



U.S. Chemical Safety and
Hazard Investigation Board

Fatal Release of Acetic Acid and Methyl Iodide Mixture at LyondellBasell La Porte Complex

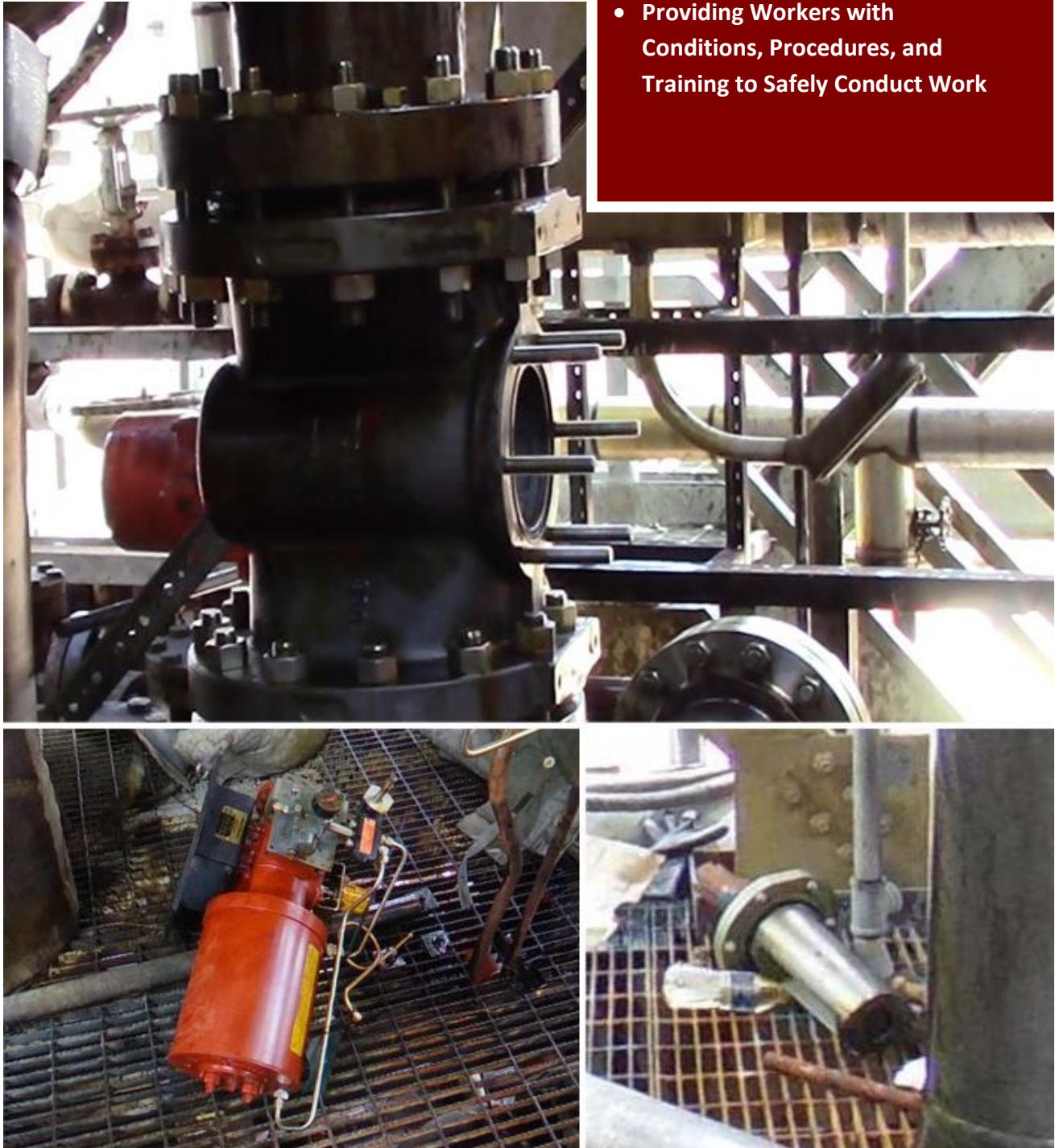
La Porte, Texas | Incident Date: July 27, 2021 | No. 2021-05-I-TX

Investigation Report

Published: May 25, 2023

SAFETY ISSUES:

- Valve Design to Prevent Human Error
- Providing Workers with Conditions, Procedures, and Training to Safely Conduct Work





U.S. Chemical Safety and Hazard Investigation Board

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to protect communities, workers, and the environment.***

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U.S. Chemical Safety and Hazard Investigation Board

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The July 27, 2021 chemical release at the LyondellBasell
La Porte Complex fatally injured two people:

Dusty Day and Shawn Kuhleman

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Abbreviations

| | |
|--------------|---|
| API | American Petroleum Institute |
| ASME | American Society of Mechanical Engineers |
| BEM | butyl ethyl magnesium |
| CCPS | Center for Chemical Process Safety |
| CSB | U.S. Chemical Safety and Hazard Investigation Board |
| EPA | Environmental Protection Agency |
| NIOSH | National Institute for Occupational Safety and Health |
| OSHA | Occupational Safety and Health Administration |
| PSM | Process Safety Management |
| RMP | Risk Management Program |
| SDS | safety data sheet |
| VMA | Valve Manufacturers Association of America |

EXECUTIVE SUMMARY

On July 27, 2021, three contract workers employed by Turn2 Specialty Companies (Turn2) at the LyondellBasell La Porte Complex in La Porte, Texas, were working to remove an actuator from a plug valve in the site's acetic acid unit.^a The actuator was being removed so that the valve could be used as an energy isolation device for a pipe spool repair job. The workers, however, inadvertently removed pressure-retaining components of the valve while attempting to remove the actuator, and the pressure ejected the plug from the valve body. Approximately 164,000 pounds of acetic acid mixture erupted from the open equipment, and all three contract workers were sprayed with the releasing acetic acid mixture. Two of the workers were fatally injured by chemical burns and toxic inhalation injuries from exposure to acetic acid and methyl iodide. Additionally, the third Turn2 worker and a LyondellBasell responder were seriously injured. LyondellBasell transported 29 other personnel to medical facilities for further evaluation and treatment. LyondellBasell's property damage resulting from the incident, including loss of use, was estimated to be \$40 million.

SAFETY ISSUES

The CSB's investigation identified the safety issues below.

- **Valve Design to Prevent Human Error.** There have been past incidents in which chemical industry workers inadvertently removed pressure-retaining components from a plug valve installed in pressurized service while attempting to remove an actuator. The CSB has identified four other similar plug valve incidents, all of which resulted in fatalities or serious injuries. The recurrence of incidents in which workers have inadvertently removed pressure-retaining components from plug valves points to the need to further re-design these valves such that it would be difficult to remove pressure-retaining components from plug valves while attempting to remove actuating equipment. ([Section 3.1](#))
- **Providing Workers with Conditions, Procedures, and Training to Safely Conduct Work.** The CSB found that LyondellBasell and Turn2 considered the actuator removal job to be a simple task and that LyondellBasell did not provide the work crew with a procedure detailing how to remove the actuator from the plug valve. In addition, neither LyondellBasell nor Turn2 trained the work crew on the steps necessary to remove the actuator, and LyondellBasell did not adequately assess the potential risk of exposing the contract crew to hazardous chemicals during the actuator removal in light of historical incidents in the industry in which workers have inadvertently removed pressure-retaining components from plug valves installed in pressurized service. ([Section 3.2](#))

CAUSE

The CSB determined that the cause of the incident was the inadvertent removal of pressure-retaining components from a plug valve in pressurized service while workers were removing the valve's actuator. Contributing to the incident was a plug valve design that did not include sufficient design features to prevent the

^a LyondellBasell used this plug valve to shut off (or turn on) the flow of methanol into an adjacent reactor. A pneumatic actuator provided the necessary torque to operate the valve.

inadvertent removal of pressure-retaining valve components, the lack of procedures to conduct the actuator removal work, and the lack of training for the workers conducting the work.

RECOMMENDATIONS

To LyondellBasell

2021-05-I-TX-R1

Update LyondellBasell policy documents to require that procedures are developed for properly removing actuating equipment from plug valves. Require that the procedures clearly identify which non-pressure-retaining components are safe to remove and pressure-retaining components that shall not be removed, as well as ensure LyondellBasell personnel are trained on these procedures. Ensure that hazardous energy is controlled when performing these procedures, as required by 29 C.F.R. 1910.147. Require in the policy document that risk assessments for process safety are conducted before the actuating equipment removal work is authorized. Ensure that sufficient procedures and safeguards are in place to prevent worker exposure to process fluid.

2021-05-I-TX-R2

Update LyondellBasell policy documents to require that LyondellBasell competent^a employee(s), as defined by 29 C.F.R. 1926.32(f), verify that contractors are competent, adequately trained, and qualified to perform the required work. To make this determination and to ensure work on process equipment is conducted in a safe manner, LyondellBasell competent employees may be required to oversee the work conducted by contractors on the process equipment. In the updated policy documents, include requirements to ensure that contract employees are informed of relevant process hazards and relevant details about the process equipment and are provided with equipment-specific procedures necessary to safely conduct their work.

To Turn2 Specialty Companies

2021-05-I-TX-R3

Update Turn2 policy documents to require that Turn2 employees are provided with written, detailed procedures for safely conducting work on process equipment and are trained on the procedures before the work is authorized to be performed.

^a OSHA defines a “competent person” as “one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.”

To American Society of Mechanical Engineers

2021-05-I-TX-R4

Revise American Society of Mechanical Engineers (ASME) Standard B16.34 *Valves—Flanged, Threaded, and Welding End* as follows:

- a. For existing plug valves, require facilities to clearly mark all pressure-retaining components (for example, with paint, accompanying warning signs, etc.). Work with American Petroleum Institute (API) and the Valve Manufacturers Association of America (VMA) to ensure a consistent methodology is specified across both API and ASME standards.
- b. Require that new plug valves be designed, consistent with Prevention through Design principles, to prevent the inadvertent removal of pressure-retaining components when removing the actuator or gearbox. Evaluate past plug valve incidents, and the associated plug valve designs involved in those incidents, when formulating a new plug valve design. Work with API and VMA to ensure a consistent methodology is specified across both API and ASME standards.

To American Petroleum Institute

2021-05-I-TX-R5

Revise API Standard 599 *Metal Plug Valves—Flanged, Threaded, and Welding Ends* as follows:

- a. State that there have been multiple incidents in which workers have inadvertently removed pressure-retaining components from plug valves while workers were attempting to remove the valve's actuator or gearbox.
- b. Recommend that facilities using plug valves establish written procedures detailing the correct way to remove the plug valve actuator or gearbox for each specific plug valve design at the facility.
- c. For existing plug valves, require facilities to clearly mark all pressure-retaining components (for example, with paint, accompanying warning signs, etc.). Work with ASME and VMA to ensure a consistent methodology is specified across both API and ASME standards.
- d. Require that new plug valves be designed, consistent with Prevention through Design principles, to prevent the inadvertent removal of pressure-retaining components when removing the actuator or gearbox. Evaluate past plug valve incidents, and the associated plug valve designs involved in those incidents, when formulating a new plug valve design. Work with ASME and VMA to ensure a consistent methodology is specified across both API and ASME standards.

To Valve Manufacturers Association of America Technical Committee

2021-05-I-TX-R6

Work with ASME and API and develop a white paper to the Valve Manufacturers Association of America addressing the issue of plug valve design with a focus on the following:

- a. Recommend as an industry good practice that facilities using plug valves establish written procedures detailing the correct way to remove the plug valve actuator or gearbox for each specific plug valve design.
- b. For existing plug valves, recommend as an industry good practice for facilities to clearly mark all pressure-retaining components (for example, with paint, accompanying warning signs, etc.). Work with ASME and API to ensure a consistent methodology is specified to the industry.
- c. Recommend new plug valves be designed, consistent with Prevention through Design principles, to prevent the inadvertent removal of pressure-retaining components when removing the actuator or gearbox. Evaluate past plug valve incidents, and the associated plug valve designs involved in those incidents, when formulating a new plug valve design recommendation. Work with ASME and API to ensure a consistent design is recommended to the industry.

1 BACKGROUND

1.1 LYONDELLBASELL LA PORTE COMPLEX

LyondellBasell is a plastics, chemicals, and refining company that owns and operates facilities located in 32 countries, including the United States [1]. The LyondellBasell La Porte complex, located in La Porte, Texas, is the world's third largest producer of acetic acid, a flavor enhancer and food preservative. The LyondellBasell La Porte complex spans approximately 550 acres and employs roughly 675 employees and contractors. The acetic acid unit at the LyondellBasell complex is covered by the Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) regulation.^a The acetic acid unit is not covered by the Environmental Protection Agency's (EPA's) Risk Management Program (RMP).^b

1.2 ACETIC ACID PRODUCTION PROCESS AND CHEMICAL HAZARDS

The production of acetic acid at the LyondellBasell La Porte Complex involves reacting methanol with carbon monoxide in the presence of a catalyst and catalyst additives, one of which is methyl iodide (**Figure 1**).

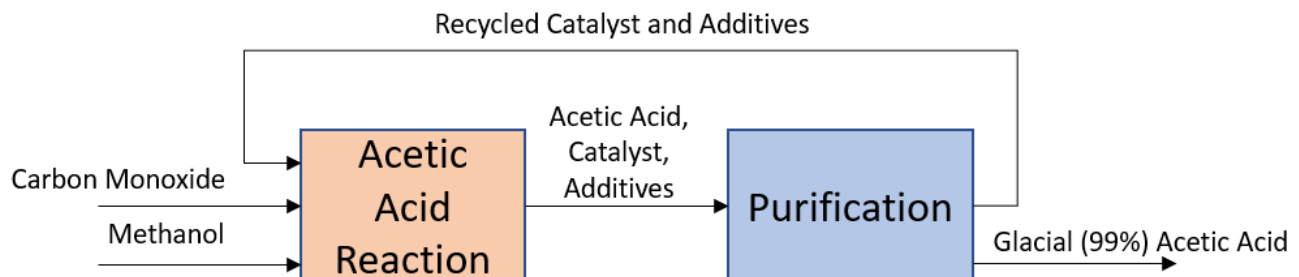


Figure 1. Simplified block flow diagram of the acetic acid reaction process. (Credit: CSB)

Acetic acid^c is a clear, colorless, corrosive liquid with a characteristic strong, acid, vinegar odor. Acetic acid has a boiling point of 244 °F and a relative vapor density of 2.1, which means that its vapors are heavier than air and will collect along the ground or in low-lying areas when exposed to atmospheric conditions.^d

LyondellBasell's SDS for acetic acid indicates that the corrosive liquid may be harmful if swallowed or inhaled into airways, and it may cause severe skin burns and eye damage upon exposure.

Methyl iodide is a colorless, noncombustible liquid with a pungent, ether-like odor [2]. Methyl iodide has a boiling point of 109 °F [2] and a relative vapor density of 4.9. The National Institute for Occupational Safety

^a The acetic acid manufacturing process is covered under OSHA's PSM regulation because the process contains methyl iodide in excess of 7,500 pounds [27].

^b The acetic acid unit is not covered by the EPA RMP because it does not contain any regulated chemicals under 40 CFR Part 68 in excess of the threshold quantity.

^c The information contained in this section references glacial acetic acid, 50% -80%, and was determined using LyondellBasell's safety data sheet (SDS).

^d Acetic acid has a vapor density of 2.1, compared with that of air, which is 1.0.

and Health (NIOSH) states that methyl iodide is a potential occupational carcinogen, and that exposure can cause eye, skin, and respiratory system irritation. [3].

At the time of the incident, the acetic acid reactor contained approximately 164,000 pounds of a liquid mixture. The liquid mixture contained over 100,000 pounds of glacial acetic acid and over 27,000 pounds of methyl iodide. The remaining contents consisted of water and other additives. When the release occurred, the temperature of the contents was at 238 °F, indicating that the bulk of the acetic acid likely remained in its liquid state while the bulk of the methyl iodide likely vaporized upon release into the atmosphere.

1.3 TURN2 SPECIALTY COMPANIES

Turn2 Specialty Companies (Turn2) is a turnaround^a services provider to the refining, petrochemical, and power industries that is headquartered in Baytown, Texas [4]. LyondellBasell had a Master Field Services Agreement with Turn2 for work that began in March 2019,^b for which Turn2 provided general mechanical and maintenance services for turnarounds and outages. In the weeks leading up to the incident, LyondellBasell assigned Turn2 to conduct work on the furnaces in one of the site's units, utilizing as many as 30 workers per day. This work included unbolting and cutting tubes, removing the furnace tubes, and reinstalling via bolting or specialty welding new tubes in the furnaces. In addition to the furnace work, Turn2 personnel also performed ancillary maintenance tasks in other areas at the La Porte Complex.

1.4 DESCRIPTION OF SURROUNDING AREA

Figure 2 shows the LyondellBasell La Porte Complex and depicts the area within one, three, and five miles of the facility boundary. Summarized demographic data for the approximately one-mile vicinity of the facility are shown below in **Table 1**. There are over 6,000 people residing in over 2,000 housing units, most of which are single units, within one mile of the LyondellBasell La Porte facility. Detailed demographic data are included in **Appendix B**.

^a A turnaround can be defined as “a planned shutdown of an asset, process, or total plant to identify and repair major potential problems in a timely manner to improve plant safety and efficiency [25].”

^b In March 2019, Turn2 was operating as Epic Specialty Companies LLC.

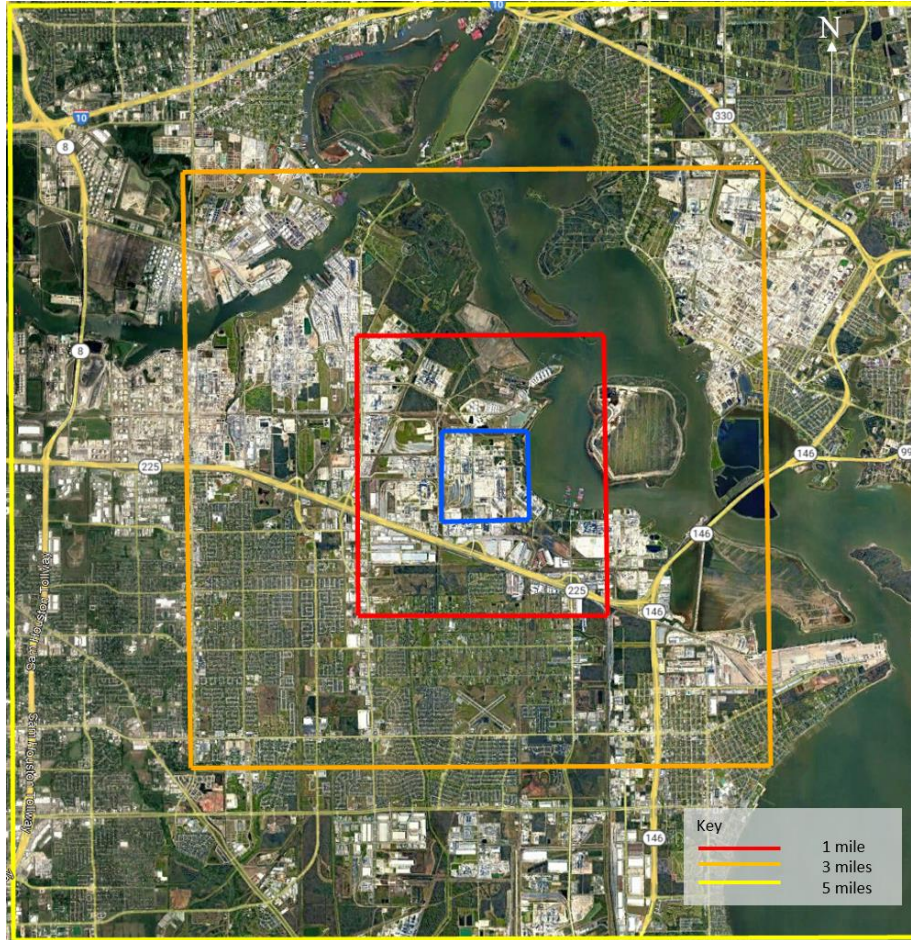


Figure 2. Overhead satellite image of the LyondellBasell La Porte complex (blue) and the surrounding area. (Credit: Google Maps, annotated by CSB)

Table 1. Summarized demographic data for the approximately one-mile vicinity of the LyondellBasell La Porte Complex. (Credit: Census Reporter)

| Population | Race and Ethnicity | | Per Capita Income | Percent Poverty ^a | Number of Housing Units | Types of Housing Units | |
|------------|--------------------|-------|-----------------------|------------------------------|-------------------------|------------------------|-----|
| | | | | | | | |
| 6,269 | White | 70% | \$45,178 ^b | 10.8% | 2,168 | Single Unit | 94% |
| | Hispanic | 28% | | | | Mobile Home | 6% |
| | Two+ | 1 % | | | | | |
| | Asian | 0.7 % | | | | | |
| | Black | 0.3% | | | | | |

^a The “Percent Poverty” figure represents the number of persons below the poverty line in the city of La Porte, Texas [21].

^b Census Reporter reports that La Porte’s per capita income was \$40,935 [21]. The Census Bureau reports that the overall per capita income for the United States from 2017–2021 was \$37,638 [22].

2 INCIDENT DESCRIPTION

On Saturday, July 24, 2021, an operations technician for the LyondellBasell acetic acid unit discovered a small leak on methanol piping upstream of the unit's acetic acid reactor. A subsequent inspection identified that the leak originated in a weld within the methanol piping. Shortly after the leak was discovered, the shutdown of an adjacent process unit required the acetic acid unit to also shut down acetic acid production. LyondellBasell personnel decided to use the shutdown opportunity to remove and repair the leaking portion of the methanol piping (**Figure 3**).

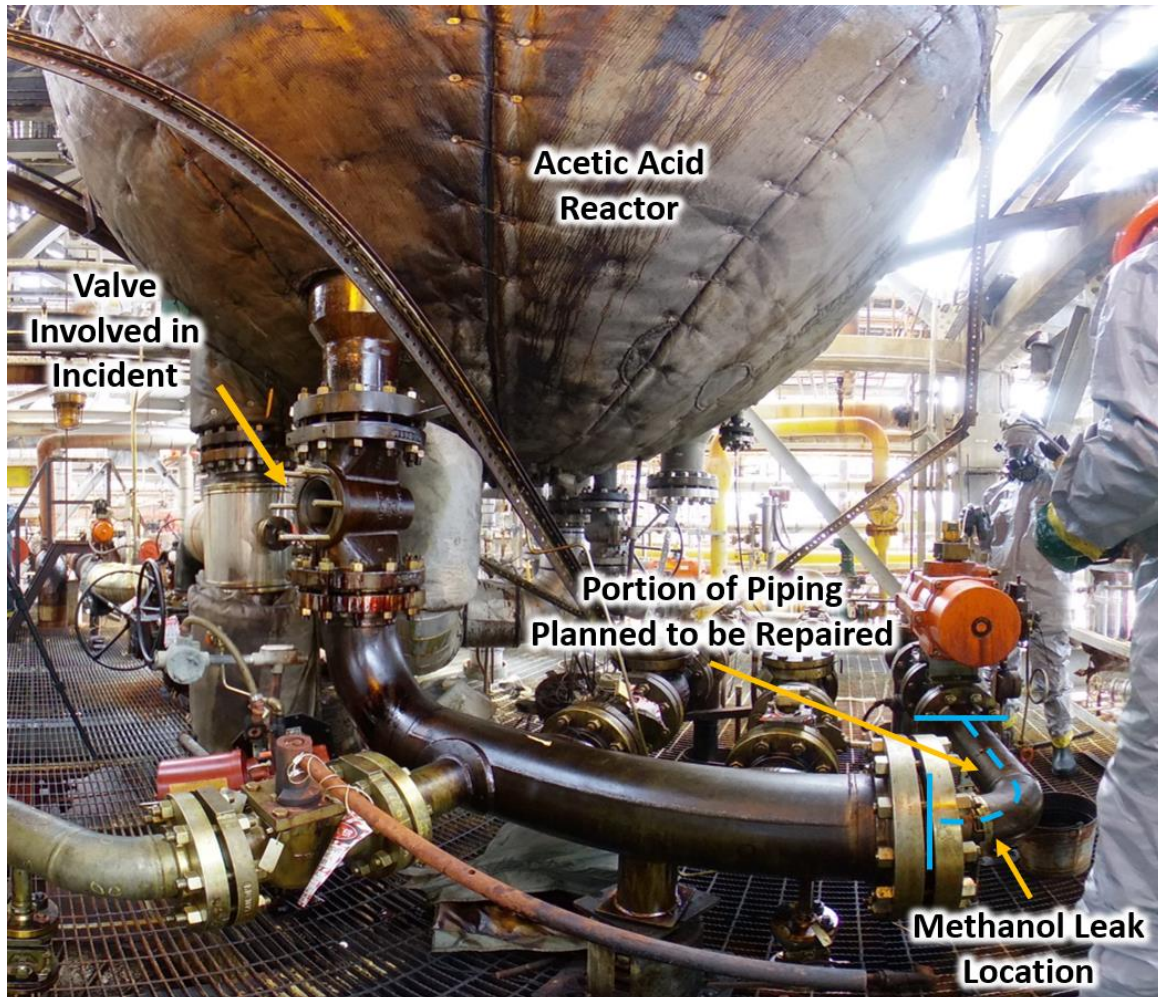


Figure 3. Post-incident photograph of the methanol leak location, the portion of the piping that LyondellBasell planned to repair, and the location of the plug valve involved in the incident. (Credit: CSB)

To isolate the piping, which contained methanol and acetic acid, LyondellBasell personnel chose to use the valve located between the leaking piping and the nearby acetic acid reactor—a pneumatically actuated eight-inch plug valve—as an isolation device (**Figure 4**). LyondellBasell's Energy Isolation Procedure specified that

the only pneumatically actuated control valves that were deemed to be approved energy isolation devices^a were those equipped with manual hand jacks, which could be physically closed and locked. LyondellBasell personnel therefore decided that they would remove the actuator connected to the plug valve (including its coupler) so that a pipe tee could be installed over the valve stem. The pipe tee would then have a chain passed through the opening with the two ends of the chain being padlocked, thus meeting the requirements for having a physical lock installed (**Figure 5**) according to their procedure. LyondellBasell directed its third-party contractor, Turn2, to perform the actuator removal task. Turn2 had communicated to LyondellBasell that it had a night crew that was qualified and available to remove the actuator.

At around 5:00 p.m. on July 27, 2021, the Turn2 superintendent and night foreman met with LyondellBasell operations personnel at the acetic acid unit operations building to review the actuator removal task. The Turn2 superintendent, the Turn2 foreman, and a LyondellBasell operator then walked into the unit, and the operator showed the two Turn2 personnel where the actuator to be removed was located. LyondellBasell did not have a procedure detailing how to remove the actuator, and neither LyondellBasell nor Turn2 trained the Turn2 personnel on how to remove the actuator.

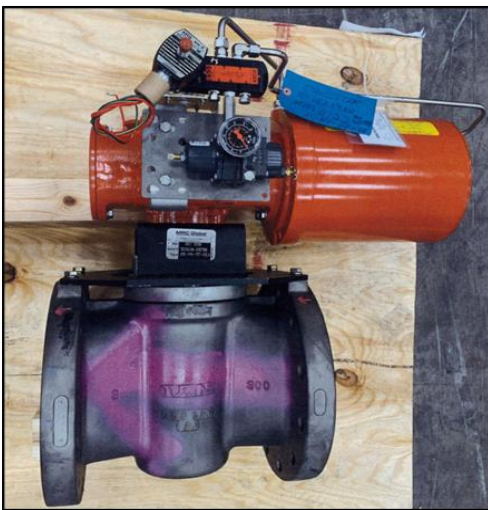


Figure 4. Plug valve involved in incident. (Credit: MRC Global)

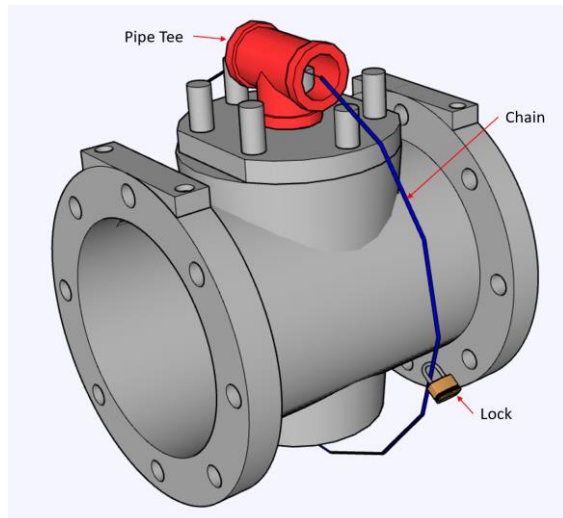


Figure 5. Schematic showing LyondellBasell's lockout plan for the plug valve. (Credit: CSB)

At around 6:45 p.m., LyondellBasell issued the work permit for the task, and a LyondellBasell operator told the U.S. Chemical Safety and Hazard Investigation Board (CSB) that he walked with the Turn2 foreman and two Turn2 pipefitters to the acetic acid unit and showed them the actuator they were to remove.^b The LyondellBasell operator then left the area, and the Turn2 foreman and two Turn2 pipefitters^c began work to remove the plug

^a OSHA defines an “energy isolation device” as “a mechanical device that physically prevents the transmission or release of energy... [26].”

^b A Turn2 worker disputes that the operator walked with the crew to the actuator before they began working to remove the actuator. The CSB was unable to confirm which statement was accurate.

^c This work crew had been working on repairing heat exchanger tubes as welders or welder helpers. The CSB did not find documentation indicating the work crew had experience installing, repairing, or removing valves or valve actuators. A Turn2 manager, however, communicated that two members of the work crew had experience removing actuators.

valve actuator. At this time, the acetic acid reactor (located directly above the location where the contractors were working) contained approximately 164,000 pounds of a 61.7% acetic acid mixture at a pressure of 130 pounds per square inch (psi) and a temperature of 238 °F. The Turn2 workers removed the insulation material from the exterior of the plug valve, then began to remove the bracket mounting bolts located on the exterior of the actuator mounting bracket (**Figure 6A**). Before removing all of the bracket mounting bolts, the Turn2 workers determined that they needed a socket wrench to remove the nuts shown in **Figure 6B**. The Turn2 foreman went to his truck to retrieve a socket wrench set, which would allow them to remove the nuts shown in **Figure 6B**. The Turn2 employees did not know that removing the nuts shown in **Figure 6B** was not necessary to remove the actuator;^a nor did they know that the nuts were pressure-retaining, holding the valve cover in place. Once the Turn2 foreman returned to the worksite, the Turn2 work crew removed all of the pressure-retaining nuts shown in **Figure 6B**, not recognizing that they had compromised the pressure integrity of the valve. The Turn2 crew then finished removing all of the bracket mounting bolts shown in **Figure 6A**.

After removing all of the bracket mounting bolts and inadvertently removing the pressure-retaining valve cover nuts from the plug valve, the Turn2 work crew removed the actuator and the affixed actuator mounting bracket from the plug valve and placed it on the deck grating (**Figure 7**). Once the actuator was removed, the Turn2 work crew noticed that the coupler was still seated in its designated slot on the top of the valve stem (**Figure 6B and 6C**). The Turn2 workers attempted to slide the coupler off of the valve stem, but because it was too tight to remove by hand, the Turn2 work crew decided to use a pry bar to try and remove it. While using the pry bar on the coupler, the combination of forces from the pry bar and the process fluid pressure inside the plug valve caused the unfastened valve cover and plug to eject from the plug valve body, and acetic acid rapidly released from the open plug valve.

^a One of the workers explained his reasoning for removing the pressure-retaining nuts shown in Figure 6B. He told the CSB they had to remove the interior fasteners because "...it's all connected. As [the actuator] sits up there, it's all connected to one another." This worker did not seem to understand that the interior fasteners were pressure-retaining and should not have been removed.

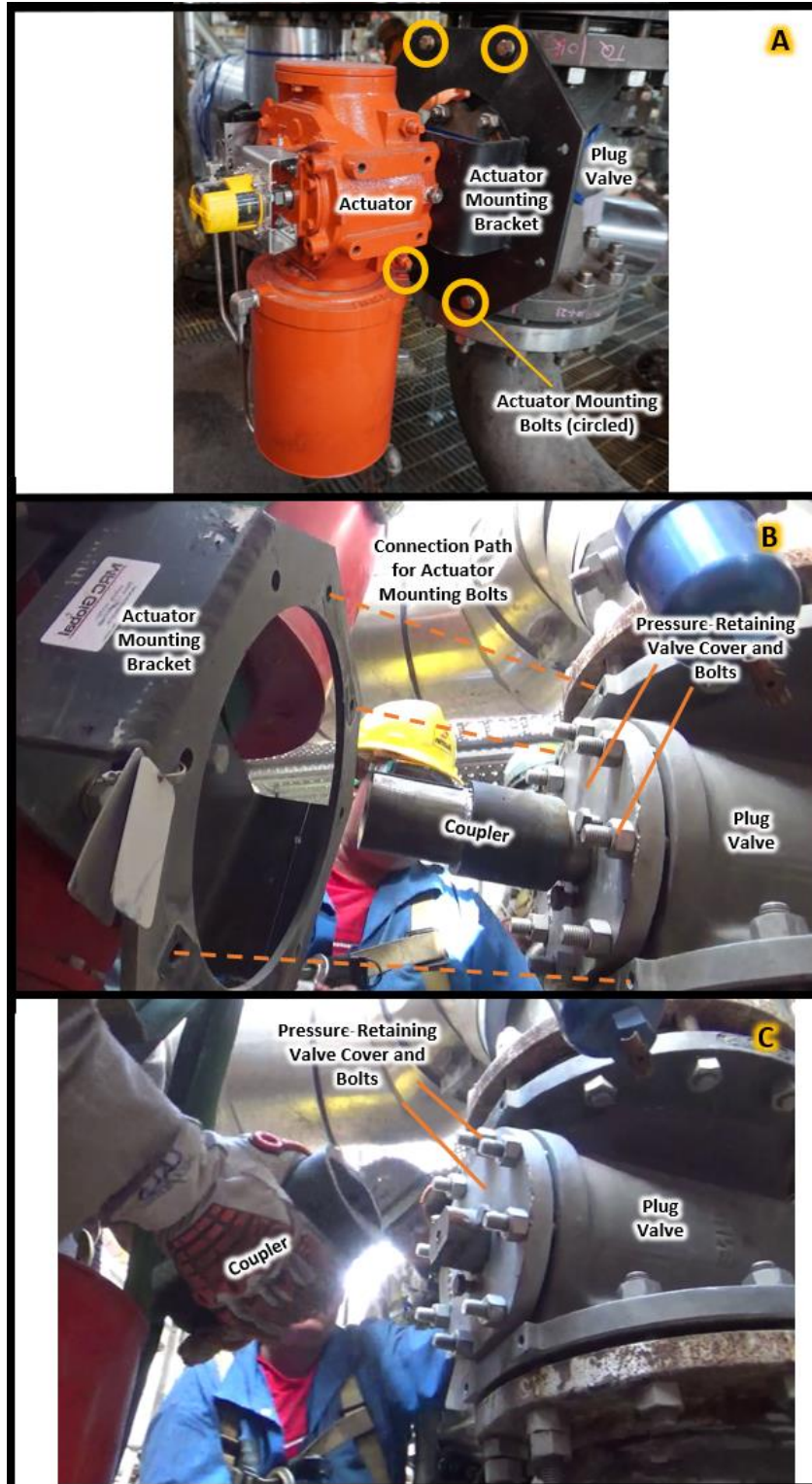


Figure 6. (A) Photo of the incident valve with the four actuator mounting bolts highlighted; (B) Photo of exemplar valve pressure-retaining nuts, and (C) Photo of exemplar valve with coupler removed. (Credit: CSB)

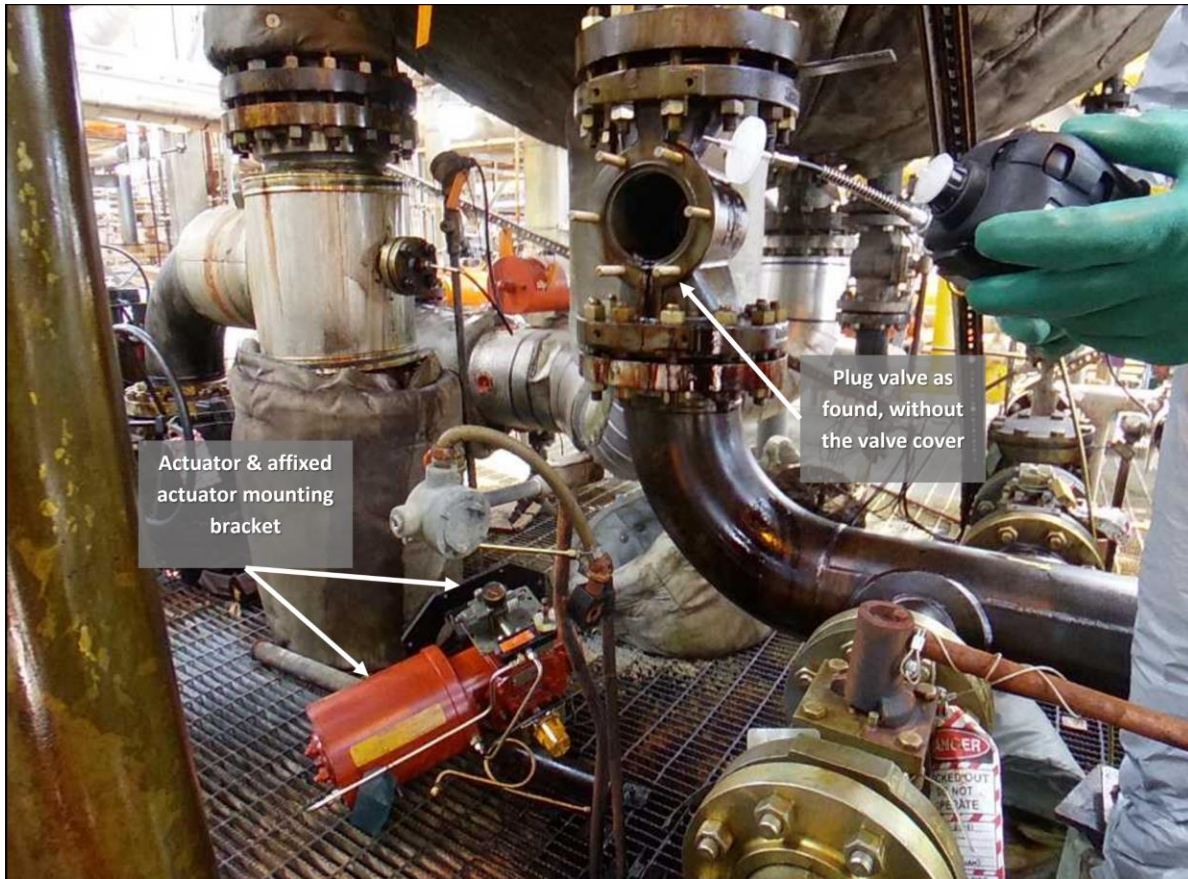


Figure 7. Post-incident photo showing the actuator and the affixed mounting bracket positioned on deck grating. (Credit: CSB)

According to recorded performance trend data for the acetic acid reactor, the liquid level in the reactor began to decrease rapidly. The entire contents of the acetic acid reactor, roughly 164,000 pounds of acetic acid mixture at 238 °F, emptied from the reactor by way of the open, unplugged valve. All three Turn2 workers were sprayed by the releasing acetic acid mixture. 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. LyondellBasell transported 29 personnel, who were working in an adjacent unit at the time of the incident, to medical facilities for further evaluation and treatment.^a

^a The CSB is unaware of any injuries reported from these personnel.

3 SAFETY ISSUES

The following sections discuss the safety issues contributing to the incident:

- Valve Design to Prevent Human Error
- Providing Workers with Conditions, Procedures, and Training to Safely Conduct Work

3.1 VALVE DESIGN TO PREVENT HUMAN ERROR

There have been at least five incidents (including the LyondellBasell incident) in which workers inadvertently removed pressure-retaining components from plug valves while they were attempting to remove connected actuating equipment, as described below.^a

3.1.1 INCIDENTS IN WHICH PRESSURE-RETAINING COMPONENTS WERE INADVERTENTLY REMOVED FROM PLUG VALVES

3.1.1.1 Puebla, Mexico, 1977 Incident

On June 19, 1977, in Puebla, Mexico, a maintenance worker incorrectly removed an actuator from a plug valve that was situated on a liquid discharge line beneath a vinyl chloride storage tank. The worker mistakenly removed pressure-retaining bolts instead of the bolts that connected the actuator to the adaptor (**Figure 8**). The plug, sleeve, and valve cover then blew out under the system pressure and caused a massive release of vinyl chloride. The vinyl chloride formed a vapor cloud that eventually ignited, and led to additional subsequent explosions, causing severe damage to the site. The incident fatally injured one person and severely injured four other people. Nearly 90 additional people suffered burns from the intense thermal radiation from one of the explosions [5].

KEY LESSON

Multiple incidents have occurred in the chemical industry where employees have inadvertently removed pressure-retaining bolts from plug valves when attempting to remove actuating equipment. This has led to plug valves coming apart, releases of hazardous materials, and serious injuries and worker fatalities.

^a The CSB is aware of other incidents in which workers inadvertently removed pressure-retaining components from other types of valves (e.g., ball valves) in pressurized service, resulting in hazardous process fluid releases. However, it appears that most incidents involving the inadvertent removal of pressure-retaining components occur when working on plug valves.

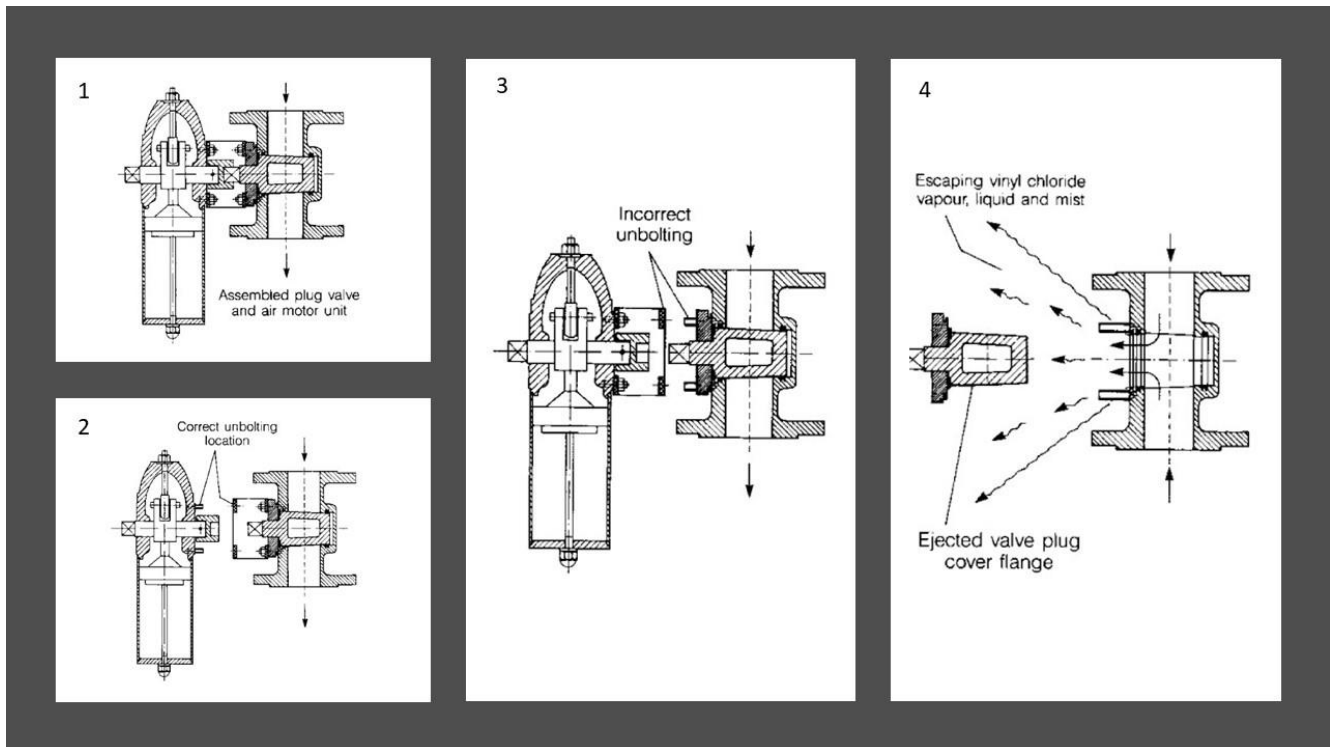


Figure 8. Series of schematics showing the inadvertently dismantled valve in the Puebla, Mexico, incident: (1) Assembled plug valve and actuator; (2) Correct unbolting locations; (3) Actual unbolting location; (4) Plug ejected from valve. (Credit: Loss Prevention Bulletin 100 [5])

3.1.1.2 U.S. Amoco Plant 1980 Incident

In October 1980, for added safety during a cleaning operation of piping, procedures required mechanics to remove the actuator for a plug valve that was to be used to isolate a polypropylene reactor, so that the valve would not be inadvertently opened during the cleaning operation. Two employees removed the pressure-retaining bolts holding the plug valve cover in place instead of the bolts holding the actuator in place. The 150-psi system pressure blew out the plug, causing the release of hydrocarbons and polymer. The resulting vapor cloud ignited, causing severe damage to the facility. Six employees were fatally injured [6, pp. 189-190] [7].

3.1.1.3 AkzoNobel Polymer Chemicals La Porte, Texas, 2013 Incident

On March 4, 2013, a contract worker was troubleshooting four valve actuation systems on a vessel containing butyl ethyl magnesium (BEM) that were not operating as designed. On the first three systems, the worker resolved the issues by replacing the fittings and air lines. Replacing these components on the fourth system, however, did not work. The worker, who was in training to be a certified instrumentation technician, first attempted to remove the actuator from its mounting bracket. When this attempt was unsuccessful, the worker removed the actuator mounting bolts, which also held the plug valve cover in place. This resulted in a release of BEM through the valve body opening, exposing the worker to BEM and causing burn injuries. The BEM, which is pyrophoric,^a also ignited following the loss of containment. The company's internal investigation determined

^a A pyrophoric substance ignites when it is exposed to air.

that the causal factors included, among other things, the absence of qualified supervision and the absence of a job-specific procedure.

3.1.1.4 ExxonMobil Baton Rouge Refinery 2016 Incident

On November 22, 2016, during the removal of an inoperable gearbox on a plug valve, the operator performing the activity removed critical pressure-retaining bolts securing the pressure-retaining top-cap of the valve instead of bolts that secured only the gearbox (**Figure 9**). When the operator then attempted to open the plug valve with a pipe wrench, the valve came apart and released isobutane into the unit, forming a flammable vapor cloud. The vapor cloud ignited and severely burned four workers. The CSB investigated this incident and published a Safety Bulletin titled *Key Lessons from the ExxonMobil Baton Rouge Refinery Isobutane Release and Fire* [8].^a

^a Link to report: <https://www.csb.gov/file.aspx?DocumentId=6045>

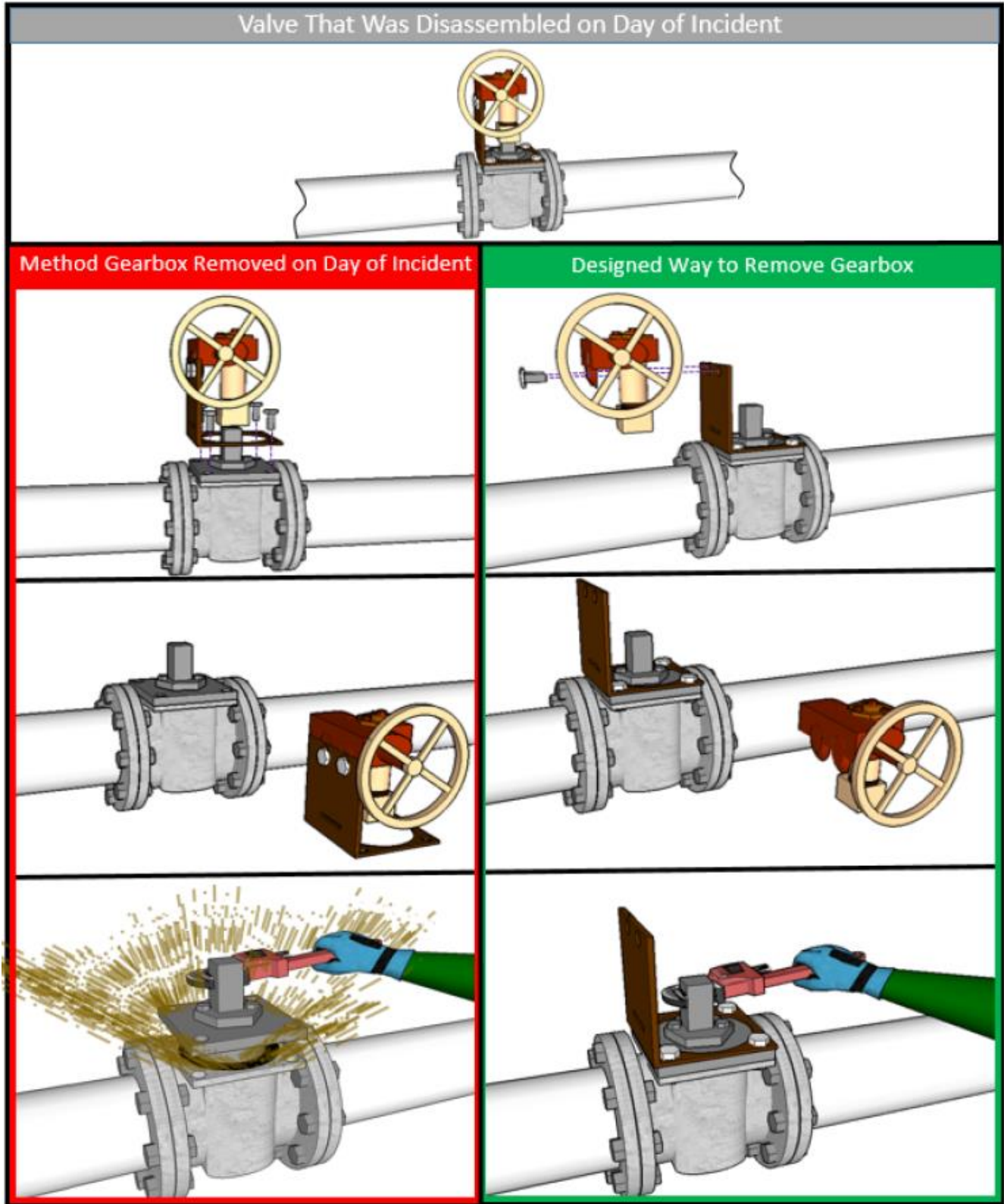


Figure 9. Depiction of the gearbox removal on the day of the ExxonMobil Baton Rouge 2016 incident (left), and depiction of how the gearbox should have been removed (right). (Credit: CSB [8])

3.1.1.5 LyondellBasell 2021 Incident

This incident is the subject of this report. Workers inadvertently removed pressure-retaining components from a plug valve while attempting to remove the valve’s actuator.

The CSB notes that the design of the plug valve involved in the LyondellBasell incident was of a newer design recommended by the American Petroleum Institute (API) Standard 599 *Metal Plug Valves—Flanged, Threaded, and Welding Ends* that would allow an actuator to be mounted or removed without affecting the pressure retention of the valve. API 599 states:

- “The [plug valve] design shall ensure the stem cannot be ejected from the valve by removal of ... actuator mounting hardware [9, p. 6].”
- “Valves supplied with the capability of mounting actuators or gear operators shall be capable of doing so without removal of any pressure-containing parts (e.g. body bolts, bonnet/cover bolts, flange bolts, packing gland bolts, packing retaining stem nut, etc.) [9, p. 8].”

This newer design, however, did not prevent workers from inadvertently removing pressure retaining components while removing the actuator.

3.1.2 NEED FOR SAFER DESIGN OF PLUG VALVES

The recurrence of incidents in which pressure-retaining components have been inadvertently removed from plug valves points to the need to further re-design these valves to prevent workers from accidentally removing pressure-retaining components while attempting to remove the actuating equipment. Listed below are methods various entities have identified to prevent people from removing certain equipment components or using incorrect tools on equipment:

- In his book *An Engineer’s View of Human Error (Third edition)*, in which the theme of the book is “*Try to change situations, not people,*” Trevor Kletz states, “A hardware solution is possible [to prevent inadvertent removal of pressure-retaining components of valves]. Bolts which can safely be undone when the plant is up to pressure could be painted green; others could be painted red.^a A similar suggestion is to use bolts with recessed heads and fill the heads with lead if the bolts should not be undone when the plant is up to pressure [10, p. 175].”

^a One of the workers at the LyondellBasell facility mentioned to the CSB, “Nothing was marked. None of the bolts were labeled ‘remove’ [or] ‘don’t remove.’”

KEY LESSON

To prevent future incidents in which workers inadvertently remove pressure-retaining components from plug valves while attempting to remove actuating equipment, facilities should clearly mark or identify pressure-retaining bolts on existing plug valves, for example through color coding techniques and/or warning labels or signs.

- Many modern cars are equipped with locking wheel nuts to deter wheel theft. These locking wheel nuts come with a matching key that must be used to remove the wheel nut [11] [12].
- Valves manufactured by the company Descote^a include a sign on the handwheel that reads “Do Not Use a Wrench” (Figure 10) [13]. Similar to this approach, plug valves could be equipped with recessed bolts and covered with an appropriate sign warning that those bolts should not be removed in pressurized service.



Figure 10. Photograph of a Descote valve’s warning sign to not use a wrench on the valve. (Credit: Steven Levy Enterprises [14])

Considering the recurrence of these incidents, a concept known as “Prevention through Design,” or PtD, should be employed when designing new plug valves to prevent the inadvertent removal of pressure-retaining components on plug valves. NIOSH defines PtD as “...anticipating and designing out or eliminating safety and health hazards in facilities, work methods, and operations, processes, equipment, tools, products, new technologies, and the organization of work” [15].

The Valve Manufacturers Association of America (VMA) is an industry trade association whose mission is, in part, to increase knowledge. The VMA strives to “provide industry expertise...” as one of its strategic priorities. The VMA has a Technical Committee that “identifies, discusses and advises VMA on key valve industry technical issues.” Part of its function is to identify good practices and develop standards affecting the industry. American Society of Mechanical Engineers (ASME) Standard B16.34 *Valves—Flanged, Threaded, and Welding End* specifies design requirements for valves, including plug valves, and API Standard 599 *Metal Plug Valves—Flanged, Threaded, and Welding Ends* specifies design requirements specifically for plug valves. These standards recommend that any mounting bolts or devices do not impact the pressure retaining components.

^a The Descote valve pictured in this report was not involved in the incident. The CSB selected this sign simply as an example of how a visual system can be used to enhance safety.

Neither standard contains requirements or recommendations to distinguish pressure-retaining components from those that are not pressure-retaining.

The CSB concludes that had the LyondellBasell plug valve pressure-retaining bolts been clearly identified (such as through paint markings or a warning label or sign), the work crew might have removed only the bolts securing the actuator to the plug valve, which would have prevented the incident. The CSB also concludes that to prevent future incidents in which workers inadvertently remove pressure-retaining components from plug valves while attempting to remove actuators and gearboxes, prevailing valve standards should be revised to require that pressure-retaining components on existing valves are clearly marked, and that new plug valves be designed to prevent the inadvertent removal of pressure-retaining components while attempting to remove the actuating equipment. The CSB notes that after the incident, LyondellBasell installed tamper-resistant mechanisms and tags on the valve cover fasteners of actuated plug valves within the unit to help prevent the inadvertent removal of pressure-retaining components while the valves are in service (**Figure 11**).



Figure 11. Example of tamper-resistant mechanism incorporated by LyondellBasell. (Credit: CSB)

The CSB recommends that ASME and API, working with the VMA, revise their plug valve design standards to require facilities to clearly mark all existing plug valve pressure-retaining components (for example, with paint and accompanying warning labels or signs), and to require that new plug valves be designed, consistent with Prevention through Design principles, to prevent the inadvertent removal of pressure-retaining components when removing the actuator or gearbox.

3.2 PROVIDING WORKERS WITH CONDITIONS, PROCEDURES, AND TRAINING TO SAFELY CONDUCT WORK

As outlined above, the same incident^a has been repeated at least five times: workers intended to remove valve actuating equipment from a plug valve, the workers inadvertently removed pressure-retaining bolts, the plug valve came apart, and hazardous process material was released, resulting in fatalities and serious injuries. In addition to demonstrating the need for plug valve design and marking improvements (discussed above), these incidents also reveal the need for improved process safety management systems at facilities with these types of valves. Process safety author Roy E. Sanders laid out the following questions in his 1996 article discussing an inadvertent valve disassembly:

- Is the risk too high to [remove actuators] while the [equipment is] full of a highly [hazardous] liquid?
- Did written procedures exist detailing this job and its precautions?
- Were maintenance mechanics trained in the procedures [16]?

Indeed, robust process safety management systems requiring risk analyses, detailed written procedures, and training on those procedures could have prevented all five of the incidents discussed in this report. Below, the conditions at LyondellBasell relating to each of the above questions are discussed.

Is the risk too high to remove actuators while the equipment is full of a highly hazardous liquid?

At the time of the incident, the acetic acid reactor located directly above the plug valve contained approximately 164,000 pounds of a 61.7% acetic acid mixture at a gauge pressure of 130 pounds per square inch (psig) and 238 °F. The acetic acid mixture was flammable and could cause severe skin burns and eye damage [17]. LyondellBasell personnel did not consider the option of de-inventorying the reactor and connected piping (or otherwise isolating the valve from hazardous energy) before the actuator removal work could be authorized, as the planned actuator removal should not have involved opening the process equipment.

The CSB concludes that in light of the repeated incidents in which workers inadvertently removed pressure-retaining valve components

KEY LESSON

Facilities with plug valves should develop formal procedures for the removal of plug valve actuating equipment that require (1) a risk assessment of all plug valve actuator removal work to ensure sufficient procedures and safeguards are in place to prevent worker exposure to process fluid, (2) written procedures detailing actuator removal steps for the specific valve design, and (3) workers to be trained on the procedure before conducting the actuator removal work.

^a The CSB notes that the design of the plug valves involved in the incidents differed.

while working to remove actuating equipment, companies should thoroughly assess the risk involved in all plug valve actuator removal work to ensure that sufficient procedures and safeguards are in place to prevent worker exposure to process fluid. At some facilities, this risk assessment may determine that depressurizing and de-inventorying equipment is required before removing plug valve actuating equipment. The CSB recommends that LyondellBasell conduct risk assessments for process safety of plug valve actuator removal work before the work is authorized.

Do written procedures exist detailing the job and its precautions?

LyondellBasell did not provide the work crew with a procedure or instructions on how to remove the actuator from the plug valve. The OSHA PSM Standard requires that “[t]he employer shall establish and implement written procedures to maintain the on-going integrity of process equipment.”^a In addition, the Center for Chemical Process Safety (CCPS) book *Guidelines for Writing Effective Operating and Maintenance Procedures* states, “Procedures should identify the hazards presented by the process. Procedures should also state precautions necessary to prevent accidental chemical release, exposure, and injury [18, p. 18].”

The CSB also found that both LyondellBasell and Turn2 personnel perceived the actuator removal to be a simple task with minimal risks. In hindsight, when asked if they had a written procedure for the task, one Turn2 worker stated, “...not at all. I think that would have been pretty helpful.” The CSB concludes that LyondellBasell failed to provide the Turn2 work crew with a written procedure and allowed the work to be done without LyondellBasell’s oversight because of the perceived simplicity of the actuator removal, as well as representations made by Turn2 that its work crew could perform the task. Had LyondellBasell provided a procedure to the Turn2 work crew that detailed the bolts to be removed for the actuator removal work and warned against removing the pressure-retaining bolts, the incident could have been prevented. The CSB recommends that LyondellBasell update its policy documents to require that procedures are developed for removing actuating equipment from plug valves. The CSB also recommends that Turn2 update its policy documents to require that Turn2 employees are provided with written, detailed procedures for safely conducting work on process equipment.

^a 29 C.F.R. 1910.119 (j) (2)

Were maintenance mechanics trained in the procedures?

LyondellBasell selected a contractor, Turn2, to conduct the actuator removal work. When the Turn2 superintendent and Turn2 foreman arrived at the unit to review the task, a LyondellBasell operator showed the Turn2 superintendent and Turn2 foreman where the actuator to be removed was located, and Turn2 proceeded with the actuator removal work that evening. The OSHA PSM Standard requires that “[t]he contract employer shall assure that each contract employee is trained in the work practices necessary to safely perform his/her job.” The CSB concludes that neither LyondellBasell nor Turn2 trained the Turn2 work crew on the steps necessary to remove the actuator. Had the Turn2 work crew been trained on which bolts to remove to safely remove the actuator from the plug valve, the incident might not have occurred. The CSB recommends that Turn2 update its policy documents to require that Turn2 employees are trained on procedures for safely conducting work on process equipment before the work is authorized to be performed.

KEY LESSON

When contractors are conducting work on or near plant equipment containing hazardous materials, it is critical for the operating company to oversee the contractor work and ensure that it is conducted in a safe manner.

Contractors may be less familiar with plant equipment than in-house staff. Further, the use of contractors often “involves a loss of control over the execution of work” by the company [19, p. 1382]. When contractors are conducting work on or near plant equipment containing hazardous materials, it is critical for the operating company to ensure the contractors are competent and qualified to perform the required work, which could include company competent employees overseeing that the contractor work is conducted in a safe manner. As stated by the Center for Chemical Process Safety (CCPS) in its book *Guidelines for Risk Based Process Safety*, “While contractors have a responsibility to monitor the action of their employees and to enforce the safety performance requirements, the ultimate responsibility for ensuring the safety of its facility rests with the company [20, p. 376].” The CSB concludes that LyondellBasell did not sufficiently determine that the contractors performing the work were competent, adequately trained, or qualified to perform the actuator removal, and LyondellBasell did not provide sufficient oversight of the actuator removal task. Had LyondellBasell ensured the contractors were competent, adequately trained, and qualified to perform the actuator removal or provided oversight by a competent LyondellBasell employee, the incident might not have occurred. The CSB recommends to LyondellBasell to update its policy documents to require that LyondellBasell competent^a employee(s), as defined by 29 C.F.R. 1926.32(f), verify that Contractors are competent, adequately trained, and qualified to perform the required work. To make this determination and to ensure that work on process equipment is conducted in a safe manner, LyondellBasell competent employees may be required to oversee the work conducted by contractors on the process equipment. The CSB also recommends that LyondellBasell ensure that contract employees are informed of relevant process hazards and relevant details about the process equipment and are provided with equipment-specific procedures necessary to safely conduct their work.

^a OSHA defines a “competent person” as “one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.”

4 CONCLUSIONS

4.1 FINDINGS

Valve Design to Prevent Human Error

1. Had the LyondellBasell plug valve pressure-retaining bolts been clearly identified (such as through paint markings or a warning label or sign), the work crew might have removed only the bolts securing the actuator to the plug valve, which would have prevented the incident.
2. To prevent future incidents in which workers inadvertently remove pressure-retaining components from plug valves while attempting to remove actuators and gearboxes, prevailing valve standards should be revised to require that pressure-retaining components on existing valves are clearly marked, and that new plug valves be designed to prevent the inadvertent removal of pressure-retaining components while attempting to remove the actuating equipment.

Providing Workers with Conditions, Procedures, and Training to Safely Conduct Work

3. In light of the repeated incidents in which workers inadvertently removed pressure-retaining valve components while working to remove actuating equipment, companies should thoroughly assess the risk involved in all plug valve actuator removal work to ensure that sufficient procedures and safeguards are in place to prevent worker exposure to process fluid. At some facilities, this risk assessment may determine that depressurizing and de-inventorying equipment is required before removing plug valve actuating equipment.
4. LyondellBasell failed to provide the Turn2 work crew with a written procedure and allowed the work to be done without LyondellBasell's oversight because of the perceived simplicity of the actuator removal, as well as representations made by Turn2 that its work crew could perform the task. Had LyondellBasell provided a procedure to the Turn2 work crew that detailed the bolts to be removed for the actuator removal work and warned against removing the pressure-retaining bolts, the incident could have been prevented.
5. Neither LyondellBasell nor Turn2 trained the Turn2 work crew on the steps necessary to remove the actuator. Had the Turn2 work crew been trained on which bolts to remove to safely remove the actuator from the plug valve, the incident might not have occurred.
6. LyondellBasell did not sufficiently determine that the contractors performing the work were competent, adequately trained, or qualified to perform the actuator removal, and LyondellBasell did not provide sufficient oversight of the actuator removal task. Had LyondellBasell ensured the contractors were competent, adequately trained, and qualified to perform the actuator removal or provided oversight by a competent LyondellBasell employee, the incident might not have occurred.

4.2 CAUSE

The CSB determined that the cause of the incident was the inadvertent removal of pressure-retaining components from a plug valve in pressurized service while workers were removing the valve's actuator.

Contributing to the incident was a plug valve design that did not include sufficient design features to prevent the inadvertent removal of pressure-retaining valve components, the lack of procedures to conduct the actuator removal work, and the lack of training for the workers conducting the work.

5 RECOMMENDATIONS

To prevent future chemical incidents, and in the interest of driving chemical safety excellence to protect communities, workers, and the environment, the CSB makes the following safety recommendations:

5.1 LYONDELLBASELL

2021-05-I-TX-R1

Update LyondellBasell policy documents to require that procedures are developed for properly removing actuating equipment from plug valves. Require that the procedures clearly identify which non-pressure-retaining components are safe to remove and pressure-retaining components that shall not be removed, as well as ensure LyondellBasell personnel are trained on these procedures. Ensure that hazardous energy is controlled when performing these procedures, as required by 29 C.F.R. 1910.147. Require in the policy document that risk assessments for process safety are conducted before the actuating equipment removal work is authorized. Ensure that sufficient procedures and safeguards are in place to prevent worker exposure to process fluid.

2021-05-I-TX-R2

Update LyondellBasell policy documents to require that LyondellBasell competent employee(s), as defined by 29 C.F.R. 1926.32(f), verify that contractors are competent, adequately trained, and qualified to perform the required work. To make this determination and to ensure work on process equipment is conducted in a safe manner, LyondellBasell competent employees may be required to oversee the work conducted by contractors on the process equipment. In the updated policy documents, include requirements to ensure that contract employees are informed of relevant process hazards and relevant details about the process equipment and are provided with equipment-specific procedures necessary to safely conduct their work.

5.2 TURN2 SPECIALTY COMPANIES

2021-05-I-TX-R3

Update Turn2 policy documents to require that Turn2 employees are provided with written, detailed procedures for safely conducting work on process equipment and are trained on the procedures before the work is authorized to be performed.

5.3 AMERICAN SOCIETY OF MECHANICAL ENGINEERS

2021-05-I-TX-R4

Revise American Society of Mechanical Engineers (ASME) Standard B16.34 *Valves—Flanged, Threaded, and Welding End* as follows:

- a. For existing plug valves, require facilities to clearly mark all pressure-retaining components (for example, with paint, accompanying warning signs, etc.). Work with American Petroleum Institute (API) and the Valve Manufacturers Association of America (VMA) to ensure a consistent methodology is specified across both API and ASME standards.
- b. Require that new plug valves be designed, consistent with Prevention through Design principles, to prevent the inadvertent removal of pressure-retaining components when removing the actuator or gearbox. Evaluate past plug valve incidents, and the associated plug valve designs involved in those incidents, when formulating a new plug valve design. Work with API and VMA to ensure a consistent methodology is specified across both API and ASME standards.

5.4 AMERICAN PETROLEUM INSTITUTE

2021-05-I-TX-R5

Revise API Standard 599 *Metal Plug Valves—Flanged, Threaded, and Welding Ends* as follows:

- a. State that there have been multiple incidents in which workers have inadvertently removed pressure-retaining components from plug valves while workers were attempting to remove the valve's actuator or gearbox.
- b. Recommend that facilities using plug valves establish written procedures detailing the correct way to remove the plug valve actuator or gearbox for each specific plug valve design at the facility.
- c. For existing plug valves, require facilities to clearly mark all pressure-retaining components (for example, with paint, accompanying warning signs, etc.). Work with ASME and VMA to ensure a consistent methodology is specified across both API and ASME standards.
- d. Require that new plug valves be designed, consistent with Prevention through Design principles, to prevent the inadvertent removal of pressure-retaining components when removing the actuator or gearbox. Evaluate past plug valve incidents, and the associated plug valve designs involved in those incidents, when formulating a new plug valve design. Work with ASME and VMA to ensure a consistent methodology is specified across both API and ASME standards.

5.5 VALVE MANUFACTURERS ASSOCIATION OF AMERICA TECHNICAL COMMITTEE

2021-05-I-TX-R6

Work with ASME and API and develop a white paper to the Valve Manufacturers Association of America addressing the issue of plug valve design with a focus on the following:

- a. Recommend as an industry good practice that facilities using plug valves establish written procedures detailing the correct way to remove the plug valve actuator or gearbox for each specific plug valve design.

- b. For existing plug valves, recommend as an industry good practice for facilities to clearly mark all pressure-retaining components (for example, with paint, accompanying warning signs, etc.). Work with ASME and API to ensure a consistent methodology is specified to the industry.
- c. Recommend new plug valves be designed, consistent with Prevention through Design principles, to prevent the inadvertent removal of pressure-retaining components when removing the actuator or gearbox. Evaluate past plug valve incidents, and the associated plug valve designs involved in those incidents, when formulating a new plug valve design recommendation. Work with ASME and API to ensure a consistent design is recommended to the industry.

6 Key Lessons for the Industry

To prevent future chemical incidents, and in the interest of driving chemical safety excellence to protect communities, workers, and the environment, the CSB urges companies to review these key lessons:

1. Multiple incidents have occurred in the chemical industry where employees have inadvertently removed pressure-retaining bolts from plug valves when attempting to remove actuating equipment. This has led to plug valves coming apart, releases of hazardous materials, and serious injuries and worker fatalities.
2. To prevent future incidents in which workers inadvertently remove pressure-retaining components from plug valves while attempting to remove actuating equipment, facilities should clearly mark or identify pressure-retaining bolts on existing plug valves, for example through color coding techniques and/or warning labels or signs.
3. Facilities with plug valves should develop formal procedures for the removal of plug valve actuating equipment that require (1) a risk assessment of all plug valve actuator removal work to ensure sufficient procedures and safeguards are in place to prevent worker exposure to process fluid; (2) written procedures detailing actuator removal steps for the specific valve design; and (3) workers to be trained on the procedure before conducting the actuator removal work.
4. When contractors are conducting work on or near plant equipment containing hazardous materials, it is critical for the operating company to oversee the contractor work and ensure that it is conducted in a safe manner.

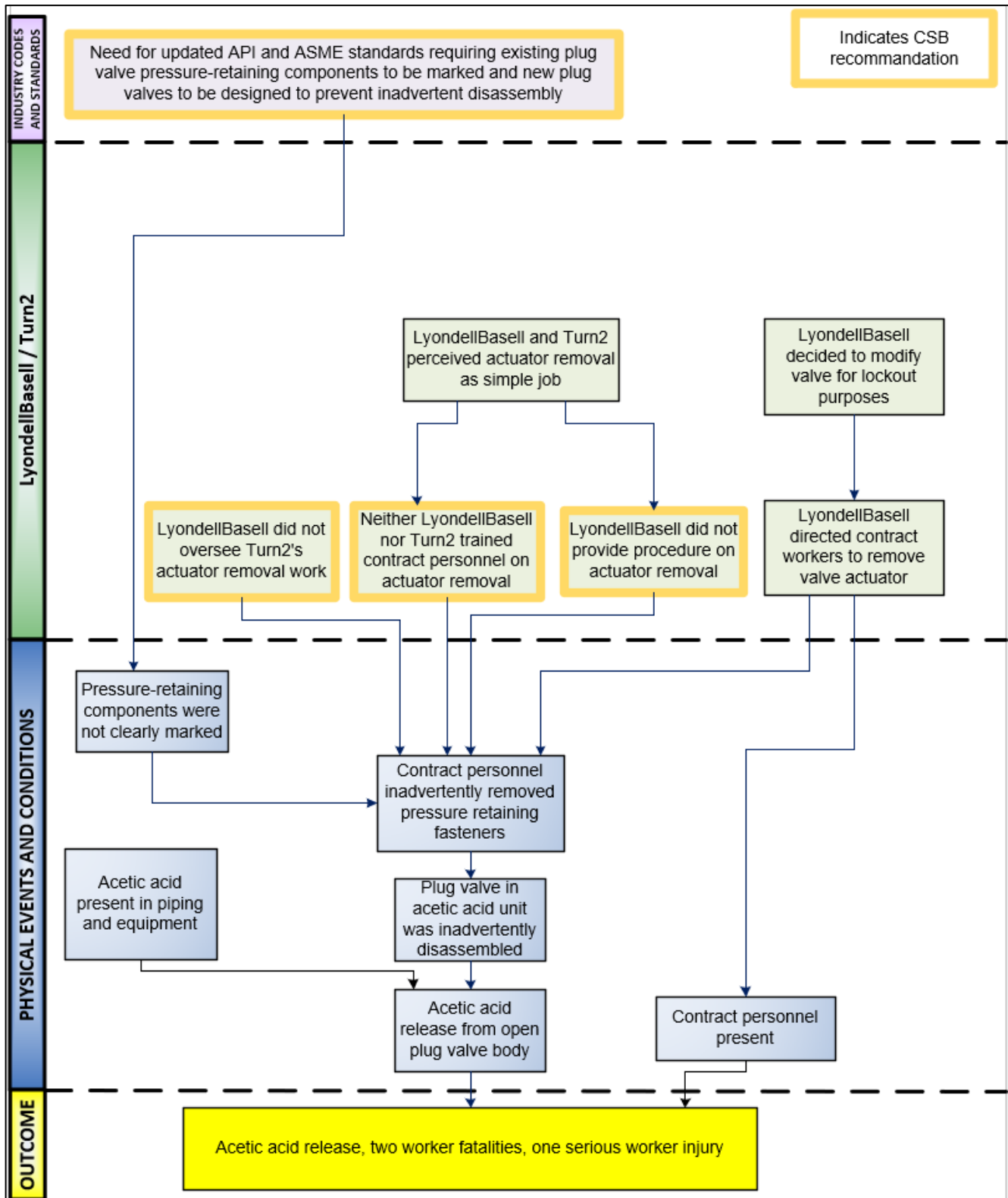
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APPENDIX A—CAUSAL ANALYSIS (ACCIMAP)

I



APPENDIX B—DESCRIPTION OF SURROUNDING AREA

The demographic information of the population residing within about one mile of the LyondellBasell La Porte complex fence line is contained in **Figure 12** and **Table 2** below.

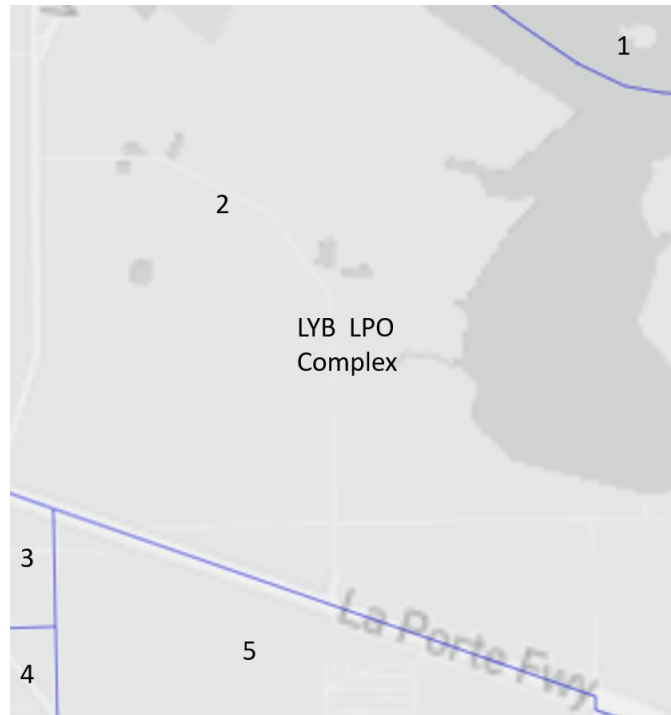


Figure 12. Census blocks within the approximately one-mile distance from the LyondellBasell La Porte complex fence line. (Credit: Census Reporter, with annotations by CSB)

Table 2. Demographic data for the approximately one-mile vicinity of the LyondellBasell La Porte complex. (Credit: Census Reporter)

| Tract Number | Population | Median Age | Race and Ethnicity | | Per Capita Income | Number of Housing Units | Types of Structures | |
|--------------|------------|------------|--------------------|----------|-------------------|-------------------------|---------------------|---------------------|
| | | | | | | | | |
| 1 | 1,740 | 46.5 | 52.0% | White | \$45,721 | 689 | 92% | Single Unit |
| | | | 1.0% | Black | | | 0% | Multi-Unit |
| | | | 0.0% | Native | | | 8% | Mobile Home |
| | | | 2.0% | Asian | | | 0% | Boat, RV, van, etc. |
| | | | 0.0% | Islander | | | X | |
| | | | 0.0% | Other | | | | |
| | | | 0.0% | Two+ | | | | |
| | | | 45.0% | Hispanic | | | | |

| | | | | | | | | |
|---|-------|------|------|----------|----------|-----|------|---------------------|
| 2 | 0 | N/A | 0.0% | White | N/A | N/A | 0% | Single Unit |
| | | | 0.0% | Black | | | 0% | Multi-Unit |
| | | | 0.0% | Native | | | 0% | Mobile Home |
| | | | 0.0% | Asian | | | 0% | Boat, RV, van, etc. |
| 3 | 1,837 | 32.8 | 87% | White | \$35,167 | 610 | 89% | Single Unit |
| | | | 0% | Black | | | 0% | Multi-Unit |
| | | | 0% | Native | | | 11% | Mobile Home |
| | | | 0% | Asian | | | 0% | Boat, RV, van, etc. |
| | | | 0% | Islander | | | X | |
| | | | 0% | Other | | | | |
| | | | 4% | Two+ | | | | |
| | | | 9% | Hispanic | | | | |
| 4 | 1,215 | 49.2 | 83% | White | \$57,752 | 410 | 100% | Single Unit |
| | | | 0% | Black | | | 0% | Multi-Unit |
| | | | 0% | Native | | | 0% | Mobile Home |
| | | | 0% | Asian | | | 0% | Boat, RV, van, etc. |
| | | | 0% | Islander | | | X | |
| | | | 0% | Other | | | | |
| | | | 0% | Two+ | | | | |
| | | | 17% | Hispanic | | | | |
| 5 | 1,477 | 32.8 | 58% | White | \$38,156 | 459 | 100% | Single Unit |
| | | | 0% | Black | | | 0% | Multi-Unit |
| | | | 0% | Native | | | 0% | Mobile Home |
| | | | 0% | Asian | | | 0% | Boat, RV, van, etc. |
| | | | 0% | Islander | | | X | |
| | | | 0% | Other | | | | |
| | | | 1% | Two+ | | | | |
| | | | 41% | Hispanic | | | | |



U.S. Chemical Safety and Hazard Investigation Board

Members of the U.S. Chemical Safety and Hazard Investigation Board:

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Sylvia E. Johnson, Ph.D.
Member

Catherine J. K. Sandoval
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