U.S. Chemical Safety and Hazard Investigation Board

CSB Safety Study: No. 2024-01-H

Remote Isolation of Process Equipment

Introduction

Over the last several years, the U.S. Chemical Safety and Hazard Investigation Board (CSB) has reviewed and investigated numerous incidents where the consequences of these occurrences escalated following a loss of containment due to the lack of effective remote isolation equipment. These incidents resulted in serious injuries, fatalities, environmental contamination, and severe damage to facilities.

In the CSB's report on its investigation of the November 2019 explosions and fires at the TPC Group chemical plant in Port Neches, Texas, the CSB concluded that improved requirements in both industry guidance documents and federal regulations are necessary to help prevent the recurrence of highly destructive and dangerous events involving the release of highly flammable or toxic materials that cannot be isolated. The CSB stated that it would "conduct further analyses of incidents involving lack of remote isolation capability to determine the appropriate course(s) of action to recommend to industry groups and regulatory agencies." [1] As a result, the CSB initiated this Safety Study to review the incidents investigated by the CSB and determine the action needed to address identified gaps and deficiencies in both industry guidance and federal regulations.

Based on this review, the CSB has found that although good industry guidance has been available for many years, the guidance has not been consistently followed. Therefore, the CSB has concluded that remote isolation requirements are needed in both industry standards and federal regulations to help mitigate the consequences of these highly destructive and dangerous events involving the release of highly flammable or toxic materials. As a result, the CSB is issuing three safety recommendations in this Safety Study: one each to the American Petroleum Institute (API), the U.S. Environmental Protection Agency (EPA), and the U.S. Occupational Safety and Health Administration (OSHA), as follows:

American Petroleum Institute (API)

2024-01-H-R1

Develop a new publication or revise an existing publication or publications that should be applicable to various facility types such as refineries, chemical and petrochemical facilities, terminals, etc. with major

1. CSB. Investigation Report: Popcorn Polymer Accumulation, Pipe Rupture, Explosions, and Fires at TPC Group Chemical Plant Butadiene Unit. December 2022. https://www.csb.gov/philadelphia-energy-solutions-pes-refinery-fire-and-explosions-/ (accessed July 1, 2024).

Figure 1. Intercontinental Terminals Company (ITC) fire involving Tank 80-8 on March 17, 2019. (Credit: ABC 13 Houston)

process equipment and atmospheric storage tanks, that details conditions that necessitate the installation of remote isolation devices [use "shall" instead of "should" language] that may be automatically activated or remotely activated from a safe location, particularly during an emergency. When establishing these conditions refer to the guidance published by CCPS entitled ***Guidelines for Fire Protection in Chemical, Petrochemical, and Hydrocarbon Processing Facilities****, Sections 8.1.10 and 8.1.11. At a minimum, the conditions should address major process equipment and atmospheric storage tanks, material volumes/weight as well as flammability, corrosivity, and toxicity.*

U.S. Environmental Protection Agency (EPA)

2024-01-H-R2

Update the Risk Management Program (RMP) rule by expanding the requirements of 40 CFR Part 68 to include an evaluation of the need for remote isolation devices for major process equipment that can be remotely activated from a safe location or automatically activated during a release. The evaluation should be included in hazard assessments, hazard reviews, and process hazard analyses.

Occupational Safety and Health Administration (OSHA)

2024-01-H-R3

Update the Process Safety Management (PSM) standard by expanding the Process Hazard Analysis (PHA) requirements under 29 CFR 1910.119(e)(3) to include an evaluation of the need for remote isolation devices for major process equipment that can be remotely activated from a safe location or automatically activated during a release.

This Safety Study also issues an important and necessary call to action for facilities with highly hazardous chemicals. To prevent future incidents, these facilities must assess whether remote isolation should be applied to major process equipment even in the absence of formal requirements in industry standards and federal regulations – and if so, install effective remote isolation equipment in a location that is safe for workers to activate it. By systematically

evaluating process equipment and applying remote isolation equipment to mitigate loss-of-containment events, companies can save lives; protect workers, communities, and the environment; and safeguard jobs and critical infrastructure vital to our nation's economy.

Lack of Remote Isolation - History Repeats Itself

On August 17, 1975, a 75,000-barrel oil storage tank overfilled and ignited at the Gulf Oil Company (Gulf) refinery in Philadelphia, Pennsylvania, one of the largest petroleum refineries in the U.S. at that time, causing two explosions and a massive fire. Firefighters worked all day to control the fire and were eventually forced to fight the fire while standing in a mixture of water and foam that contained hydrocarbons. The level of the flammable mixture rose throughout the day, until it finally encountered an ignition source, causing a sudden fire that engulfed several firefighters. The tragic incident resulted in the deaths of eight Gulf firefighters, injuries to seven Philadelphia firefighters and four Gulf firefighters, and more than $10 million in damage.[2]

During the incident, a damaged naphtha storage tank was feeding the fire by releasing between 500 and 600 gallons of liquid naphtha every minute.[3] Because the tank was not equipped with a remote isolation valve, firefighters had to take extreme efforts to access and close the valve on the tank manually. According to an article published in the *Ottawa Citizen* on August 19, 1975, firefighters had to push a rowboat through a tank dike that was flooded with hot crude oil, foam, and water as the fire burned around them in order to reach the tank so that they could manually close the valve (shown in Figure 2). Officials told the *Ottawa Citizen* that the firemen sprayed water on the small boat and on the tank to lower temperatures, which were estimated to be as high as 700 degrees Fahrenheit.[4] Had a remotely operated emergency isolation valve been installed on the naphtha storage tank, it could have been closed much sooner and likely would have helped limit the spread of the fire, from a much safer distance, without requiring firefighters to unnecessarily risk their lives.

In 2019, the CSB investigated an incident at the very same refinery, then called the Philadelphia Energy Solutions (PES) Refinery. Although nearly 44 years had passed, the CSB found that once again the lack of remote isolation equipment at the refinery increased the severity of the incident. On June 21, 2019, a pipe elbow in the PES hydrofluoric acid (HF) alkylation unit ruptured, and a large vapor cloud – composed of roughly 95 percent propane, 2.5 percent HF, and other hydrocarbons – engulfed part of the unit. The vapor cloud ignited two minutes after the start of the release, causing a large fire and subsequent explosions. During the incident, over 5,000 pounds of highly toxic HF were released, a 38,000-pound vessel fragment launched off-site and landed on the other side of the Schuylkill River, and an estimated property damage loss of $750 million resulted. In its investigation of the incident, the CSB found that there were no remotely operated emergency isolation valves installed in the HF alkylation unit that could have stopped the release.[5] The CSB concluded that had this safety equipment been available, the release of hydrocarbons from the pipe elbow would have been minimized and the subsequent explosions could have been prevented. Instead, the incident ultimately led to the closing of the facility. In its 2020 report "100

Figure 2. Image of firefighters working to close valve on storage tank. Courtesy of the Special Collections Research Center. Temple University Libraries. Philadelphia, PA.

2. Robert Burke, "Remembering the Gulf Oil Refinery Fire." *Firehouse*. https://www.firehouse.com/rescue/article/10465196/eight-firefighters-died-in-1975-tragedy-in-philadelphia (accessed March 13, 2024).
3. "Six firefighters die in oil refinery blaze". *Ottawa Citizen*. August 19, 1975. https://news.google.com/newspapers?id=nalyAAAAIBAJ&sjid=ku0FAAAAIBAJ&pg=4127%2C574720 (accessed March 13, 2024).
4. *Ibid.*
5. CSB, "Investigation Report: Fire and Explosions at Philadelphia Energy Solutions Refinery Hydrofluoric Acid Alkylation Unit." https://www.csb.gov/csb-releases-final-report-into-2019-pes-fire-and-explosion-in-philadelphia/ (accessed March 13, 2024).

Largest Losses in the Hydrocarbon Industry," Marsh JLT Specialty[6] (Marsh), a global insurance broker and risk adviser, ranked the PES incident as the third-largest refinery loss to occur worldwide since 1974.[7]

Lack of Effective Remote Isolation Capabilities: The Main Issue

The fact that two loss-of-containment incidents at the same facility more than 40 years apart could not be safely isolated and as a result drastically escalated, highlights the key concern. The CSB continues to investigate incidents where the lack of effective remote isolation is a critical factor in the incident severity. Many companies in the chemical industry have not fully recognized that the effective remote isolation of equipment is critical to quickly stopping releases of hazardous materials and can reduce not only worker injuries but also damage to facilities and the environment and risks to surrounding communities. Having the ability to safely, quickly, and effectively isolate a release ultimately saves lives, protects jobs, and safeguards critical infrastructure. These two Philadelphia incidents alone resulted in the deaths of eight firefighters, multiple injuries, more than $760 million in property damage, damage to the environment, and the closing of the facility.

Whether the associated equipment is referred to as remotely operated emergency isolation valves, remotely operated shutoff valves, emergency isolation valves, emergency block valves, or some other name, the topic of remote isolation of process equipment is neither a technically complex issue for the chemical industry, nor a new one. Unfortunately, history often has repeated itself, sometimes at the very same facility as demonstrated above, even though experience has shown that without proper remote isolation capabilities to allow a release to be stopped from a safe location, an incident can escalate from a relatively minor loss of containment to a large-scale chemical release, sometimes resulting in raging fires and explosions that fatally injure workers, destroy facilities, and drastically impact surrounding infrastructure and communities.

The CSB has reviewed and investigated several chemical incidents involving hazardous chemical releases that could not be quickly isolated, and the agency has issued recommendations that led to the development of voluntary standards and industry guidance specific to the remote isolation of process equipment. However, these chemical incidents continue to occur. Based upon the CSB's investigations and findings surrounding these incidents, the CSB concludes that reliance on existing industry guidance concerning remote isolation alone is not sufficient. While strengthening voluntary standards is important, the CSB has concluded that regulatory requirements associated with remote isolation of process equipment are necessary.

It is critical that facilities in the U.S. that use or store large quantities of hazardous chemicals evaluate and improve upon their remote isolation capabilities. A key opportunity to evaluate remote isolation needs is during the Process Hazard Analysis—a systematic review that is required by U.S. regulations to evaluate process hazards and their safeguards.

Select CSB Investigations Involving Lack of Remote Isolation Equipment

Although the need to provide workers with effective remote isolation equipment has been well-established, many facilities in the U.S. chemical industry remain vulnerable. The CSB investigated six incidents – four of them in 2019 alone – in which the lack of remote isolation contributed to the increase in severity and led to a fatality, serious worker injuries, extensive property damage to facilities and nearby homes, severe environmental consequences, and in some cases, company bankruptcy. These incidents are discussed below.

The CSB made important recommendations stemming from the investigations, described in the incident summaries below, that resulted in improvements to industry standards and the creation of best practice guidance. The summaries will demonstrate that despite these improvements, based upon the fact that loss-of-containment incidents continue to escalate due to a lack of safe remote isolation capabilities, the current remote isolation industry standards alone are insufficient.

6. Marsh is a leading insurance broker and risk advisor that provides industry-focused brokerage, consulting, and claims advocacy services, leveraging data, technology, and analytics to help reduce its clients' total cost of risk.
7. Marsh JLT Specialty. "100 Largest Losses in the Hydrocarbon Industry." 26th ed., March 2020 (Online). https://www.marsh.com/en/industries/energy-and-power/insights/100-largest-losses-2024.html (accessed June 11, 2024).

1. Formosa Plastics Propylene Explosion

OCTOBER 6, 2005

On October 6, 2005, a release of highly flammable liquid propylene and a subsequent vapor cloud explosion occurred at the Formosa Plastics Corporation, USA, (Formosa) complex in Point Comfort, Texas, after a forklift towing a trailer collided with a line containing the highly flammable liquid propylene at the facility. Sixteen workers were injured, the process unit was heavily damaged, and a nearby school was evacuated.

Figure 3. Photo included in the CSB Formosa Investigation Report. This photo shows the forklift involved in the incident.

The CSB investigated the incident[8] and found that operators were unable to reach the manual valves capable of stopping the release due to an advancing vapor cloud that forced them to retreat. For the same reason, the operators were also unable to reach the local control station to quickly turn off the pumps supplying propylene. The CSB concluded that had a remotely operated valve been installed upstream of the pumps supplying the propylene, the propylene flow could have been halted and the incident likely would have ended quickly, possibly even before ignition occurred. The CSB also concluded that had remote control of the pumps been possible from the control room, the propylene flow could have been quickly reduced, potentially reducing the severity of the incident.

The CSB noted that remotely operated isolation valves can mitigate consequences of large accidents and stated that companies should address isolation philosophy as part of the hazard review process. While Formosa had addressed isolation of minor leaks, the company's written hazard analysis did not consider a catastrophic loss of containment within the unit. Nor did it consider whether local isolation valves would be accessible or whether remotely operated isolation devices would be necessary in the event of a loss of containment.

The CSB recommended that the Center for Chemical Process Safety (CCPS) incorporate guidance for remote equipment isolation into the next revision of the CCPS's *Guidelines for Hazard Evaluation Procedures*. In response, the CCPS developed new guidance called *Remote Isolation of Process Equipment*.[9] This guidance document provides that "[t]he need for guidance on remote isolation of equipment to minimize loss of containment and its consequences is clear." The CCPS guidance document addresses remote isolation as a way to mitigate the release of hazardous material when there has

8. For a copy of the CSB's case study on the incident *see* https://www.csb.gov/formosa-plastics-propylene-explosion/ (accessed February 1, 2023).
9. J. Murphy, "Remote Isolation and Shut Off," Center for Chemical Process Safety/AIChE. Available at https://www.aiche.org/ccps/remote-isolation-and-shut (accessed January 24, 2023).

been a loss of containment. The CCPS notes that remote isolation of hazardous material can be accomplished with the appropriate location of remotely operated emergency block valves (EBVs). The CCPS recommends the use of remotely operated EBVs because they can be operated safely away from where the loss of containment may occur. The CCPS guidance also provides the following important direction:

- Remotely operated EBVs should be located such that major process equipment or unit operations can be isolated in the event of a loss of containment – examples include at loading/unloading lines in hazardous service; at the inlet and outlet of compressors and reactors; at the inlet of pumps from vessels with 10,000 pounds of flammable material; at major lines entering or leaving a system of vessels containing more than 10,000 pounds of flammable chemicals, which operate together to perform a unit operation such as distillation, refrigeration, or reaction; and at the battery limits for pipelines containing hazardous materials;
- Each chemical process should be evaluated so that EBVs are properly located;
- Automated activation through EBVs provides a more immediate response to potential danger, eliminates potential operator error, and results in more rapid isolation; and
- Advantages of manual activation include avoidance of false trips and avoidance of the potential failure of an automatic device.

The CSB closed its recommendation to the CCPS as an "acceptable action" in November 2008.

Figure 4. Photo included in the CSB Formosa Investigation Report. This photo shows Formosa Emergency Response Team equipment.

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2. Valero McKee Refinery Propane Fire

FEBRUARY 16, 2007

On February 16, 2007, a propane fire erupted at the Valero McKee Refinery in Sunray, Texas, injuring four workers and causing the total shutdown and evacuation of the refinery. The CSB investigated the incident[10] and found that the fire began following a leak in the propane deasphalting (PDA) unit and spread quickly, in part because of the rapid collapse of a major pipe rack carrying flammable hydrocarbons. Some of the rack's support columns had not been fireproofed.

The CSB also found that the rapidly expanding fire prevented field operators from closing manual isolation valves or reaching local pump controls to isolate the high-pressure propane being vented to the atmosphere. Control room operators were unable to shut off the flow of propane because there were no remotely operable shut-off valves, or ROSOVs,[11] in the PDA unit. The CSB stated that ROSOVs should be used in areas, such as the PDA unit, where fast and effective isolation is needed to reduce the impact of major hazardous releases. In this case, the lack of remote isolation significantly increased the size and duration of the fire, resulting in extensive damage to the PDA unit, the main pipe rack, and an adjacent process unit. The CSB also found that the McKee Refinery's process hazard analysis (PHA) failed to identify and address the need for ROSOVs in the PDA unit to rapidly isolate LPG releases. The CSB stated that although the American Petroleum Institute (API) Recommended Practice (RP) 2001, *Fire Protection in Refineries,* discussed the use of isolation valves in emergencies, including considering access to valves during fires, it did not provide specific guidance on the design, location, and use of ROSOVs for the rapid isolation of LPG processes during emergencies.

The CSB recommended that the API revise API RP 2001 and API RP 2030, *Application of Fixed Water Spray Systems for Fire Protection in the Petroleum Industry,* to require that conformance with these recommended practices would include the design, installation, and use of ROSOVs and interlocked equipment controls to enable the safe and rapid emergency isolation of process equipment containing highly pressurized flammables. In response to the CSB's recommendation, the API updated its 2012 version of RP 2001 by adding Section 5.4.3.4.2 on

Figure 5. Photos included in the CSB Valero McKee Investigation Report. This photo is courtesy of the Associated Press.

10. For a copy of the CSB's final investigation report on the incident, *see* https://www.csb.gov/valero-refinery-propane-fire/ (accessed April 28, 2020).
11. ROSOVs, also called emergency isolation valves, are equipped with actuators and are configured to be quickly and reliably operated from a safe location, such as a well-sited control room.

ROSOVs, which states the following:

> *Where a review establishes a need, remotely operated shutoff valves (ROSOV) should be considered during the PHA and FHA [fire hazard analysis] processes. Use of these and other isolation valves should be included in emergency procedures. However, use of automatic (fire or heat actuated) self-closing valves should be used only after a hazard analysis or MOC review to determine whether inadvertent activation may cause undesired consequences. This review should confirm the automatic valve system is inherently safe by a rigorous process safety review since closure of the valve in a nonfire situation or at the wrong time in a fire event may have undesirable consequences, such as causing excessive pressure in a process system or preventing the orderly shutdown sequence of equipment or transfer of product from tanks or vessels during an emergency. The review should include a determination of the safest alternative ("open" or "closed") on loss of power if ROSOV are used. Discussion of emergency valves (ROEIV [remotely operated emergency isolation valve], EIV [emergency isolation valve], EBV [emergency block valve], ROSOV) can be found in API 553 and UK HSE Information Sheet CHIS2.*

Based on the addition of this language to API RP 2001, in July 2016 the CSB closed its recommendation to the API as Acceptable Alternative Action," noting that although the guidance is voluntary, it provides more information on the installation and use of ROSOVs for process units with pressurized flammables. According to the CSB, had Valero McKee followed such practices, the uncontrolled fire likely would have been contained.

Although the CSB closed its recommendation to the API, some language in Section 5.4.3.4.2 nevertheless still needs to be revised. API RP 2001 states, "*Where a review establishes a need, remotely operated shutoff valves (ROSOV) should be considered during the PHA and FHA processes."* The distinction between

Figure 6. Photo included in the CSB Valero McKee Investigation Report. This photo as taken approximately 90 seconds after ignition (from surveillance video).

"a review" that "establishes a need" and "the PHA and FHA processes" is unclear. Incidents continue to occur where there has been a release of large quantities of hazardous chemicals with no means for workers to safely isolate the leak remotely. The change in API RP 2001 was a positive and necessary step, but the standard has not yet achieved incident consequence mitigation. As a logical and reasonable 'next step' in the advancement of process safety, API RP 2001 should specify detailed conditions for when remote isolation devices are required for major process equipment that can be promptly activated from a safe location or automatically activated during an accidental release.

Incidents continue to occur where there has been a release of large quantities of hazardous chemicals with no means for workers to safely isolate the leak remotely. The change in API RP 2001 was a positive and necessary step, but the standard has not yet achieved incident consequence mitigation.

3. Intercontinental Terminals Company Tank Fire

MARCH 17, 2019

On March 17, 2019, a large fire erupted at the Intercontinental Terminals Company, LLC (ITC) bulk liquid storage terminal located in Deer Park, Texas. The fire originated in the vicinity of Tank 80-8, an 80,000-barrel aboveground atmospheric storage tank that contained a blend of naphtha and butane, a flammable liquid typically used as a feedstock or blend stock for the production of gasoline. ITC was unable to isolate or stop the release of naphtha product from the tank, and the fire continued to burn, intensify, and spread to an additional 14 tanks located in the same containment area. The fire caused substantial property damage, including the destruction of fifteen 80,000-barrel aboveground atmospheric storage tanks and their contents. The fire burned for three days, until it was extinguished on March 20, 2019. This incident also significantly impacted the environment. A containment wall around the tanks was breached and released an estimated 21 million gallons of hydrocarbon and petrochemical products, firefighting foam, and contaminated water into Tucker Bayou and adjacent water, sediments, and habitats. From there, the released materials flowed into Buffalo Bayou, and on to the Houston Ship Channel and surrounding waters. Because of the contamination, a seven-mile stretch of the Houston Ship Channel was closed, as were several waterfront parks in Harris County and the city of LaPorte. In addition, the local community experienced serious disruptions, including several shelter-in-place orders due to benzene-related air quality concerns. A shelter-in-place was issued for the entire City of Deer Park, and local schools and businesses either closed or operated under modified conditions. A portion of a major highway in the area was also closed. ITC estimated that property damage resulting from the incident exceeded $150 million.

The CSB found that Tank 80-8 and the other aboveground storage tanks located in the tank farm were not equipped with remotely operated emergency isolation valves, or ROEIVs, that would allow for quick and reliable operation from a safe location. The butane-enriched naphtha product that was released from Tank 80-8 via a failed pump could not be remotely or automatically isolated, and it fueled the fire that intensified around the tank.

In general, the need for this type of remote isolation equipment would have been identified through hazard assessments, such as those required by the OSHA Process Safety Management (PSM) standard and the EPA Risk Management Program (RMP) rule, as well as insurance company audits and/or corporate risk evaluations. Unfortunately, because of an exemption related to atmospheric storage tanks, the PSM

Figure 7. Photos included in the CSB ITC Investigation Report. The photo on the eft shows the initial ITC tank fire that ignited at Tank 80-8 on March 17, 2019 (Credit: HCFMO). The photo on the right shows the ITC fire involving Tank 80-8 as it progressed on March 17, 2019 (Credit: ABC13 Houston).

Figure 8. Photo included in the CSB ITC Investigation Report. This photo shows an overhead view of the First & Second 80's tank farm containment wall failure that allowed materials to enter the surrounding waterways on Friday, March 22, 2019. (Credit: ITC).

standard did not apply to the tanks in the tank farm. The EPA RMP rule also did not apply due to ITC's characterization of the flammability of the butane-enriched naphtha product.[12]

An insurance audit conducted for the ITC Deer Park terminal in October 2018 indicated that storage tanks located in another area of the terminal were equipped with electric motor operated valves (MOVs). These MOVs were programmed to close automatically, and the feed pumps were programmed to shut down automatically, under certain scenarios. Although ITC had equipped twelve of the fifteen 80,000-barrel storage tanks in the impacted tank farm with ROEIVs, Tank 80-8 was not one of them. Also, ITC did not equip these tanks with shut-off valves that would fail closed,[13] for example by installing fusible link valves, programming logic, or other protective measures to help ensure that these valves would automatically close in the event of a power outage, fire, or other event. The CSB concluded that ITC's decision not to equip Tank 80-8 with ROEIVs contributed to emergency responders' inability to control the fire early in the response, enabling a single pump seal failure to escalate to a catastrophic incident. As a result, the CSB recommended that ITC install ROEIVs at the Deer Park Terminal configured to "Fail-Closed" for all atmospheric storage tanks that contain highly hazardous chemicals or liquids with a flammability rating of National Fire Protection Association (NFPA)-3 or higher.

In addition, the CSB provided a key lesson for the industry:

> *Companies that handle large volumes of flammable or highly hazardous substances should assess their capability to remotely isolate these substances in the event of a loss of containment. Aboveground atmospheric storage tanks that contain large volumes of these substances should be equipped with remotely operated emergency isolative valves (ROEIVs) so that releases can be mitigated quickly and remotely from a safe location. The ROEIVs should be equipped with fusible links or configured to automatically close in the event of a power outage or other event ("Fail-Closed").*

12. As a result of these findings, the CSB issued the following recommendations to OSHA and EPA:
    CSB Recommendation No. 2019-01-I-TX-R7 to OSHA:
    Eliminate the atmospheric storage tank exemption from the PSM standard.

    CSB Recommendation No. 2019-01-I-TX-R8 to EPA:
    Modify 40 CFR §68.115(b)(2)(i) to expand coverage of the RMP rule to include all flammable liquids, including mixtures, with a flammability rating of NFPA-3 or higher.
13. "Fail closed" means that a device or system is set to shut down and prevent further operation when failure conditions are detected.

4. KMCO, LLC Fatal Fire and Explosion

APRIL 2, 2019

On April 2, 2019, a flammable isobutylene vapor cloud exploded at the KMCO, LLC (KMCO) facility in Crosby, Texas. The event resulted in one fatality and two serious injuries. The incident occurred while KMCO operations staff were making a batch of sulfurized isobutylene, a lubrication additive product. At 10:41 a.m., a fist-sized piece of metal broke away from the body of a three-inch cast iron y-strainer in the batch reactor's liquid isobutylene supply piping. KMCO's operations staff moved other workers out of the immediate area and entered the release area and manually closed valves. This stopped the flow of isobutylene, but more than 10,000 pounds of it had already been released and a vapor cloud formed. The vapor cloud suddenly exploded, killing one of two operators who were within the cloud and seriously burning the other operator and a nearby shift supervisor. The explosion also substantially damaged portions of the KMCO facility. News outlets reported that the explosion shook nearby homes and was heard throughout the surrounding community.

The CSB found that when the y-strainer ruptured, KMCO's workers lacked the ability to isolate the isobutylene release from a safe location, such as from within the blast-resistant control room. Had KMCO workers been able to close the actuated block valve installed just upstream of the y-strainer from the control room, the amount of isobutylene released and the subsequent harm to workers could have been greatly reduced.

The CSB found that when the y-strainer ruptured, KMCO's workers lacked the ability to isolate the isobutylene release from a safe location, such as from within the blast-resistant control room. Had KMCO workers been able to close the actuated block valve installed just upstream of the y-strainer from the control room, the amount of isobutylene released and the subsequent harm to workers could have been greatly reduced. The CSB noted that a 2010 report developed from insurance underwriting purposes had advised KMCO that the lack of remote isolation capability had the potential for a significant incident and recommended that KMCO expand its existing PHA program to include the analysis of the largest flammable

Figure 9. Photo included in the CSB KMCO Investigation Report. The photo shows a life flight helicopter that responded to the incident to transport injured workers. (Credit: ABC).

liquid release sources and commit to the installation of fire-safe, remote-actuated automatic isolation valves in strategic process areas, especially those involving isobutylene (as well as ethylene oxide and propylene oxide). At the time of the April 2019 incident, however, KMCO had not addressed this recommendation for its isobutylene system. Neither KMCO's 2014 PHA nor its 2015 PHA included any discussion of remote isolation or recommendations to equip the isobutylene system with remote isolation valves.

Following this incident, KMCO filed for bankruptcy, and the company is no longer in business. Consequently, the CSB did not make any recommendations to KMCO.[14] However, the CSB provided the following key lesson for industry:

> *The goal of keeping workers safe and the goal of quickly isolating releases to minimize the consequences of an incident should not be mutually exclusive. Both can be achieved by applying robust safety systems and establishing effective emergency response programs. Providing remotely operated emergency isolationvalves in strategic locations can allow workers to stop a release quickly from a safe location.*

Figure 10. Photos included in the CSB KMCO Investigation Report. The photo shows an aerial view of the fire.

14. Altivia Oxide Chemicals, LLC (Altivia) purchased the Crosby, Texas, facility in 2020 and informed the CSB that the process involved in the incident would be dismantled as part of Altivia's efforts to install two new oxide reactors and start production by the end of 2020. As a result, the CSB did not issue any recommendations to Altivia either. Nevertheless, the CSB urged Altivia to read this report closely and understand the factors that led to the incident at the KMCO facility and the lessons stemming from it. The CSB also stated that if hereafter Altivia reinitiates the process or any equipment involved in this incident, the company should ensure that the facts, conditions, and circumstances that caused the incident—and contributed to its severity—are not repeated.

5. Philadelphia Energy Solutions Refinery Fire and Explosions

JUNE 21, 2019

On June 21, 2019, a pipe elbow ruptured in the Philadelphia Energy Solutions (PES) hydrofluoric acid (HF) alkylation unit, resulting in a large vapor cloud – composed of roughly 95 percent propane, 2.5 percent HF, and other hydrocarbons – that engulfed part of the unit and ignited two minutes after the start of the release, causing a large fire. Three explosions occurred shortly thereafter. Roughly 40 minutes into the release, a refinery worker was able to manually turn on the water pump that supplied the HF mitigation water cannons, which then allowed the cannons to spray water to help suppress the released HF. PES estimated that roughly 676,000 pounds of hydrocarbons and over 5,200 pounds of

Figure 11. Photos included in the CSB PES Investigation Report. The photos show video stills of the explosions (Credit: NBC10 Philadelphia).

Figure 12. Photo shows an aerial view of the fire at the PES refinery. (Credit: CBS Philadelphia.)

Figure 13. Photo of fire erupting at the PES refinery. (Credit: CNN).

highly toxic HF were released during the event. Five workers experienced minor injuries. The incident resulted in an estimated property damage loss of $750 million and ultimately led to the facility closing.

The CSB found that there were no ROEIVs installed in the HF alkylation unit to remotely and automatically isolate the large hydrocarbon sources adjacent to the failed elbow. The CSB concluded that had PES installed such valves, the release of hydrocarbons from the pipe elbow would have been minimized and subsequent explosions would have been prevented.[15] Based on these findings, the CSB issued a recommendation to the API to update API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units* to require, among other things, installation of ROEIVs on the inlet(s) and outlet(s) of all HF containing vessels, and hydrocarbon containing vessels that meet defined threshold quantities. This recommendation remains open at the time of this Safety Study.

The CSB found that there were no ROEIVs installed in the HF alkylation unit to remotely and automatically isolate the large hydrocarbon sources adjacent to the failed elbow. The CSB concluded that had PES installed such valves, the release of hydrocarbons from the pipe elbow would have been minimized and subsequent explosions would have been prevented.

15. CSB. "Investigation Report: Fire and Explosions at Philadelphia Energy Solutions Refinery Hydrofluoric Acid Alkylation Unit." https://www.csb.gov/csb-releases-final-report-into-2019-pes-fire-and-explosion-in-philadelphia/ (accessed March 27, 2024).

6. TPC Group Port Neches Explosions and Fire

NOVEMBER 27, 2019

On November 27, 2019, a series of explosions occurred at the TPC Group (TPC) Port Neches Operations (PNO) facility, located in Port Neches, Texas, after highly flammable butadiene was released from the process unit. The explosions caused extensive facility damage, which included a process tower that propelled through the air and landed within the facility, multiple other process towers that fell within the unit, and fires that burned for more than a month within the facility. The butadiene unit was destroyed, forcing the facility to cease butadiene production operations indefinitely. Two TPC employees and a contractor reported minor injuries, and at least five local residents reported injuries. The explosion damaged nearby homes and buildings, and media reports indicated that the blast was felt up to 30 miles away. The explosion also led to reduced usage of the Sabine-Neches Waterway, the nation's third largest waterway by cargo volume and a major economic driver in the U.S. The incident caused $450 million in on-site property damage and $153 million in off-site property damage to nearby homes and businesses.[16]

The CSB found that a dangerous substance known as popcorn polymer, which can form in processes with high-purity butadiene, accumulated in a temporary dead leg[17] in piping at the facility that was created when a process pump was taken out of service for maintenance. During the offline period, popcorn polymer developed and exponentially expanded in the dead leg piping section until the pressure in the piping increased to the point that the piping ruptured, releasing butadiene from the process unit.

The CSB noted that in April 2016, in connection with a review of the facility, the insurance company FM Global had observed that the butadiene process unit was not equipped with ROEIVs and stated:

> *This large C4 Processing Plant has a large single area where crude C4 products are distilled, extracted, reacted, and distilled again into different product streams. Across the units, the plant reports there are no emergency motorized shutoff valves except for a few within the Tank Farm. Engineering has estimated depressurization to take up to 10 to 12 hr. in some sections of the process unit. Due to the minimal distance between process blocks across the Gantry ways, access for manual firefighting is fair, at best. Emergency isolation will help limit the size of a release. This could greatly aid in manual firefighting efforts and prevent more processing areas getting involved. Also, by reducing the fire area, property damage and the time to complete repairs will also be reduced.*[18]

FM Global recommended that TPC "improve remote isolation capabilities within the tank farm and within the process units." The FM Global report stated that TPC should "[i]solate the incoming and outgoing lines of columns, exchangers, tanks, and vessels with holdups in excess of 1,500 gal. (roughly 10,000 lb[s].)."[19]

The CSB concluded that had the TPC PNO butadiene process been equipped with remote isolation valves, it is possible that (1) the feed to the column upstream of the release could have been stopped shortly after the release began, minimizing the size of the initial vapor cloud, and (2) any secondary releases caused by the initial explosion could have been mitigated early in the incident. Stopping the release(s) through the use of remotely operated valves could have prevented some of the subsequent explosions and fires, thereby minimizing the damage caused by the incident.

The CSB analyzed API RP 553, *Refinery Valves and Accessories for Control and Safety Instrumented*

16. CSB. Investigation Report: Popcorn Polymer Accumulation, Pipe Rupture, Explosions, and Fires at TPC Group Chemical Plant Butadiene Unit. December 2022. https://www.csb.gov/philadelphia-energy-solutions-pes-refinery-fire-and-explosions-/ (accessed March 27, 2024).
17. A dead leg is a piping segment is open to the process but does not have flow through it (for example due to a closed valve in the segment, preventing flow).
18. CSB Investigation Report. TPC. December 2022; pp 46-47. https://www.csb.gov/tpc-port-neches-explosions-and-fire/ (accessed May 7, 2024).
19. *Id* at 47.

Figure 14. Photos included in the CSB TPC Investigation Report. The photo on the left shows the explosion. The photo on the right also shows the explosion at 1:48 p.m. on November 27, 2019, which propelled one of the unit towers into the air. (Credit: Huntsman Corporation).

Systems, which provides recommendations for emergency block valves (EBVs). TPC had relied on this standard at its facility. RP 553 defines EBVs as "a means of isolating flammable or toxic substances in the event of a leak or fire"[20] and classifies EBVs into four types:

- **Type A:** "A manually operated fire-safe block valve installed at the equipment. This type of valve is installed when ignition is not expected in the event of a leak."
- **Type B:** "This fire-safe block valves should be installed at minimum of 7.6 m (25 ft) from the leak source when ignition is expected. The Type B valve is manually operated and is limited to sizes up to and including [8 inches in diameter] …"
- **Type C:** "The Type C valves is a power-operated Type B valve. The valve should be power-operated if larger than [8 inches in diameter]. … Controls are accessible from the valve location."
- **Type D:** "This is an EBV with remote controls. There is no restriction as to where the valve may be located, but the controls should be a minimum of 12 m (40 ft) from the leak source and should be out of the fire zone."[21]

The CSB noted that API RP 553 does not detail conditions for which a Type D (remotely operated) EBV is required and concluded that had the TPC facility been equipped with "Type D" EBVs, the feed to the Final Fractionator A column could have been stopped shortly after the release began, potentially minimizing the size of the initial vapor cloud, and any secondary releases caused by the initial explosion could have been stopped early in the incident. Stopping the releases by using ROEIVs could have prevented some of the subsequent explosions, thereby minimizing the damage caused by the incident.

Although the CSB did not issue any recommendations relating to ROEIVs, the CSB provided a key lesson for industry in its investigation report:

> *Companies that handle large inventories of flammable or toxic material should assess their capability to remotely isolate these inventories in the event of a loss of process containment. Manual and locally controlled emergency block valves ("Type A," "Type B," and "Type C," as defined by API RP 553) serve no reliable function in catastrophic incidents, since the valves often cannot be safely accessed during these events, thereby preventing the ability to isolate equipment and stop releases. Equipment that handles large inventories of flammable or toxic material should be equipped with "Type D" remotely operated emergency isolation valves so that hazardous releases can be quickly and remotely stopped from a safe location.*[22]

20. API RP 553. *Refinery Valves and Accessories for Control and Safety Instrumented Systems.* October 2012; p 94.
21. *Id* at 7.
22. CSB Investigation Report. TPC. December 2022; p 50.

Conditions that Necessitate Remote Isolation

While API RP 553 and RP 2001 apply to petroleum refineries, the incidents discussed above demonstrate that remote isolation guidance and requirements should be addressed in a variety of operations at a variety of facility types and industry segments that have major process equipment and atmospheric storage tanks.

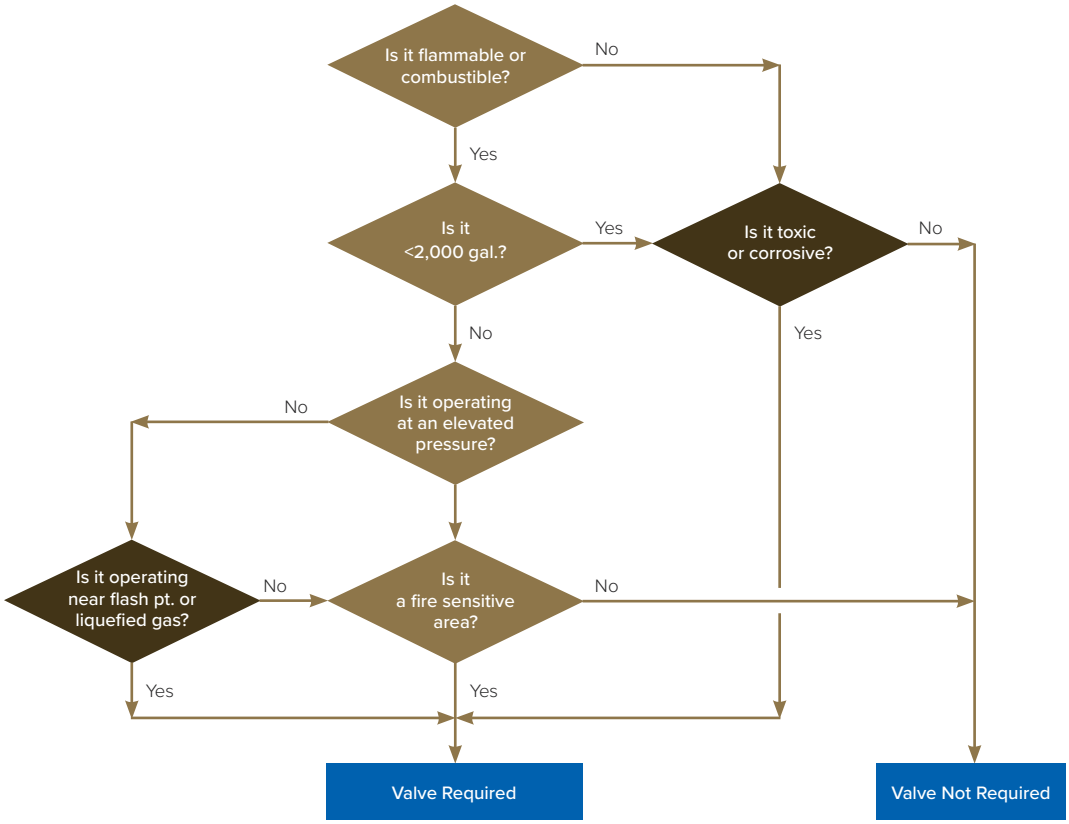

Figure 15. Remote Isolation Decision flow chart. Credit: CCPS.

Moreover, although the API does not establish criteria for when remote isolation is needed, the CCPS does. In 2003, the CCPS produced guidance for remote isolation equipment in its book *Guidelines for Fire Protection in Chemical, Petrochemical, and Hydrocarbon Processing Facilities.*[23] In the book, the CCPS provides general guidance on when to provide remote isolation capability. For example, the CCPS states:

> *Equipment such as pumps, compressors, tanks, and vessels associated with large inventories of flammable gas or liquid (>5,000 gallons) should be provided with equipment emergency isolation valves to stop the flow of material if a leak occurs.*[24]

In addition to general guidance, however, the CCPS provides a flow chart as an example of a tool that companies can use to determine whether remote isolation equipment should be installed, and where.[25] This chart is illustrated in Figure 15 above.

The CSB found in its KMCO investigation that had this tool been applied to KMCO's isobutylene system, remote isolation equipment should have been provided. The CSB applied this tool, which has been available since 2003, to the other incidents discussed in this Safety Study, all of which occurred after 2003. The CSB determined that had the tool been applied to each facility's system that experienced the loss of containment, effective remote isolation equipment should have been provided. Had appropriate remote isolation equipment been provided, the major consequences of all the incidents would likely have been significantly mitigated. The CSB believes that many more incidents could be mitigated by facilities applying this tool or a similar tool to their systems during hazard reviews to determine the need for effective remote isolation capabilities from a safe location.

23. CCPS, Guidelines for Fire Protection in Chemical, Petrochemical, and Hydrocarbon Processing Facilities. New York: Center for Chemical Process Safety. 2003.
24. *Id at* 123.
25. *Id* at 267.

National Transportation Safety Board Recommendation on Remote Isolation

The CSB is not the only federal investigative agency that has examined the role that a lack of remote isolation capabilities plays in the severity of an incident. On September 9, 2010, a 30-inch-diameter segment of an intrastate natural gas transmission pipeline known as Line 132, owned and operated by the Pacific Gas and Electric Company (PG&E), ruptured in a residential area in San Bruno, California. PG&E estimated that 47.6 million standard cubic feet of natural gas were released. The gas ignited, resulting in a fire that destroyed 38 homes and damaged 70 others. Eight people were killed, many were injured, and many more were evacuated from the area. The National Transportation Safety Board (NTSB) investigated the incident and found that the lack of either automatic shutoff valves or remote-control valves on the line contributed to the severity of the accident.[26] As a result, the NTSB issued Recommendation P-11-011 to the Pipeline and Hazardous Materials Safety Administration (PHMSA):

> *Amend Title 49 Code of Federal Regulations 192.935(c) to directly require that automatic shutoff valves or remote control valves in high consequence areas and in class 3 or 4 locations be installed and spaced at intervals that consider the factors listed in that regulation.*[27]

On April 8, 2022, PHMSA published a final rule titled "Pipeline Safety: Requirement of Valve Installation and Minimum Rupture Detection Standards" amending the Federal Pipeline Safety Regulations (49 CFR parts 190 through 1999). Among other provisions, the new rule requires the installation of rupture-mitigation valves, also known as remote control or automatic shut-off valves, or alternative equivalent technologies, and establishes minimum performance standards for the operation of those valves to mitigate the public safety and environmental consequences of pipeline ruptures.[28] The final rule became effective on October 5, 2022, but it does not address all the NTSB recommendation requirements. The NTSB notes on its website that PHMSA plans to take several additional actions to address the gaps in the rulemaking and satisfy the intent of the NTSB's recommendation, including:

- Updating PHMSA's special permit conditions
- Creating a new directive on valves; and
- Requiring operators to inform PHMSA of the number of valves installed on their systems to protect high consequence areas and class 3 and 4 segments, and how they are monitored and operated for emergency closure.

As a result, the NTSB has classified the recommendation as "Open – Acceptable Alternate Response."[29]

Figure 16. Police photo of San Bruno Pipeline fire.

26. For additional information on this incident, visit https://www.ntsb.gov/investigations/Pages/DCA10MP008.aspx (accessed May 9, 2024).
27. For additional information on this recommendation, visit https://data.ntsb.gov/carol-main-public/sr-details/P-11-011 (accessed May 9, 2024).
28. 87 Fed. Reg. 20940. https://www.federalregister.gov/documents/2022/04/08/2022-07133/pipeline-safety-requirement-of-valve-installation-and-minimum-rupture-detection-standards (accessed May 9, 2024).
29. See https://data.ntsb.gov/carol-main-public/sr-details/P-11-011 (accessed May 0, 2024).

Guidance on Remote Isolation by the U.K. Health and Safety Executive

Per this Safety Study, the CSB also examined the topic of remote isolation on a global scale. The United Kingdom (U.K.) has implemented regulatory guidance on this topic, which could be an example for future U.S. regulations.

Following a series of serious incidents where the lack of remote isolation played a key role in the severity of each incident, the U.K.'s Health and Safety Executive (HSE), which regulates workplace safety, developed robust guidance for facilities that use or store hazardous chemicals to assess whether remote isolation is needed, along with detailed steps for implementation.

In 2004, the HSE developed guidance entitled *Remotely operated shutoff valves (ROSOVs) for emergency isolation of hazardous substances* to assist facilities in assessing whether there is a need for a ROSOV[30] on an existing or new piece of equipment and provide detailed steps for implementation. The HSE noted that the development of this guidance was influenced by the investigation of an incident at the Associated Octel Company Limited (Octel) at Ellesmere Port, Cheshire, England, in February 1994, as well as the investigation of a fire in the fluidized bed catalytic cracking unit at the BP Grangemouth Refinery in Scotland in June 2000.[31] Both of these incidents are described below. According to the HSE, this guidance was necessary because "[i]n an emergency, rapid isolation of vessels is one of the most effective means of preventing a loss of containment or limiting its size."[32]

1. Associated Octel Company Chemical Limited Release and Fire

On February 1, 1994, a release of reactor solution from a recirculating pump near the base of an ethyl chloride (EC) reactor vessel occurred at the Octel plant in Ellesmere Port, Cheshire, England.[33] The reactor solution was highly flammable, corrosive and toxic, and a white cloud soon enveloped the facility. Almost two hours later, after various unsuccessful attempts to isolate and mitigate the leak, the flammable vapors of the reactor solution ignited, resulting in a major fire.[34] The incident caused extensive damage to the plant, requiring a complete rebuild. The HSE investigated the incident and concluded that it had escalated rapidly because the facility was unable to stop the initial release. The manually operated valves, which could have isolated the inventories in the three process vessels, were very difficult to access during the emergency because of their location. According to the HSE, "These problems could have been prevented and the inventories rapidly isolated if remotely operated shut off valves (ROSOVs) had been installed."[35] As a result of this finding, the HSE issued Lesson 5, which states:

> *As part of their comprehensive risk assessments, companies in control of chemical process plants at major hazards sites should critically review the provision of remotely operated shut off valves (ROSOVs) at both storage and process vessels in which significant inventories of dangerous substances are held.*[36]

30. HSE defines a ROSOV as *a "valve designed, installed and maintained for the primary purpose of achieving rapid isolation of plant items containing hazardous substances in the event of a failure of the primary containment system (including, but not limited to, leaks from pipework, flanges, and pump seals). Closure of the valve can be initiated from a point remote from the valve itself. The valve should be capable of closing and maintaining tight shutoff under foreseeable conditions following such a failure (which may include fire).* HSE. "Remotely operated shutoff valves (ROSOVs) for emergency isolation of hazardous substances: Guidance on good practice." 2004; p 4. https://www.hse.gov.uk/pubns/priced/hsg244.pdf. (Accessed May 7, 2024).
31. HSE. "Remotely operated shutoff valves (ROSOVs) for emergency isolation of hazardous substances: Guidance on good practice." 2004; p 4. https://www.hse.gov.uk/pubns/priced/hsg244.pdf. (Accessed March 13, 2024).
32. *Ibid.*
33. Octel is a chemical manufacturing company. The prime activity at this site has been the production of motor fuel anti-knock compounds.
34. HSE. "The chemical release and fire at the Associated Octel Company Limited: A Report of the Investigation by the Health and Safety Executive into the Chemical Release and Fire at the Associated Octel Company, Ellesmere Port, Cheshire. 1st February 1994." p 1. https://www.hse.gov.uk/comah/sragtech/caseoctel94.htm (accessed June 11, 2024).
35. *Id* at 40.
36. *Ibid.*

In addition, the HSE issued Lesson 6:

> *HSE, in conjunction with other interested parties, should develop and publish additional guidance on the provision of ROSOVs and other methods of mitigating risks on process plant.*[37]

2. BP Grangemouth Fire

Between May 29, 2000, and June 10, 2000, three incidents occurred at the BP Grangemouth Complex ("the Complex") in Scotland. The public expressed concern to the HSE due to the frequency and pattern of these three incidents, as well as their potential to be more serious. The HSE investigated the incidents and on August 18, 2003, released a Major Incident Investigation Report.

The HSE found that the Fluidized Catalytic Cracker Unit (FCCU) at BP Grangemouth was shut down on May 29, 2000, following a power distribution failure. On June 10, 2000, during start-up procedures that began the day before, there was a significant leak of hydrocarbons from the FCCU, creating a vapor cloud that ignited, resulting in a serious fire. The fire was extinguished several hours later. HSE determined that the leak was a result of the fracture of a tee branch pipe due to fatigue failure. This resulted in the release of highly flammable liquid at elevated temperature and pressure, which found an ignition source nearby and ignited. The HSE concluded that the failure of the tee-piece connection pipework was likely caused by a combination of the incorrectly fitted tee-piece connection, the inadequately supported pipework, and the cyclic stresses caused by the increased start-up/shutdown activity on the plant. This eventually led to fatigue and failure of the piping.[38]

As a result of its investigation, the HSE recommended, among other things, that prior to restart BP install ROSOVs to allow for rapid remote isolation of significant process inventories in order to minimize the consequences of an uncontrolled leak and to allow for remote emergency shutdown of ancillary equipment, such as pumps.[39] The HSE also recommended that BP review its philosophy on remote isolation and its implications for other plants on the Complex.[40]

Following its investigation the HSE developed and released its ROSOV guidance.[41] The guidance states that facilities should assess the need to fit a ROSOV "wherever there is the potential for a major accident as a result of loss of containment of a hazardous substance, the consequences of which could be significantly reduced by rapid isolation."[42] According to the HSE, manual valves "should never be used in situations where the employee effecting the isolation would be placed in danger."[43] The potential for a major accident, according to the document, depends on a range of factors, including:

- The nature and properties of the substance;
- The quantity of substance released;
- The size and nature of populations at risk and their proximity to the plant; and
- The presence of other plant equipment including confining structures and other hazardous inventories (escalation potential).[44]

Ultimately, according to the HSE, the decision of whether to implement remote isolation is based on an assessment of:

- The likelihood that the major accident will occur; and
- The consequences (in terms of the extent and severity of harm to people).[45]

37. *Ibid.*
38. HSE. "Major Incident Investigation Report: BP Grangemouth Scotland, 29th May – 10th June 2000; A Public Report Prepared by the HSE on Behalf of the Competent Authority." August 18, 2003; pp 58-59.
39. *Id* at 62.
40. *Id* at 63.
41. HSE. "Remotely operated shutoff valves (ROSOVs) for emergency isolation of hazardous substances: Guidance on good practice." 2004. https://www.hse.gov.uk/pubns/priced/hsg244.pdf. (Accessed March 13, 2024).
42. HSE. "Remotely operated shutoff valves (ROSOVs) for emergency isolation of hazardous substances: Guidance on good practice." 2004; p 13. https://www.hse.gov.uk/pubns/priced/hsg244.pdf. (Accessed March 13, 2024).
43. *Id* at 14.
44. *Ibid.*
45. *Ibid.*

Global Perspectives on Remote Isolation

The concept of installing remote isolation equipment at chemical facilities is not new and has been examined at length by highly regarded process safety experts around the world. For example, in a 1969 safety newsletter, process safety pioneer Trevor Kletz discussed three accident reports where explosions had fatal consequences.[46] One accident occurred in Africa, one in Germany, and one in the United States. Among other things, Kletz, who worked as a safety advisor at Imperial Chemical Industries (ICI) at the time, called out two important lessons from these reports:

- The need for automatic gas detectors in places where leaks are likely to occur; and
- The need for remotely operated isolation valves, so that leaks can be isolated from a safe location.[47]

In 1975, Kletz wrote another safety newsletter for *Chemical Engineering Progress*[48] entitled "Emergency Isolation Valves for Chemical Plants," which noted that it was impractical to install emergency isolation valves for every piece of equipment which might leak; rather, they should be installed only when the chance of a leak is significant, or the potential consequences are serious.[49] Kletz noted three situations that should be considered:

1. The equipment is particularly likely to leak; for example, very hot or cold pumps.
2. The equipment is less likely to leak, but if it does leak, a very large quantity of material will run out and there is no way to stop it; and
3. The equipment is less likely to leak, but if it does so, the leak will be very large.[50]

Additionally, Sam Mannan, a world-renowned expert on chemical process safety and the former executive director of the Mary Kay O'Connor Process Safety Center (MKOPSC), wrote in 2012 that the operation of emergency isolation valves should be sufficiently remote so that the operator can close them readily in an emergency, without having to approach a gas

46. Trevor Kletz, "Imperial Chemical Industries Heavy Organics Division, Safety Newsletter Introduction" and "Imperial Chemical Industries Heavy Organics Division, Safety Newsletter Issue 14." 1969. IChemE provides the entire series of ICI Newsletters on its website.
47. *Ibid.*
48. Chemical Engineering Progress is a publication of the American Institute of Chemical Engineers (AICHE).
49. Trevor Kletz, "Emergency Isolation Valves for Chemical Plants." Chemical Engineering Progress, Volume 71, No. 9. September 1975; p 137.
50. *Ibid.*

cloud or a fire or use a ladder. The most ideal situation, according to Mannan, is remote operation from the control room.[51]

According to a guidance document by Marsh, the ability to isolate large inventories of hazardous materials promptly and safely is a key design consideration and risk-control measure for process equipment. According to Marsh, the most effective method for isolation is through the use of ROEIVs.[52] Marsh defines ROEIVs as safety-critical equipment whose primary purpose is to provide effective and timely isolation of plant equipment containing hazardous substances in the event that the primary containment system fails, including leaks from piping and associating fittings.[53]

In a paper presented at the 2020 Virtual Spring Meeting and 16th Global Congress on Process Safety, 54th Annual Loss Prevention Symposium, the authors H. Pimenta of FM Global and M. Martins of the University of San Paulo, argued, as Kletz had in 1975, that emergency isolation valves are impracticable for every piece of equipment. Defining the locations for remote isolation valves in a facility is extremely important and can be done using elements of process safety such as Management of Change (MOC) and PHA.[54] According to Pimenta and Martins, emergency isolation valves are highly recommended for the following conditions:

- The system (equipment and piping) is particularly likely to leak ignitable liquids (i.e. very hot or cold pumps);
- The size of the vessel exceeds 660 gallons; or
- The expected leak rate is greater than 66 gallons per minute.[55]

Pimenta and Martins also listed the following as minimum criteria for emergency isolation valves:

- Closes within five seconds after actuation;
- Closes on failure of the electrical supply, air supply, or release of fusible element;
- Closes in the direction of the liquid flow so system pressure may hold the valve in the closed position;
- Closes against a pressure of at least 150 percent of the design rating;
- Is installed to prevent alterations (bypass, blockage) that will make the valve ineffective;
- Can only be reset manually; and
- Must withstand a fire for at least 15 minutes.[56]

These perspectives clarify not only when remote isolation equipment is necessary, but also what type of isolation valve is appropriate for each process or situation.

Marsh defines ROEIVs as safety-critical equipment whose primary purpose is to provide effective and timely isolation of plant equipment containing hazardous substances in the event that the primary containment system fails, including leaks from piping and associating fittings.

51. Sam Mannan, *Lees' Loss Prevention to the Process Industries, Volumes 1-3 – Hazard Identification, Assessment and Control (4th Edition) – 12.7.13 Valve Interlocks.* 2012; p 529. Retrieved from https://app.knowvel.com/hotlink/pdf/id.kt00BF#8K2/lees-loss-prevention/valve-interlocks.
52. Marsh JLT Specialty. "Remotely Operated Emergency Isolation Valves (ROEIVs): Risk engineering position paper." https://www.marsh.com/us/industries/energy-and-power/insights/risk-engineering-paper-remotely-operated-emergency-isolation-valves.html (accessed January 24, 2023). September 2020; p 4.
53. *Ibid.*
54. Center for Chemical Process Safety (CCPS)/AIChE. *2020 Virtual Spring Meeting and 16th Global Congress on Process Safety Proceedings, 54th Annual Loss Prevention Symposium (LPS), August 17-21, 2020. How Emergency Isolation Valves Can Effectively Mitigate the Consequences of Early Pool Fires.* Retrieved from https://app.knovel.com/hotlink/pdf/id:kt-012MIJN1/virtual-spring-meeting/how-emergency-isolation.
55. *Ibid.*
56. *Ibid.*

Conclusion

As several major incidents investigated by the CSB have demonstrated,[57] many chemical facilities are not protected with remote isolation equipment that can help mitigate loss-of-containment incidents. These incidents, if allowed to progress, can result in fatalities, injuries, damage to equipment, the destruction of facilities, and serious harm to surrounding infrastructures, communities, and the environment.

As shown by the HSE, on a global scale, major incidents have led to the development of robust guidance for facilities to assess whether remote isolation is needed, along with detailed steps for implementation. Additionally, as shown by the NTSB's San Bruno investigation, this issue is applicable to many industry segments and has resulted in calls for regulatory change.

As such, the CSB concludes that additional action is needed. The API should improve existing voluntary standards by establishing criteria for various facility types including petroleum refineries as well as chemical petrochemical facilities with major process equipment and atmospheric storage tanks, that details conditions that necessitate the installation of remote isolation devices that may be automatically activated or remotely activated from a safe location during an emergency. Additionally, while strong industry standards are needed, regulatory gaps must also be addressed. EPA and OSHA must implement regulatory requirements for the critical review of major process equipment to determine whether the consequences from a major loss-of-containment event can be significantly reduced by safe, rapid, and remote isolation of process equipment[58] following a release.

The CSB further believes that companies have a responsibility to promptly adopt the use of the CCPS flow chart or an equivalent methodology during all future hazard reviews to evaluate whether and where remote isolation should be applied for all major process equipment – and then implement those findings.

The CSB further believes that companies have a responsibility to promptly adopt the use of the CCPS flow chart or an equivalent methodology during all future hazard reviews to evaluate whether and where remote isolation should be applied for all major process equipment – and then implement those findings. By systematically evaluating process equipment and applying remote isolation equipment to mitigate major loss-of-containment events, companies can save lives, protect jobs, protect the environment, and safeguard critical infrastructure vital to the economy.

57. The following is a list of accidental release incidents reported to or investigated by the CSB (including the incidents discussed above in this Safety Study) that would likely have been less severe had remote isolation been effectively employed as a mitigative safeguard:
    - DPC Enterprises Festus Chlorine Release - August 14, 2002
    - Honeywell Chemical Incidents - July 20, 2003
    - DPC Enterprises Glendale Chlorine Release - November 17, 2003
    - Formosa Plastics Propylene Explosion - October 6, 2005
    - Valero McKee Refinery Propane Fire - February 16, 2007
    - CITGO Refinery Hydrofluoric Acid Release and Fire - July 19, 2009
    - DuPont Belle Toxic Chemical Releases - January 23, 2010
    - Millard Refrigerated Services Ammonia Release - August 23, 2010
    - Intercontinental Terminals Company (ITC) Tank Fire - March 17, 2019
    - KMCO LLC Fatal Fire and Explosion - April 2, 2019
    - Philadelphia Energy Solutions (PES) Refinery Fire and Explosions - June 21, 2019
    - TPC Port Neches Explosions and Fire - November 27, 2019
    - Foundation Food Group Fatal Chemical Release - January 28, 2021
    - Chemtool Rockton Facility Mineral Oil Release and Fire [incident report] – June 14, 2021
58. As demonstrated in the CSB's Philadelphia Energy Solutions investigation, any application of remote isolation of major process equipment should be robust and resilient. Redundancy should also be a consideration.

Recommendations

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

American Petroleum Institute

2024-01-H-R1

Develop a new publication or revise an existing publication or publications that should be applicable to various facility types such as refineries, chemical and petrochemical facilities, terminals, etc. with major process equipment and atmospheric storage tanks, that details conditions that necessitate the installation of remote isolation devices [use "shall" instead of "should" language] that may be automatically activated or remotely activated from a safe location, particularly during an emergency. When establishing these conditions refer to the guidance published by CCPS entitled *Guidelines for Fire Protection in Chemical, Petrochemical, and Hydrocarbon Processing Facilities*, Sections 8.1.10 and 8.1.11. At a minimum, the conditions should address major process equipment and atmospheric storage tanks, material volumes/weight as well as flammability, corrosivity, and toxicity.

To U.S. Environmental Protection Agency (EPA)

2024-01-H-R2

Update the Risk Management Program (RMP) rule by expanding the requirements of 40 CFR Part 68 to include an evaluation of the need for remote isolation devices for major process equipment that can be remotely activated from a safe location or automatically activated during a release. The evaluation should be included in hazard assessments, hazard reviews, and process hazard analyses.

Occupational Safety and Health Administration

2024-01-H-R3

Update the Process Safety Management (PSM) standard by expanding the Process Hazard Analysis (PHA) requirements under 29 CFR 1910.119(e)(3) to include an evaluation of the need for remote isolation devices for major process equipment that can be remotely activated from a safe location or automatically activated during a release.

U.S. Chemical Safety and Hazard Investigation Board

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