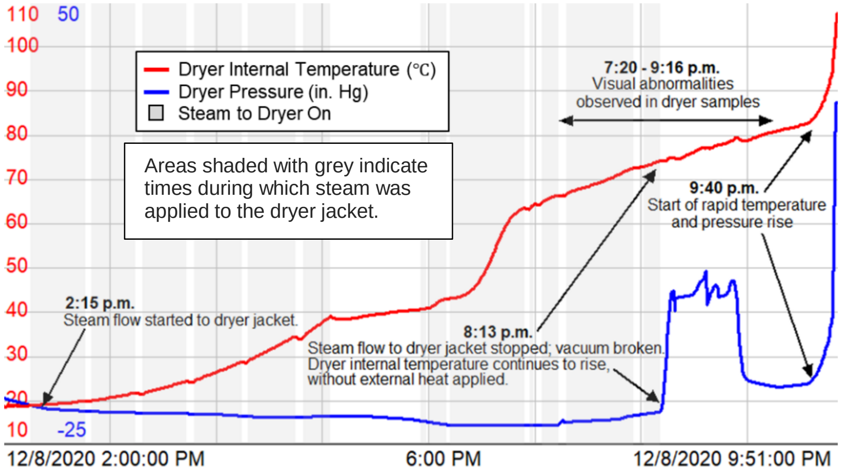

Figure 1: Optima Belle's rotary dryer operating conditions on 08 December 2020

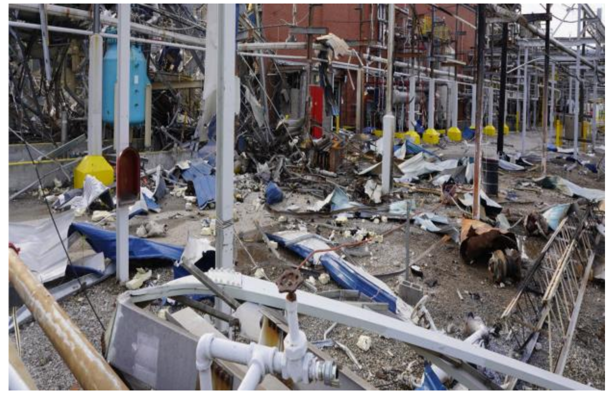

Figure 2: The aftermath of the explosion at Optima Belle LLC

Incident type: Chemical decomposition reaction and explosion

Time, day, date: approximately 10:00 p.m., Tuesday, 08 December 2020

Location: Belle, West Virginia, U.S.

Industrial sector: Contract (toll) chemicals manufacturing

Substance(s) involved: Sodium dichloroisocyanurate dihydrate

Number killed: 1 **Number injured:** 1

Organisation: Optima Belle LLC

Description:

Optima Belle LLC is a contract (toll) chemicals manufacturer. The company was contracted by Clearon Corporation (Clearon) to make anhydrous sodium dichloroisocyanurate (trade named CDB-63®) by dehydrating (removing the water from) batches of sodium dichloroisocyanurate dihydrate, a white solid, trade named CDB-56®. Both materials are used as sanitisers and disinfectants for household and industrial applications. The dehydration process was being performed in a steam jacket heated, pressure-rated, Hastelloy® rotary double-cone dryer operating under vacuum conditions. No laboratory or pilot-scale trials were performed before committing the first of batch of ca. 4,000 kg of CDB-56® to the dryer. While dehydrating this first batch, dark specks were observed in the samples of white material that were periodically taken from the dryer to test for moisture and visual appearance. Even though the dryer was corrosion-resistant, its stainless steel valves were not. Corrosion of some of these stainless steel valves was suspected of causing the dark specks, and the dryer's rotation was stopped while employees inspected two of the valves. Contrary to the "Emergency Shutdown Procedure", cold water was not applied to the dryer's jacket nor was a vacuum applied while the dryer's rotation was stopped. The dryer's internal temperature continued slowly increasing (Figure 1) even though steam was not being supplied to the jacket. At 8:37 p.m., a vacuum was pulled again on the dryer but the dryer's rotation was not restarted, and the dryer's recorded internal temperature was 77 °C. By approximately 9.30 p.m., following some further processing and a telephone consultation with Clearon, it was agreed to stop the batch operation for the night and continue troubleshooting the dark specks in the morning. Around the same time, a nitrogen blowdown of the dryer's jacket began. Following the telephone call, an operator left the control room to manually open valves to stop the nitrogen blowdown to the jacket and apply cooling water. At this time, the dryer's recorded internal temperature was slightly above 80 °C. At approximately 9:40 p.m., before employees could resume rotating the dryer, the dryer temperature and pressure increased sharply as the CDB-56® decomposed, releasing gases that increased the dryer's internal pressure above its design pressure. The last recordings in the historian data indicate the dryer temperature reached 108 °C and the dryer pressure reached 33 inches of Hg (in. Hg) before the dryer catastrophically exploded. The cause of the rotary dryer's over-pressurization and its ultimate explosion was a self-accelerating decomposition of heated CDB-56® inside the dryer unit. Metal debris and dryer fragments propelled off-site and within the facility, striking a methanol pipe that subsequently caught fire. Toxic chlorine gas was also released. The explosion prompted local authorities to issue a shelter-in-place order for the region within ca. 3 km of the Optima Belle site for over four hours. The facility experienced property damage estimated at $33.1 million, and debris was found almost 0.8 km from the site. The control room operator who was working to apply cooling water to the dryer's jacket was fatally injured. He was found alive, trapped under debris but died later at the hospital due to a sodium dichloroisocyanurate intoxication from the fumes he had inhaled. Two other operators were evaluated for respiratory irritation, and one local resident reported a minor leg injury.

Contributing factors:

● Optima Belle did not adequately understand the potential for, analyze the hazards of, or detect and mitigate the self-accelerating thermal decomposition reaction. ● Clearon failed to transmit sufficient process safety information to Optima Belle. Post-incident testing found that CDB-56® begins a runaway exotherm at approximately 81 °C when heated in a closed container. But the CDB-56® technical data and safety data sheet (SDS) provided by Clearon to Optima Belle listed a CDB-56® decomposition temperature of 240 °C to 250 °C. ● Clearon and Optima Belle had ineffective process safety management systems, poor knowledge management, and failed to follow existing industry guidance for toll manufacturing. ● Though a reactive chemical, CDB-56® is not covered under OSHA's Process Safety Management Standard or the U.S. EPA's Risk Management Program Rule. Optima Belle was therefore not required to implement risk mitigation and management systems that could have prevented this incident.

Some lessons learned:

● Outsourcing the production or processing of a hazardous material does not outsource the responsibility for process safety. ● Conduct appropriate laboratory and pilot-scale trials before committing batches to plant-scale processing. ● Do not take SDS data at face value when processing reactive chemicals at elevated temperatures & pressures; when in doubt, many tools exist to identify if a chemical has thermal or reactive hazards that could lead to a process safety incident. ● Companies' systems for managing and sharing knowledge should ensure that important, and sometimes archived, process safety information can be readily retrieved when needed. ● The importance of applying a process safety management program even when not a regulatory requirement.

DECEMBER

2024

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
						1
2	3	4	5	6	7	8 2020: Chemical decom-position & explosion, Optima Belle LLC
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					