

CASE STUDY



U.S. Chemical Safety and Hazard Investigation Board

Key Lessons for Preventing Inadvertent Mixing During Chemical Unloading Operations

Chemical Reaction and Release in Atchison, Kansas

MGPI Processing, Inc.

Incident Date: October 21, 2016

Over 140 Sought Medical Attention, 6 Hospitalized

No. 2017-01-I-KS

Published December, 2017



KEY ISSUES:

- Design of Chemical Transfer Equipment
- Automated and Remote Emergency Shut-offs
- Pipe Markings
- Chemical Unloading Procedures
- Human Factors
- Emergency Planning



The **U.S. Chemical Safety and Hazard Investigation Board** (CSB) is an independent Federal agency whose mission is to *drive chemical safety change through independent investigations to protect people and the environment*.

The CSB is a scientific investigative organization; it is not an enforcement or regulatory body. Established by the Clean Air Act Amendments of 1990, the CSB is responsible for determining the root and contributing causes of accidents, issuing safety recommendations, studying chemical safety issues, and evaluating the effectiveness of other government agencies involved in chemical safety. More information about the CSB is available at www.csb.gov.

The CSB makes public its actions and decisions through investigative publications, all of which may include safety recommendations when appropriate. Examples of the types of publications include:

CSB Investigation Reports: formal, detailed reports on significant chemical accidents and include key findings, root causes, and safety recommendations.

CSB Investigation Digests: plain-language summaries of Investigation Reports.

CSB Case Studies: examine fewer issues than a full investigative report, case studies present investigative information from specific accidents and include a discussion of relevant prevention practices.

CSB Safety Bulletins: short, general-interest publications that provide new or timely information intended to facilitate the prevention of chemical accidents.

CSB Hazard Investigations: broader studies of significant chemical hazards.

Safety Videos: high-quality outreach products that support the agency's mission to improve worker and environmental protection.

CSB publications can be downloaded at www.csb.gov or obtained by contacting:



U.S. Chemical Safety and Hazard Investigation Board

Office of Congressional, Public, and Board Affairs
1750 Pennsylvania Ave NW, Suite 910
Washington, DC 20006
(202) 261-7600

No part of the conclusions, findings, or recommendations of the CSB relating to any chemical accident or the investigation thereof may be admitted as evidence or used in any action or suit for damages. See 42 U.S.C. § 7412(r)(6)(G).

GLOSSARY

Acid: a substance capable of donating a hydrogen ion (e.g., sulfuric acid). A solution of acid and water has a pH less than 7.

Base: a substance capable of accepting a hydrogen ion from a proton donor (e.g., sodium hypochlorite). An aqueous solution of a base, or alkali, has a pH greater than 7. A base reacts with an acid to produce a salt.

Bill of Lading: a document issued by a carrier that details the type, quantity, and destination of the goods being transported.

Cargo tank: a tank intended primarily for the carriage of liquids, gases, solids or semi-solids that is attached to or forms part of a motor vehicle; also referred to as a “tanker” in this Case Study.

Cargo tank motor vehicle: a motor vehicle with one or more cargo tanks permanently attached to or forming an integral part of the motor vehicle.¹

Cam lever dust cap: a metal or plastic cap that attaches to the fill line connection point to prevent debris and access to the fill line. These caps contain levers that, when in the closed position, prevent the removal of the cap. The levers can be locked in the closed position to prevent unauthorized access.

Connection point: the point at which a hose connects to a fill line.

Day tank: a tank that contains enough chemical inventory to be used in one day or a short period of time; day tanks are typically refilled daily or as needed by transferring chemicals from larger bulk storage tanks.

Discharge hose: the hose from the cargo tank motor vehicle connected to the fill line.

Fill lines: facility piping where hoses are connected to unload chemicals from cargo tank motor vehicles.

Heating, ventilation and air conditioning: systems that provide thermal comfort and air quality in indoor spaces.

Motor carrier: a general term for chemical distributors that deliver chemicals via highway.

Mod B area: where the incident took place at MGPI. It includes the transfer equipment, tank farm, process area, and control room.

Mod B building: the building within the Mod B area that contains the indoor chemical processes, a locker room, laboratory, and the control room.

Plume: a continuous release of a gas cloud.

Split rings: metal rings with a split around the circumference used to attach two objects; also known as key rings.

Transfer equipment: a general term for the fill lines, valves and piping used to unload and transfer chemicals from cargo tank motor vehicles to storage tanks.

ACRONYMS AND ABBREVIATIONS

AAR & IP	After-Action Report and Improvement Plan
ACDEM	Atchison County Department of Emergency Management
AFD	Atchison Fire Department
ANSI	American National Standards Institute
API	American Petroleum Institute
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
ATSDR	Agency for Toxic Substances and Disease Registry
CCPS	Center for Chemical Process Safety
CEPR	Commission on Emergency Planning and Response
CI	Chlorine Institute

¹ 49 C.F.R. § 171.8 (2017).

CIA	Chemical Industry Association	NEP	National Emphasis Program
Cl	chlorine	NIOSH	National Institute for Occupational Safety and Health
CSB	U.S. Chemical Safety and Hazard Investigation Board	NPRM	Notice of Proposed Rulemaking
CTMV	cargo tank motor vehicle	NRC	National Response Center
DOT	U.S. Department of Transportation	NSSP	National Syndromic Surveillance Program
EMS	Emergency Medical Services	OSHA	U.S. Occupational Safety and Health Administration
EPA	U.S. Environmental Protection Agency	pH	potential of hydrogen
EPCRA	Emergency Planning and Community Right-to-Know Act	PHA	process hazard analysis
ERPG	Emergency Response Planning Guidelines	PHMSA	U.S. Pipeline and Hazardous Materials Safety Administration
FMCSA	U.S. Federal Motor Carrier Safety Administration	PO	propylene oxide
H ₂ SO ₄	sulfuric acid	PPE	personal protective equipment
hazmat	hazardous materials	ppm	parts per million
HMEP	Hazardous Materials Emergency Preparedness	PSM	Process Safety Management of Highly Hazardous Chemicals
HMR	Hazardous Materials Regulation	RMP	Risk Management Program
HOCl	hypochlorous acid	SDS	Safety Data Sheet
HVAC	heating, ventilation and air conditioning	SERC	State Emergency Response Commission
KDEM	Kansas Department of Emergency Management	SO ₂	sulfur dioxide
KDHE	Kansas Department of Health and Environment	VOC	volatile organic compound
LEPC	Local Emergency Planning Committee	WWTP	Wastewater Treatment Plant
NACD	National Association of Chemical Distributors		
NaClO	sodium hypochlorite		

1.0 INTRODUCTION

This Case Study examines the October 21, 2016, inadvertent mixing of incompatible chemicals at the MGPI Processing, Inc. (MGPI) facility in Atchison, Kansas. The mixture of the two chemicals, sulfuric acid and sodium hypochlorite (better known in its less concentrated form as bleach), produced a cloud containing chlorine and other compounds. The cloud impacted workers onsite and members of the public in the surrounding community. The incident occurred during a routine chemical delivery of sulfuric acid from a Harcros Chemicals (Harcros) cargo tank motor vehicle (CTMV) at the MGPI facility tank farm.

The Atchison County Department of Emergency Management (ACDEM) ordered thousands of community members to shelter-in-place and other community members to evacuate in some areas. Over 140 individuals, including members of the public, MGPI employees, and a Harcros employee, sought medical attention; one MGPI employee and five members of the public required hospitalization as a result of exposure to the cloud produced by the reaction.

While two specific substances were involved in this incident, the accidental mixing of many acids and bases or other incompatible chemicals during unloading operations and other activities can lead to potentially dangerous reactions. Chemical unloading operations from CTMVs may be perceived as simple compared to other processes in fixed facilities, but because these operations can involve extremely large quantities of chemicals, the consequences of an incident may be severe.² According to the National Association of Chemical Distributors (NACD), more than 39.9 million tons of product were delivered to customers every 8.4 seconds in 2016. Therefore, facility management must pay careful attention to the design and operation of chemical transfer equipment by applying the hierarchy of controls and by considering human factors to reduce the opportunity for inadvertent mixing and to mitigate consequences should an event occur. In addition, in situations where CTMV drivers are directly involved in unloading chemicals, there must be shared responsibility between the chemical distribution company and

TABLE OF CONTENTS

- 1.0 Introduction
- 2.0 Background
- 3.0 Incident Description
- 4.0 Chemical Analysis
- 5.0 Incident Analysis
- 6.0 Similar Incidents During Unloading Operations
- 7.0 Industry Associations and Guidance
- 8.0 Regulatory Oversight and Guidance
- 9.0 MGPI and Harcros Post-Incident Changes
- 10.0 Key Lessons
- 11.0 Conclusion
- 12.0 Recommendations
- Appendix A – Simplified Logic Tree
- Appendix B – Recommended Practices

facility management to ensure chemicals are unloaded safely. This Case Study examines the factors that contributed to the incident at MGPI and includes key lessons for preventing similar incidents for facilities receiving chemicals and the companies delivering them.

2.0 BACKGROUND

2.1 MGPI PROCESSING, INC.

The MGPI facility is located near a primarily urban part of the city of Atchison, Kansas, about 50 miles northwest of Kansas City, Missouri. The company, originally established as a small distillery in 1941, is an operating subsidiary of MGP Ingredients, Inc. MGPI has two operating segments at the Atchison plant: distilled products, including food-grade alcohol, distillers feed, fuel-grade alcohol and corn oil; and ingredients, which consists of specialty and commodity wheat starches and proteins for food and non-food applications. The Atchison facility contains grain processing, distilling operations, warehousing, laboratories, and office buildings and employs 140 personnel, of which 100 are represented by the United Food and Commercial Workers Union Local 74D.

2.2 HARCROS CHEMICALS

Harcros manufactures and distributes industrial and specialty chemicals and blends to a broad range of industrial customers

² Center for Chemical Process Safety. *Unloading and Loading Hazardous Materials Process Safety Beacon* [Online], September 2015 <https://www.aiche.org/sites/default/files/cep/20150920.pdf> (accessed September 12, 2017).



Figure 1. MGPI's Mod B facility in Atchison, Kansas (Source: MGPI).

throughout the United States; primarily in the Midwest and Southeast. Headquartered in Kansas City, Kansas, Harcros operates two chemical manufacturing facilities and 29 distribution locations. Harcros operates about 50 hazardous material CTMVs for chemical deliveries.³ In 2016, Harcros supplied sulfuric acid, sodium hydroxide, and propylene oxide to the process area where the incident at MGPI occurred.

3 Federal Motor Carrier Safety Administration. *Safety Measurement Profile for Harcros Chemicals Inc.* <https://ai.fmcsa.dot.gov/SMS/Carrier/980774/CompleteProfile.aspx> (accessed September 12, 2017).

2.3 PROCESS DESCRIPTION

The October 2016 incident occurred at MGPI's Mod B area, where specialty wheat starches are manufactured to customer specifications (Figure 1). At Mod B, different chemicals are utilized to satisfy various desired characteristics of the specialty and commodity starches, including the use of sulfuric acid to modify starch through pH adjustment, and the use of sodium hypochlorite to oxidize starch. The Mod B area, separated from the main plant by railroad tracks, is located on an access road

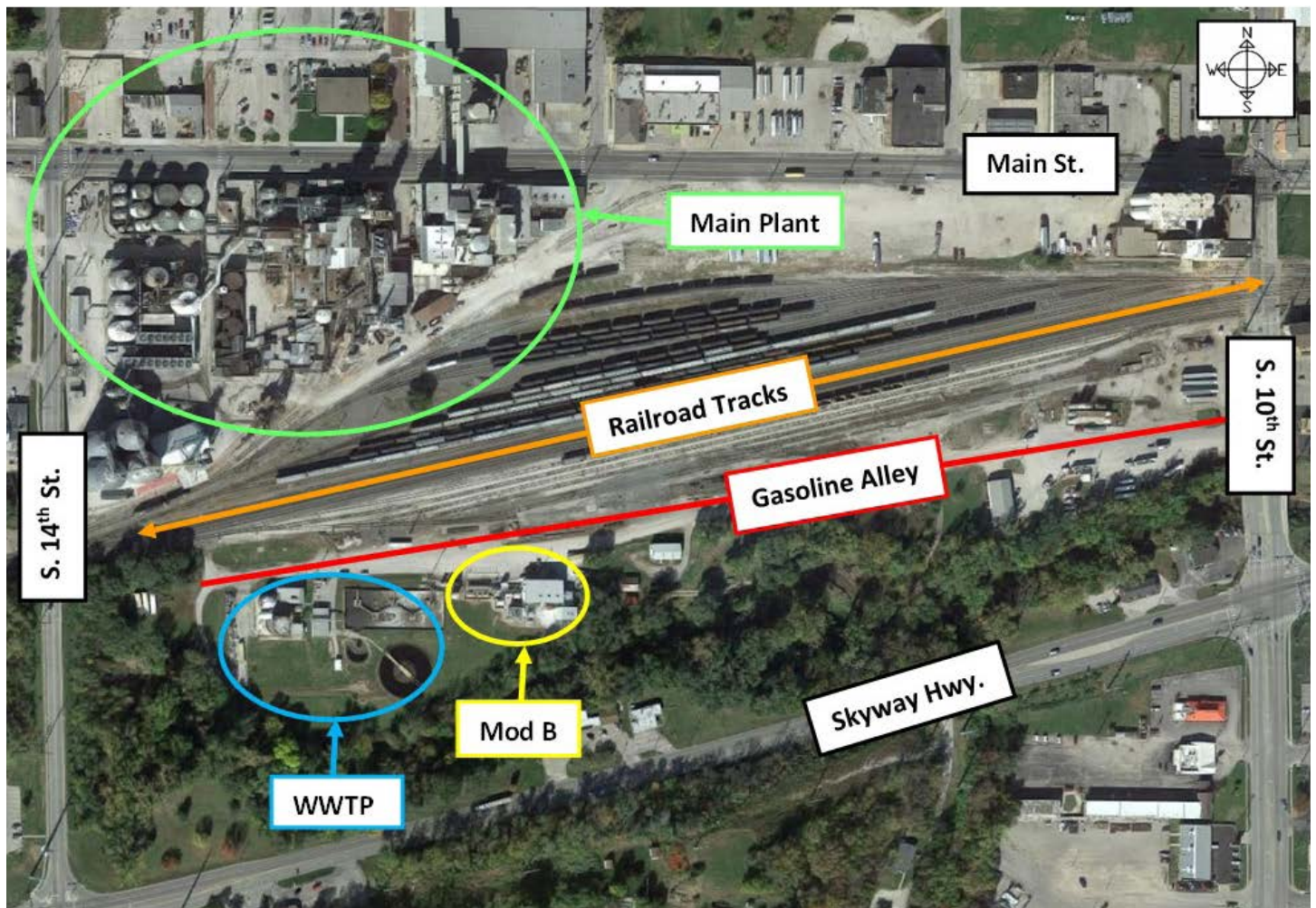


Figure 2. MGPI and surrounding area (Source: Google).

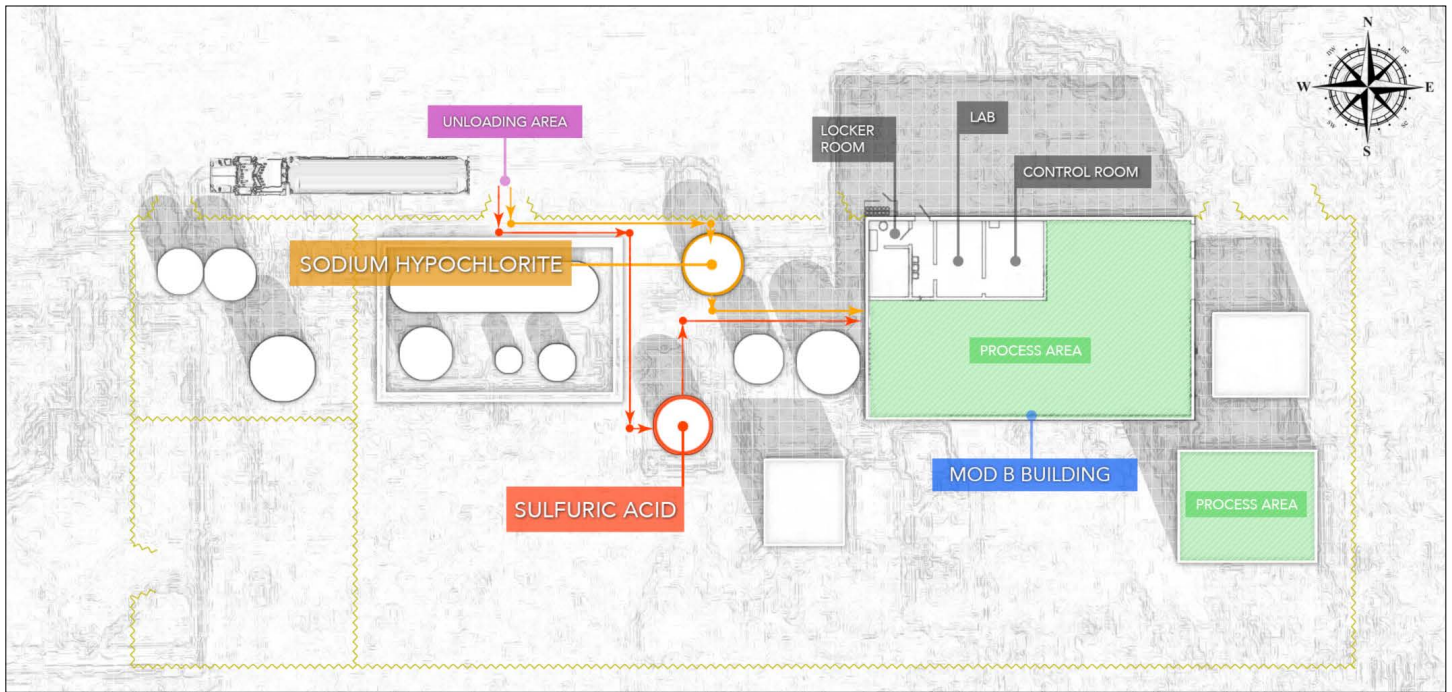


Figure 3. Mod B chemical unloading area and tank farm (left) and Mod B building (right) (Source: CSB).

called Gasoline Alley, and is adjacent to MGPI's Wastewater Treatment Plant (WWTP) (Figure 2).

The Mod B area comprises the Mod B building and an adjacent outdoor tank farm (Figure 3). The Mod B building contains an indoor process area where chemicals are combined to manufacture product. The building also contains a locker room, laboratory, and the control room where operators perform most of their duties, which include monitoring process conditions.

On the perimeter of the tank farm is the unloading area through which CTMVs from various companies deliver bulk quantities of five chemicals: sodium hypochlorite,⁴ sulfuric acid, propylene oxide, sodium hydroxide, and acetic anhydride.⁵ CTMV drivers transfer chemicals by connecting discharge hoses from the cargo tanks to the fill lines. From there, chemicals



Figure 4. Chemical unloading operations at the time of the incident (Source: MGPI).⁶

flow through piping to several large bulk storage tanks in the tank farm (Figure 4). Operators then transfer smaller quantities of the chemicals, as needed, into day tanks and/or process vessels for production inside the Mod B building.

Among the chemicals delivered to Mod B is 12.5% sodium hypochlorite, a more concentrated version of bleach. MGPI receives sodium hypochlorite at the chemical unloading area where it is transferred by piping to an outdoor 6,500-gallon bulk tank, and stored at atmospheric pressure. Operators then

⁴ Sodium hydroxide is also referred to as "caustic" in this Case Study.

⁵ The U.S. Occupational Safety and Health Administration's Process Safety Management of High Hazardous Chemicals standard (29 C.F.R. § 1910.119) applies to two chemicals stored above threshold quantities at Mod B: propylene oxide (a flammable liquid received at the unloading area) and phosphorous oxychloride (not received at the unloading area). The two chemicals involved in this incident are not covered under the standard.

⁶ MGPI took this photo of the Harcos CTMV connected to the fill line shortly after the incident. Deluge systems were on at this time to mitigate the release.

transfer sodium hypochlorite by piping into a smaller day tank in the Mod B building. From there, it is transferred into a process vessel as needed. Another chemical delivered to Mod B is sulfuric acid. MGPI receives 30% sulfuric acid at the chemical unloading area in an outdoor 8,500-gallon day tank. Operators transfer sulfuric acid from the day tank directly into the process.

2.3.1 PRE-INCIDENT CHEMICAL UNLOADING OPERATIONS

To access the fill lines for a chemical delivery, operators first unlock a barbed wire gate that encloses the tank farm area and five fill lines designated for each chemical (Figure 4). Next, operators unlock the padlock on the cam lever dust cap that secures the fill line for the chemical being delivered. Cam lever dust caps prevent access to fill lines by capping the end of the fill lines when they are not in use. As seen in Figure 5, cam lever dust caps are secured by engaging two levers and locking them in place with a padlock and two split rings. CTMV drivers rely on operators to unlock and identify the fill line designated for the chemical being transferred. Operators then show drivers the appropriate fill line. Once the equipment is unlocked, operators return to the control room. Drivers then remove the dust cap and connect their chemical discharge hose from the cargo tank to the fill line. After completing delivery, drivers place the dust cap back on the fill line and re-secure it by locking the padlock. It was, and is, MGPI's practice to unlock fill line dust caps only for delivery.



Figure 5. A locked cam lever dust cap on a fill line at Mod B (Source: CSB).

3.0 INCIDENT DESCRIPTION

3.1 THE INCIDENT

At approximately 7:35 AM on October 21, 2016, a Harcros CTMV arrived at the MGPI Atchison facility to complete a scheduled delivery of 30% sulfuric acid. Upon arrival, the Harcros employee (driver)⁷ exited the cab and began to pressurize the cargo tank for unloading. At approximately 7:42 AM, the driver took the bills of lading to the Mod B building where the MGPI night shift operator on duty reviewed and signed the paperwork for accepting a delivery. Because the driver arrived at MGPI at 7:35 AM, prior to the start of dayshift, the night shift operator accepted the delivery.

At 7:44 AM, the operator escorted the driver from the Mod B building to the chemical unloading area. When they reached the rear of the CTMV, the driver set his paperwork on the back of the cargo tank and walked down the passenger side to finish donning his personal protective equipment (PPE).⁸ During this time, the operator unlocked the gate in front of the transfer equipment and removed the lock on the cam lever dust cap for the sulfuric acid fill line. The operator placed the lock from the sulfuric acid fill line on the angle iron above the fill line (Figure 6). The driver removed the seal⁹ from the back of the cargo tank, handed it to the operator, and then retrieved the hose from the CTMV to begin the connections. The operator reports that he pointed out the location of the sulfuric acid fill line to the driver and that the driver acknowledged the location; the driver, however, reports that the operator did not point out the fill line. The operator then returned to the Mod B building at approximately 7:47 AM before he saw the driver connect the discharge hose to the fill line. The driver removed the dust cap from the first unlocked fill line that he saw at the facility, which he assumed to be the sulfuric acid fill line. The driver connected the hose to the fill line and then connected the hose to the truck. The driver checked

7 The Harcros driver is one of multiple Harcros drivers who made sulfuric acid deliveries to Mod B in 2016. Harcros had made many deliveries of sulfuric acid in the previous year, of which the driver made six. No Harcros driver was involved in any delivery of sodium hypochlorite, as this chemical was delivered by another chemical distribution company.

8 The driver donned a chemical resistant coat, rubber gloves, a hard hat with a face shield, and safety glasses.

9 Seals are placed on the trailer valves and caps of cargo tanks to prevent tampering with the contents and so that those receiving deliveries can ensure that the contents of the trailer match what is stated on the bill of lading and other paperwork. The seals are designed to be broken to ensure that they cannot be removed and placed back on a cargo tank. The numbers on the seals are supposed to match the numbers on the paperwork prepared by the shipper.

the air pressure in the cargo tank,¹⁰ checked for leaks, and upon not finding any, opened the facility's valve and then the valve on the cargo tank to begin discharging sulfuric acid. The driver returned to his cab, checked his air pressure on the way, climbed inside, and set his paperwork down. During this time, the MGPI day shift operator and a trainee were in the Mod B building discussing plant operating status with the night shift operator.

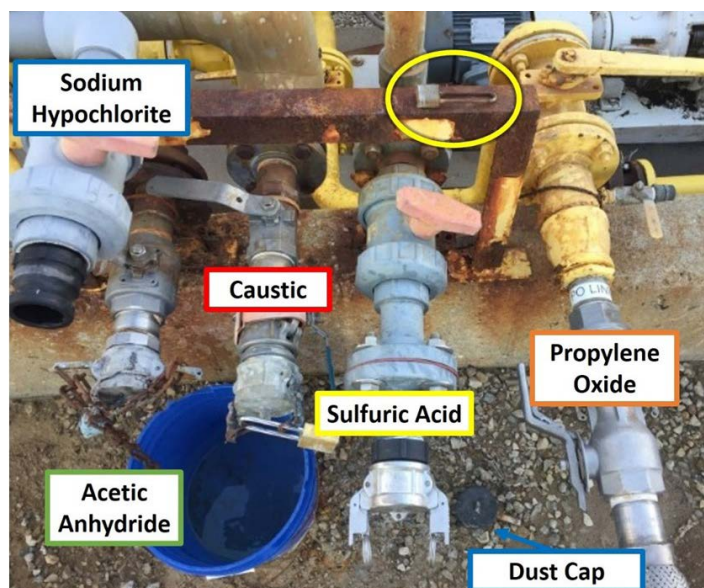


Figure 6. As-found state of connection area post-incident. Sulfuric acid fill line padlock (circled) placed on angle iron. Sodium hypochlorite dust cap on ground beneath fill lines (Source: CSB).

Shortly before 8:00 AM a greenish-yellow gas began emitting from the sodium hypochlorite bulk tank, forming a cloud. The cloud grew, covering the Harcros truck and the Mod B building, and then migrated offsite in a northeast direction.

The three operators inside the Mod B control room at the time of the release quickly became aware of the reaction by the odd smell of gas that entered the building. They immediately attempted to access their emergency escape respirator face pieces, but were unable to do so because the respirator face pieces were not stored in a readily accessible location or had been moved.¹¹ As a result,

¹⁰ Drivers check the air pressure using the air gauge and pressure regulator. The amount of pressure applied depends on several variables that must be considered for each load, such as viscosity and other physical properties of the product, temperature and humidity, equipment parameters, length of pipe between the truck and tank, and air supply at the customer's site.

¹¹ The night and day shift operators attempted to retrieve their respirator face pieces from their respective lockers but were unable to do so. The face pieces connect to 5-minute escape bottles. The trainee did not have a locker because MGPI does not assign lockers to trainees. The trainee normally kept his respirator on a counter in the control room; however, the previous shift moved it because they needed counter space (Section 5.4).

all three operators were forced to evacuate the building without respiratory protection. After exiting, operators ran northeast (Figure 2) through the cloud until they reached fresh air near the railroad tracks. At the railroad tracks, one of the operators used his radio to alert MGPI employees of the emergency. Following this alert, another company employee contacted 911 at 7:59 AM.

The driver, who was in the cab of the truck, first noticed the gas cloud in his rearview mirror. He tried to get to the connection area at the rear of the truck by running down the driver side, but the gas overwhelmed him. The driver turned around and attempted the same from the passenger side but again was overwhelmed by the gas. At this point, the manager of the adjacent WWTP saw the release and shouted for the driver to run in his direction. The WWTP manager brought the driver inside the WWTP control room, gave him water, and radioed MGPI employees that the driver was inside and out of the cloud. The WWTP manager also alerted MGPI management of the release by phone and radio.

Although the sulfuric acid dust cap was unlocked immediately prior to unloading, the CSB found that the sodium hypochlorite fill line was also accessible to the driver (Figure 7). The driver connected the sulfuric acid discharge hose to the unsecured fill line for the sodium hypochlorite bulk tank, which resulted in the inadvertent mixing of approximately 4,000 gallons of sulfuric acid and 5,850 gallons of sodium hypochlorite. This mixture of incompatible materials resulted in a reaction that promoted the release of a cloud containing chlorine gas and other compounds (Section 4.0).



Figure 7. Sodium hypochlorite dust cap with missing split ring. The missing split ring prevented the dust cap from being secured by the padlock (Source: CSB).

3.2 EMERGENCY RESPONSE

The Atchison Fire Department (AFD) received notification of the chemical release at 8:02 AM and units arrived on scene at 8:05 AM. The cloud, or plume, was estimated to extend a few hundred feet high and to be slowly migrating on the ground to the north-northeast. Due to the time of day, there was a significant amount of traffic in the immediate vicinity of the plant and the fire department blocked nearby intersections to restrict and re-direct drivers from entering the plume. By 8:10 AM, the Mod B operators were en route to the hospital and at about the same time, MGPI informed emergency responders that a "chlorine-like" plume was likely caused by a reaction when sulfuric acid and sodium hypochlorite were inadvertently mixed. Around that same time, the Atchison County Department of Emergency Management (ACDEM) advised 11,000 Atchison citizens to shelter-in-place.¹² MGPI worked with the fire department to develop a plan to mitigate the release. Minutes later, the plume shifted to the northwest, requiring emergency responders to evacuate to a safer location. By 8:43 AM, a hazardous materials (hazmat) trailer arrived with additional emergency responders and equipment. Responders were able to safely close the discharge valve on the cargo tank and turn off the truck engine. They also set up a water spray and manually activated the Mod B deluge (sprinkler) system to suppress the plume generated by the chemical reaction.

As the plume shifted to the west of Mod B, it began to migrate towards the WWTP where the WWTP manager, driver, and the two firefighters who attended to the driver were located. When they saw that the plume was heading in their direction, they evacuated the area. An Emergency Medical Services (EMS) vehicle then transported the driver to the hospital for treatment of his symptoms from exposure to the cloud. At the same time, a motor vehicle accident near the plant required assistance from the two firefighters. While treating the vehicle accident victims, the plume shifted, due to the wind, and exposed the two firefighters, both of whom were transported to the hospital.

From a helicopter, the Kansas Highway Patrol monitored the size and movement of the plume throughout the morning to assist emergency responders. The wind shift presented challenges

12 ACDEM used TV, radio, and social media to alert the community of the shelter-in-place and evacuation orders.

for emergency responders and, as the plume began to move toward the north and west of the city, it slowed due to low wind speed.¹³ ACDEM issued evacuation orders to schools and residents to the north who were not in the plume. Buses safely transferred 800 middle and high school students upwind to the south side of Atchison. By approximately 10:30 AM, the Kansas Highway Patrol reported to emergency responders that the plume was on the north and west outskirts of the city and dissipating rapidly. At 11:00 AM, approximately 3 hours after the incident, ACDEM communicated an all clear and lifted the shelter-in-place and evacuation orders.

3.3 CONSEQUENCES

Because of the chemical reaction and release, four MGPI employees, the Harcros driver, and over 140 community members sought medical attention.¹⁴ Of these, one MGPI employee was admitted to a hospital after being directly exposed to the toxic cloud and was released three days later. Five citizens were admitted to the hospital, of which four were released within two days and one was released five days later. Consistent with acute exposure to chlorine, many who visited a hospital or medical center reported general respiratory issues including shortness of breath, coughing, and throat irritation. Of those not admitted to a hospital, a majority were sent home after examination, while a few left prior to any examination.

Chlorine is a yellow-green gas that can irritate the eyes, skin, and respiratory tract.¹⁵ The extent of symptoms varies with the concentration, route, and duration of exposure, and some symptoms are delayed (Table 1).¹⁶ Most long-term health effects from acute exposures are typically associated with complications developed after exposure to high concentrations.¹⁷

-
- 13 The closest weather station, in St. Joseph, MO, reported calm winds until 10:53 AM on October 21, 2016.
- 14 The CSB collected patient information from nearby hospitals and clinics for individuals who sought medical attention as a result of the release.
- 15 Centers for Disease Control and Prevention. *Facts about Chlorine*. <https://emergency.cdc.gov/agent/chlorine/basics/facts.asp> (accessed September 12, 2017).
- 16 According to the ATSDR, the concentrations listed above are approximate; the effects will depend also on exposure duration. In general, people who suffer from respiratory conditions such as allergies or hay fever, or who are heavy smokers, tend to experience more severe effects than healthy subjects or nonsmokers. Agency for Toxic Substances and Disease Registry. *Toxicological Profile for Chlorine*. <https://www.atsdr.cdc.gov/toxprofiles/tp172.pdf> (accessed November 27, 2017).
- 17 Centers for Disease Control and Prevention. *Facts about Chlorine*. <https://emergency.cdc.gov/agent/chlorine/basics/facts.asp> (accessed September 12, 2017).

TABLE 1. Potential health effects of short-term chlorine exposure, based on animal and human studies (Source: ATSDR).

Concentration	Potential health effects ¹⁸
1-3 ppm	Mild nose irritation
5 ppm	Eye irritation
5-15 ppm	Throat irritation
30 ppm	Immediate chest pain, vomiting, changes in breathing rate and cough
40-60 ppm	Lung injury and fluid in lungs (pulmonary edema)
430 ppm for 30 minutes	Death
1,000 ppm for a few minutes	Death

4.0 CHEMICAL ANALYSIS

The CSB commissioned a chemical analysis to characterize the contents of the tanks and truck involved in the incident.¹⁹ Investigators collected samples from the sodium hypochlorite bulk tank, where the suspected mixing of sodium hypochlorite and sulfuric acid occurred; the downstream sodium hypochlorite day tank; and the remaining liquid in the CTMV after the incident. Laboratory testing confirmed that a sodium hypochlorite solution and 30% sulfuric acid were involved, consistent with the expected contents of the bulk tank and truck.²⁰ Analysis of the samples revealed no evidence of elements other than those found in sodium hypochlorite and sulfuric acid.

The sodium hypochlorite (NaClO) used at MGPI is supplied as a diluted aqueous solution, containing sodium hypochlorite (10-16%), sodium chloride (12%), sodium hydroxide (4%) and water (balance). The sodium hypochlorite solution is a clear yellow liquid with a characteristic bleach odor. It is a strong base that can react with acids and ammonia, and

organic or other chlorinating compounds.²¹ When mixed with acids, the hypochlorite ion is known to form chlorine gas, which evolves from the solution, and can cause a serious chlorine release.²² Sulfuric acid (H₂SO₄) is a strong acid that violently reacts with bases (alkalis) and is corrosive to most metals. It can react violently with water and other organic materials, resulting in the evolution of heat and irritating gases.²³

The CSB also commissioned an analysis to fully understand the potential reaction pathways on the day of the incident to determine what products might have been created and released. Contractors evaluated the effect of meteorological conditions on both the generation of reaction products and the behavior of the plume in the atmosphere. The analysis concluded that, while the precise chemistry cannot be definitively determined, the primary toxic reaction products were likely chlorine and other chlorine-containing compounds.²⁴ Upon mixing, the sodium hypochlorite and sulfuric acid immediately initiated a highly exothermic, or heat-producing, reaction.²⁵ The liquid that was added to the tank and the gases that evolved from the reaction were released through a 3-inch diameter atmospheric vent and an 18-inch lid on the roof of the bulk tank.

Depending on the temperature and pH of the mixture, and the amount of mixing that occurred as sulfuric acid was introduced to the sodium hypochlorite tank, several different series of reactions may have occurred. The products of the initiating reactions likely further reacted to generate additional toxic gas (g) products and aqueous (aq), ionic species. These may have included:

- chlorine gas (Cl₂(g)),
- chlorine dioxide (ClO₂(g)),
- hydrogen chloride (HCl(g)) or hydrochloric acid (HCl(aq)),
- sodium sulfate (Na₂SO₄(aq)),
- sodium bisulfate (NaHSO₄(aq)),
- water, and
- oxygen (O₂(g))

18 Agency for Toxic Substances and Disease Registry. *Toxicological Profile for Chlorine*. <https://www.atsdr.cdc.gov/toxprofiles/tp172.pdf> (accessed September 12, 2017).

19 Case Forensics. *Characterization of Reactants MGPI Processing Inc. in Atchison Kansas*. [Online] 2017. http://www.csb.gov/assets/1/19/2445003_Report_Redacted.pdf (accessed September 12, 2017).

20 The sulfuric acid density of the two Harcros CTMV samples was 1.228 g/cm³ and 1.227 gm/cm³, respectively, consistent with the density of 30% sulfuric acid. The sodium hypochlorite from the downstream day tank had a pH of 12.3 post incident. 12.5% sodium hypochlorite has a pH range of 11.5 to 13.5. Case Forensics. *Characterization of Reactants MGPI Processing Inc. in Atchison Kansas*. [Online] 2017. http://www.csb.gov/assets/1/19/2445003_Report_Redacted.pdf (accessed September 12, 2017).

21 The Chlorine Institute. Pamphlet 96, Sodium Hypochlorite Manual, 4th ed.; The Chlorine Institute: Arlington, VA, October 2011.

22 The Chlorine Institute. Pamphlet 96, Sodium Hypochlorite Manual, 4th ed.; The Chlorine Institute: Arlington, VA, October 2011.

23 National Institute of Occupational Safety and Health. *Pocket Guide to Chemical Hazards, Sulfuric Acid*. <https://www.cdc.gov/niosh/npg/npgd0577.html> (accessed September 12, 2017).

24 Peterson, E.; Reed, M. *MGPI Investigation Support – Chemical Reactions and Air Modeling*; Technical Report for CSB; Washington, DC, 2017.

25 Peterson, E.; Reed, M. *MGPI Investigation Support – Chemical Reactions and Air Modeling*; Technical Report for CSB; Washington, DC, 2017.

The sulfuric acid lowered the pH of the sodium hypochlorite, which, combined with the heat produced by the reaction, accelerated the rate of sodium hypochlorite decomposition. As a result, several major and minor reactions may have occurred, involving both the reactants and products formed by their decomposition.²⁶ A likely reaction pathway between sulfuric acid and sodium hypochlorite produced hypochlorous acid and sodium sulfate. The hypochlorous acid further decomposed to form chlorine and chlorine dioxide. Chlorine dioxide can itself decompose to form chlorine gas and oxygen gas. Chlorine dioxide will also react with hydrochloric acid to form chlorine gas and water at temperatures around 40 to 70 degrees Celsius (104 to 158 degrees Fahrenheit).²⁷ These chlorine-containing compounds have a greenish-yellow tint. Several MGPI employees described the cloud as yellow-green to CSB investigators (Figure 8). See the CSB [Contractor's Report](#) for a technical summary of the potential chemical reactions.

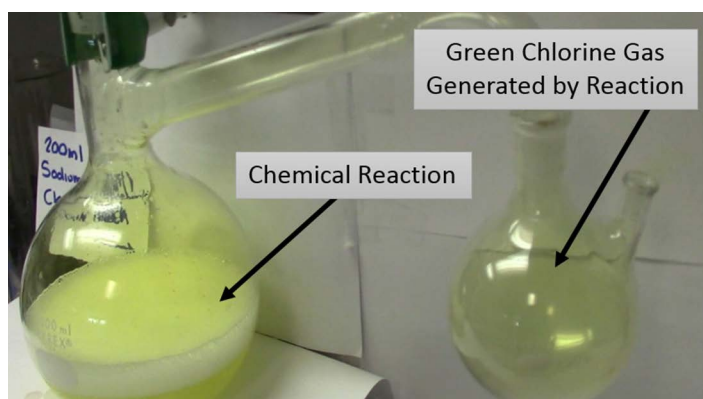


Figure 8. Chemical reaction approximately 1 minute after Harcos sulfuric acid sample was added to fresh Clorox® bleach (5-10% sodium hypochlorite).²⁸ The mixture of the two resulted in the formation of small chlorine gas bubbles (left) collected in a distillation apparatus (right) (Source: CSB).

As discussed in Section 3.3, the series of reactions produced by the inadvertent mixing created toxic products that can cause adverse health effects. These health effects largely depend on the concentration of the toxic products yielded as a result. Though the reactions and the quantity of the reaction products are dependent on source conditions and the environment (e.g., temperature,

concentration, pH, etc.), contractors conservatively assumed that the sodium hypochlorite might have completely decomposed during the incident.²⁹ The maximum theoretical quantity of chlorine gas produced by the reaction was estimated to be 3,490 pounds, assuming that no chlorine further reacted or was otherwise removed from the plume.³⁰ A reaction between chlorine and water in the plume would likely reduce the overall amount of chlorine gas.³¹

There was no real-time air monitoring data available during the incident that would have detected the concentrations of chemicals present in the plume. MGPI had stationary air monitors in and around the Mod B area, but these were to detect concentrations of propylene oxide and phosphorous oxychloride. Shortly after emergency responders mitigated the reaction by closing the discharge valve on the truck, they conducted air quality monitoring and determined the air quality was safe in the building and immediate area where the incident occurred. Additionally, the U.S. Environmental Protection Agency (EPA) arrived at 1:00 PM and began on-site and perimeter air monitoring with handheld detectors equipped with chlorine sensors. Monitoring results were negative for chlorine. Environmental consultants hired on behalf of MGPI also conducted real-time air monitoring using a variety of instruments at 3:30 PM and detected levels of chlorine from 0.1 to 11.7 parts per million (ppm) in the immediate vicinity of Mod B.³² At the time of the monitoring, approximately 5 hours after much of the cloud had dissipated, chlorine concentrations were below detectable limits in the community.

Contractors also modeled a hypothetical release using PHAST™ software to understand the characteristics of a chlorine gas cloud under similar atmospheric conditions. The PHAST software uses mathematical calculations to predict how chemicals disperse in the atmosphere. The results of the dispersion models are largely dependent on the characteristics of the release source and surrounding atmosphere. Though the plume modeling provides some of the basic characteristics of the cloud present on the day of the incident, the plume concentrations and distance

26 Peterson, E.; Reed, M. *MGPI Investigation Support – Chemical Reactions and Air Modeling*; Technical Report for CSB; Washington, DC, 2017.

27 Peterson, E.; Reed, M. *MGPI Investigation Support – Chemical Reactions and Air Modeling*; Technical Report for CSB; Washington, DC, 2017.

28 *Safety Data Sheet for Clorox Regular Bleach*; 1; The Clorox Company; Oakland, CA, June 12, 2015. <https://www.thecloroxcompany.com/wp-content/uploads/cloroxregular-bleach12015-06-12.pdf> (accessed September 12, 2017).

29 Peterson, E.; Reed, M. *MGPI Investigation Support – Chemical Reactions and Air Modeling*; Technical Report for CSB; Washington, DC, 2017.

30 Peterson, E.; Reed, M. *MGPI Investigation Support – Chemical Reactions and Air Modeling*; Technical Report for CSB; Washington, DC, 2017.

31 Peterson, E.; Reed, M. *MGPI Investigation Support – Chemical Reactions and Air Modeling*; Technical Report for CSB; Washington, DC, 2017

32 Air monitoring instruments also detected 0.1-0.2 ppm of sulfur dioxide present onsite in 3 of 62 samples.

traveled do not reflect actual conditions. This is because the model does not account for potential side reactions, weather fluctuations, or other conditions that may have diluted the chlorine and other compounds on the day of the incident.

An analysis of the atmospheric conditions and hypothetical release modeling concluded that weather played a significant role in the severity of the incident at MGPI. The exothermic reaction provided buoyancy to the relatively hot gases, which likely caused the plume to rise above the bulk tank and then disperse downwind.³³ According to data from the closest weather station, the air transitioned from fog and calm winds, to fog with slight winds from the south, within the first hour of the incident.³⁴ Under these conditions, the atmosphere is considered stable, with little or no wind or atmospheric turbulence³⁵ (or mixing). When the atmosphere is stable during a chemical release, plume dispersion is slow because chemicals do not readily mix or dilute in the atmosphere.³⁶ The presence of fog and high humidity in the air, however, may have improved conditions on the day of the incident because the air was saturated with moisture, which may have dissolved chlorine within the developing and existing plume. The buoyancy of the plume, however, may have kept the greatest concentrations of chlorine and other chemicals at higher elevations in the community, thereby lessening the potential impact at ground level.

5.0 INCIDENT ANALYSIS

5.1 HUMAN FACTORS

The CSB identified several human factors issues that affected how the operator and the driver interacted with the chemical transfer equipment, which ultimately led to the incident. This section describes these deficiencies, and how applying safer design strategies could have reduced reliance on operator and driver action. “Human factors” addresses the interactions in a work

environment among workers, equipment, and processes³⁷ and includes a broad range of areas that can influence safety, such as the design and physical characteristics of a work area; worker stress and fatigue; and the systems under which work is carried out, such as procedures, training, and communication.³⁸ Because workers must often interact with equipment to operate and maintain process plants, facility management must carefully examine the role of human factors to reduce or eliminate opportunities for failures when identifying process hazards and evaluating safeguards. Human factors must be integrated into all levels of the hierarchy of controls—from design to administrative controls to PPE—to ensure controls are effective and can be understood.³⁹

When the risks associated with hazardous chemicals cannot be eliminated through substitution or other inherently safer approaches,⁴⁰ the next best approach is to design a system that meets the limitations of human and machine interactions, and provides additional layers of protection.⁴¹ For all processes and equipment that require human interaction, facilities must apply human factors to understand how workers interface with and use equipment.⁴² Key attributes of equipment, such as accessibility, size, shape, labeling, and color schemes, should be configured by considering human physical and mental capabilities.⁴³ For example, equipment

33 Peterson, E.; Reed, M. *MGPI Investigation Support – Chemical Reactions and Air Modeling*; Technical Report for CSB; Washington, DC, 2017.

34 Peterson, E.; Reed, M. *MGPI Investigation Support – Chemical Reactions and Air Modeling*; Technical Report for CSB; Washington, DC, 2017.

35 Atmospheric turbulence is irregular air motion or wind that fluctuates in both speed and direction. This condition allows for an increased mixing of chemicals within the atmosphere. Hanna, S.; Britter, R. *Wind flow and Vapor Cloud Dispersion at Industrial and Urban Sites* [Online]; CCPS/AIChE: New York, 2002; pp 14. <http://app.knovel.com/hotlink/toc/id:kt002YJLV/wind-flow-vapor-cloud/definitions-concepts> (accessed December 6, 2017).

36 Wells, G. *Major Hazards and their Management* [Online]. IChemE: Rugby, Warwickshire UK, 1997; pp 33. <http://app.knovel.com/hotlink/toc/id:kt00A7EN31/major-hazards-their-management/wind-dispersion> (accessed December 6, 2017).

37 Crowl, D. *Human Factors Methods for Improving Performance in the Process Industries--Introduction* [Online]; Center for Chemical Process Safety/AIChE: New York, NY, 2007. <http://app.knovel.com/hotlink/pdf/id:kt004MHZ41/human-factors-methods/introduction> (accessed September 12, 2017).

38 Crowl, D. *Human Factors Methods for Improving Performance in the Process Industries--Introduction* [Online]; Center for Chemical Process Safety/AIChE: New York, NY, 2007. <http://app.knovel.com/hotlink/pdf/id:kt004MHZ41/human-factors-methods/introduction> (accessed September 12, 2017).

39 The hierarchy of controls is the concept of applying a hierarchical order of controls to eliminate or reduce hazards and their consequences. CCPS. *Guidelines for Engineering Design for Process Safety--Introduction*, 2nd ed. [Online]; Center for Chemical Process Safety/AIChE: New York, NY, 2012. <http://app.knovel.com/hotlink/pdf/id:kt00A68RS1/guidelines-engineering/inherent> (accessed September 12, 2017).

40 Inherently safer approaches eliminate hazards by, for example, using less hazardous materials and process conditions.

41 *A Human Factors Roadmap for the Management of Major Accident Hazard*. [Online], HSE: Merseyside, United Kingdom. <http://www.hse.gov.uk/humanfactors/resources/hf-roadmap.pdf> (accessed September 12, 2017).

42 Crowl, D. *Human Factors Methods for Improving Performance in the Process Industries--Introduction* [Online]; Center for Chemical Process Safety/AIChE: New York, NY, 2007. <http://app.knovel.com/hotlink/pdf/id:kt004MHZ41/human-factors-methods/introduction> (accessed September 12, 2017).

43 Crowl, D. *Human Factors Methods for Improving Performance in the Process Industries--Introduction* [Online]; Center for Chemical Process Safety/AIChE: New York, NY, 2007. <http://app.knovel.com/hotlink/pdf/id:kt004MHZ41/human-factors-methods/introduction> (accessed September 12, 2017).

TABLE 2. Mod B fill line chemical incompatibilities; unsafe combinations designated by **X** (Source: CSB).⁴⁴

	Sulfuric Acid	Sodium Hypochlorite	Sodium Hydroxide	Acetic Anhydride	Propylene Oxide
Sulfuric Acid		X	X	X	X
Sodium Hypochlorite ⁴⁵	X			X	X
Sodium Hydroxide	X			X	X
Acetic Anhydride ⁴⁶	X	X	X		X
Propylene Oxide ⁴⁷	X	X	X	X	

must be designed so that it is suitable for the designated task, avoids unnecessary complexity, and its components must be recognizable and consistent with user training and experience.

5.1.1 DESIGN OF CHEMICAL TRANSFER EQUIPMENT

5.1.1.1 FILL LINE PROXIMITY

The CSB found that the proximity of the sulfuric acid fill line to the sodium hypochlorite fill line at Mod B increased the likelihood for an incorrect connection during chemical unloading. The five chemical fill lines in the Mod B chemical transfer area were all located near each other; significantly, the sodium hypochlorite fill line was about 18 inches from the sulfuric acid fill line (Figure 9).⁴⁸ In addition to the incompatibility of sodium hypochlorite and sulfuric acid, the other chemicals delivered to Mod B presented reactivity hazards if mixed (Table 2).

Physically isolating or using distance to separate fill lines can lower the risk of incorrect connections.⁴⁹ Physical separation is

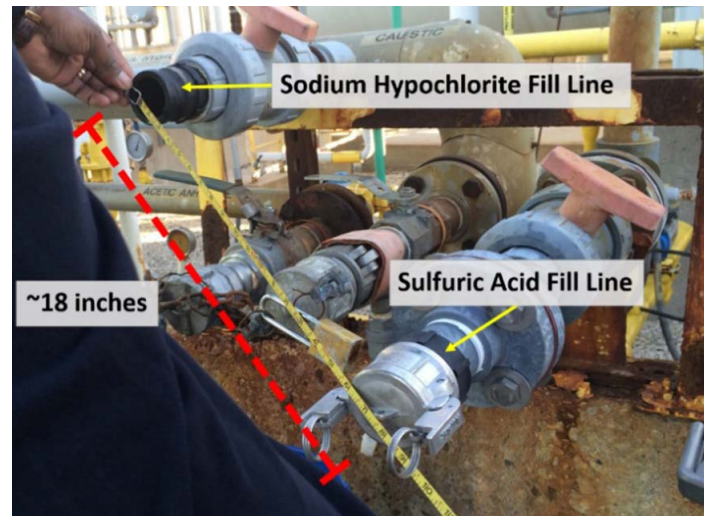


Figure 9. Distance between fill lines (Source: CSB).

considered a passive control⁵⁰ and can be especially important when receiving various classes and types of chemicals. Laboratories and the transportation industry apply physical separation to chemical storage to prevent mixing during spills or leaks from chemical containers. Unloading acids in an area located away from the unloading area for bases decreases the risk of an unintended reaction because a CTMV driver would have to drive to a different area of a facility to unload the chemical to an incorrect and incompatible fill line.

5.1.1.2 IDENTICAL CONNECTIONS AND LOCKS

A post-incident examination of the unloading area revealed that the sodium hypochlorite and the acetic anhydride dust caps were not secured on the fill lines at the time the operator

44 Although a violent reaction is not expected for some of the chemical combinations in Table 2, one can result when chemicals are combined under certain conditions. Refer to the chemical manufacturers' Safety Data Sheet (SDS) for information regarding incompatibility and reactivity. In addition to SDS, the CSB also used the EPA Chemical Reactivity Worksheet for reactive combinations of chemicals: <http://response.restoration.noaa.gov/reactivityworksheet>. The Chlorine Institute. Pamphlet 96, Sodium Hypochlorite Incompatibility Chart, 4th ed; The Chlorine Institute: Arlington, VA, October 2011.

45 The Chlorine Institute. Pamphlet 96, Sodium Hypochlorite Incompatibility Chart, 4th ed; The Chlorine Institute: Arlington, VA, October 2011.

46 Acetic anhydride reacts violently with alcohols, amines, oxidants, strong bases, and water. National Institute for Occupational Safety and Health (NIOSH). *Pocket Guide to Chemical Hazards, Acetic Anhydride* [Online], CDC: Atlanta, GA, July 2015, <https://www.cdc.gov/niosh/ipcsneng/neng0209.html> (accessed November 27, 2017).

47 Central Michigan University. *Chemical Incompatibility Chart*. <https://www.cmich.edu/fas/fsr/rm/EHS/Documents/chemical%20compatibility%20chart.pdf> (accessed September 12, 2017).

48 The CSB determined that the chemical fill lines were first installed with this same configuration at Mod B in 1996. Although the CSB did not identify any previous incidents associated with incorrect connections, the fill line proximity increased the likelihood of the inadvertent connection in this incident.

49 CCPS. *Guidelines for Process Safety in Batch Reaction Systems--Table 3: Equipment Configuration and Layout* [Online], 1999, p 11, 15, 33.

<http://app.knovel.com/hotlink/pdf/id:kt003JMGR1/guidelines-process-safety/equipment-configuration>. (accessed September 12, 2017).

50 A passive control minimizes the hazard through process and design strategies without active functioning of a device or human interaction. Examples of passive controls include spacing and using incompatible hose couplings. CCPS. *Guidelines for Engineering Design for Process Safety--Introduction*, 2nd ed. 5.1.1 [Online], Center for Chemical Process Safety/AIChE: New York, NY, 2012. <http://app.knovel.com/hotlink/pdf/id:kt00A68RS1/guidelines-engineering/inherent> (accessed September 12, 2017).

unlocked the sulfuric acid dust cap for the delivery. The sodium hypochlorite dust cap was unable to be locked because it was missing a split ring on one lever. Without the split ring on one of the cam levers, it was impossible to secure the dust cap on the

Physically isolating or using distance to separate fill lines can lower the risk of incorrect connections during bulk unloading operations

fill line with the padlock (Figures 5 and 7).⁵¹

The CSB was unable to determine why the sodium hypochlorite dust cap was missing a split ring nor how long it was left unsecured on the fill line prior to the incident. It is possible that the sodium hypochlorite

dust cap was not secured by the driver of the last sodium hypochlorite delivery nine days prior, and this went unnoticed by MGPI. Mod B operators reported that the split rings experienced chemical corrosion and this could have caused the split ring to deteriorate and fall off the dust cap. Though not causal, the CSB observed that the acetic anhydride dust cap was also missing a split ring on one lever. On the acetic anhydride dust cap, a chain was attached to a split ring on only one cam lever and wrapped around the empty lever, giving it the appearance of being secured on the fill line (Figure 6).

MGPI started using dust caps to prevent product contamination or tampering issues on all receiving lines in response to a 2010 food safety inspection. Though the practice of locking dust caps is not a specific requirement for process safety or environmental reasons, when executed properly, it was the only physical barrier preventing drivers from incorrectly connecting to the wrong fill line. MGPI had no design or engineering controls preventing the driver from making an incorrect connection. At the time of the incident, the Mod B fill lines were similar in appearance and identically sized. Because operators had a practice of keeping the fill lines locked with dust caps when not in use, drivers typically relied on operators to unlock the dust cap for the correct

fill line before they made a connection. Since both fill lines had the same diameter and orientation, the driver could connect the sulfuric acid hose to the incorrect, but unlocked, sodium hypochlorite fill line.

Chemical process plants and chemical distributors can

reduce the likelihood of an incorrect connection by designing and selecting equipment so that connections or manual configurations of components are difficult or impossible to perform in error.⁵² This includes designing fill lines so that a particular hose can be connected only to a fitting mated to receive it. The use of uniquely sized or shaped hose couplings and fill line connectors is another example of a passive control that eliminates or reduces the possibility of connecting the wrong hose and inadvertently transferring material (Figure 10).

In reviewing the range of fitting diameters offered by various hose manufacturers, the CSB found that the size and orientation of the fill lines used at Mod B are consistent with common industry practice. Based on information from the chemical distribution industry, 2- and 3-inch round hose couplings and fill line receivers are most common for this type of service. Though the identical size of the fill lines allows facilities to receive chemicals from multiple distributors, it also provides the opportunity for a wrong connection. Since the incident, Harcros has worked with MGPI to select uniquely shaped transfer equipment for sulfuric acid to make it impossible for drivers to connect another delivery hose to that line (Section 9.0). Facilities that receive multiple chemicals should work with distributors to determine what size and shape hose couplings are feasible and modify unloading equipment accordingly.

Work with motor carriers to select hose couplings and fill line connections with uniquely shaped and color-coded fittings for each chemical or class of chemicals

51 Through mechanical functionality testing of the as-found sodium hypochlorite dust cap and single split ring, the CSB determined there was no other way to lock the dust cap on the fill line using only the padlock and one split ring (e.g., by inserting the padlock through the lever that was missing the split ring).

52 CCPS. *Inherently Safer Chemical Processes-- A Life Cycle Approach: 4.5.10 Limitation of Available Energy* 2nd ed.; [Online], Center for Chemical Process Safety/AIChE New York, NY, 2009. <http://app.knovel.com/hotlink/pdf/id:kt0068GQQ3/inherently-safer-chemical/limitation-available> (accessed September 12, 2017).

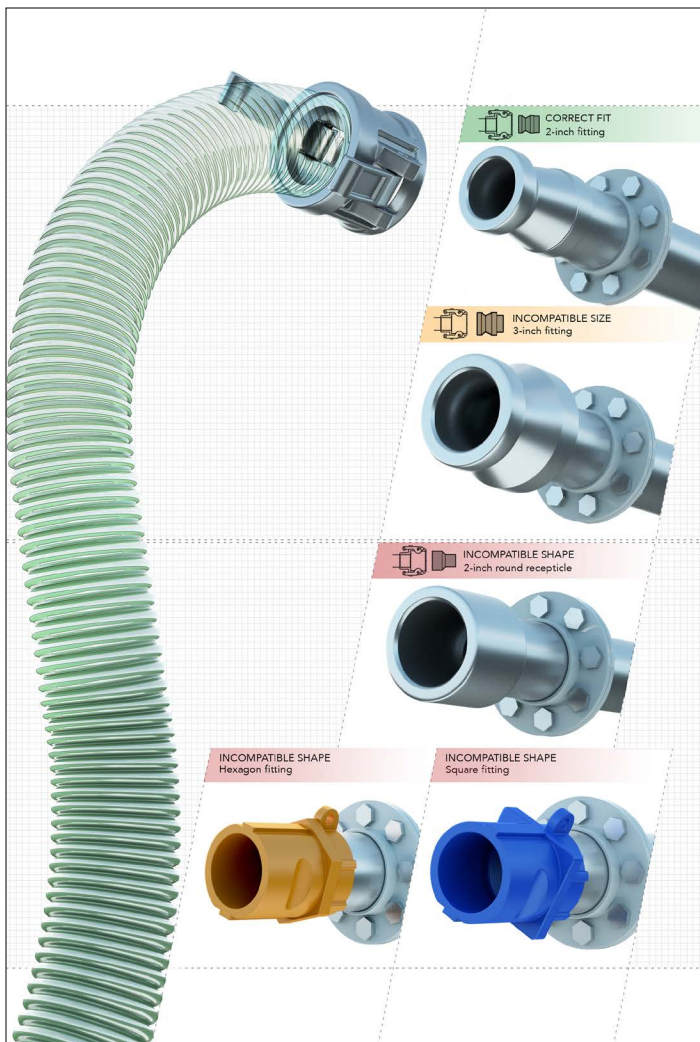


Figure 10. Combination of fill line shapes and sizes to avoid incorrect connections during deliveries (Source: CSB).

Color coding can also assist in ensuring proper connections. Colors associated with each class of chemicals can be used for pipe markers, couplings, fill lines and transfer piping.⁵³ For example, the facility and chemical distributor could select orange hexagon shaped couplings and fill line receivers for acids and square purple couplings and receivers for bases.

The CSB also evaluated whether MGPI's practice of placing identical padlocks on the sodium hypochlorite and sulfuric acid dust caps increased the likelihood of an incorrect connection. Though not causal, the CSB found that this method could result in an incorrect connection because the same key could unlock both chemicals and, as a result, could unlock the wrong dust cap in error. Contrary to Mod B, the onsite WWTP, which

53 The American Society of Mechanical Engineers (ASME) Standard A13.1, *Scheme for the Identification of Pipes*, includes a color chart that defines color schemes for six categories of chemicals and four user-defined color options for other chemicals.

receives four chemicals⁵⁴ via CTMV about 200 feet from the Mod B transfer area, uses a different padlock and key for each fill line.⁵⁵ Using different padlocks and keys for each valve prevents operators from unlocking the incorrect valve with another key.

5.1.2 PIPE MARKING

Pipe markings, labels, and tags are extremely important in process plants and all facilities that handle hazardous chemicals to ensure that workers can identify equipment that requires

manipulation and to communicate hazards that cannot be controlled by other means. Proper equipment identification reduces errors of commission⁵⁶ with using the wrong piece of equipment or performing

Pipe markings on transfer equipment and piping should be accurate and legible. Pipe markers should be placed as close to the fill line as possible

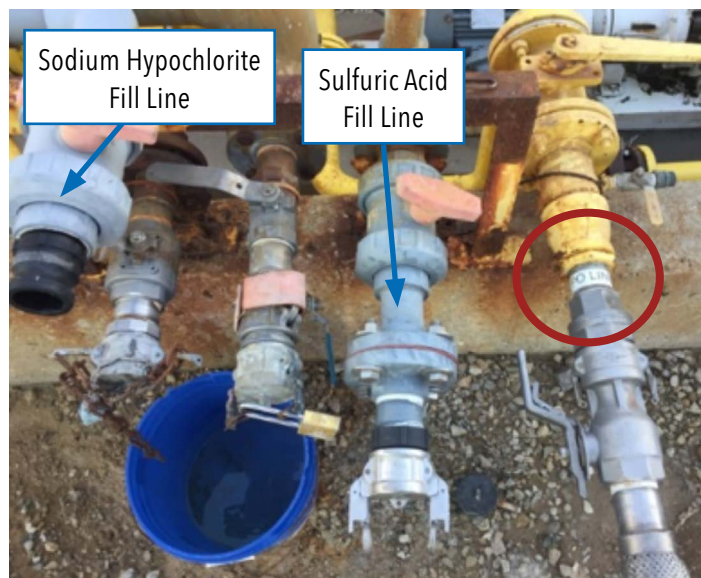


Figure 11. Neither sodium hypochlorite nor sulfuric acid fill lines had pipe markers or identification tags affixed at connection points. MGPI did have a pipe marker on the propylene oxide (PO) fill line near the connection point (circled) (Source: CSB).

54 The MGPI onsite WWTP receives phosphoric acid, sodium hydroxide (caustic), urea, and ferric chloride.

55 MGPI had locks on the transfer valves for three of the four fill lines at the WWTP. The caustic line contained a cap, intended to be secured and locked on the end of the fill line through the cam levers, similar to the Mod B fill lines. The CSB observed that though the cap was on the end of the caustic fill line, it was not locked at the time of the incident, as one lever also appeared to be missing a split ring.

56 An error of commission is typically associated with performing a task out of sequence by using the wrong control or entering the wrong value.

the wrong action.⁵⁷ The CSB found several key deficiencies in the pipe marking system at the Mod B unloading area that likely contributed to the incorrect connection. The CSB noted that, of the five fill lines in the area, only propylene oxide had a pipe marker at its connection point (Figure 11). Had MGPI placed pipe markers or identification tags on all the fill line connection points (or at the very least, on the sodium hypochlorite fill line connection point), it might have been immediately obvious to the driver that he was connecting the discharge hose to the incorrect fill line.

The CSB also found that the placement and orientation of the pipe markings downstream of some of the Mod B fill lines made it difficult for drivers less familiar with the piping arrangement to confirm that they made a correct connection. It is common practice for pipe markers to be placed at multiple points along piping, from start (e.g., connection point) to finish (e.g., tank).⁵⁸ These pipe markers must be strategically placed so that they can be easily followed and visually accessible from a normal line of vision⁵⁹; effective placement allows the pipes to be “traced.” The CSB observed pipe markers along the sulfuric acid and sodium hypochlorite piping and found that MGPI did not place pipe markers as close to the fill line connection points as possible. The piping immediately downstream of all the Mod B fill lines changed direction at a 90-degree elbow (Figure 12, right). Both the sodium hypochlorite and sulfuric acid pipe markers were located several feet downstream of the pipe elbow and fill line (Figure 12, right). The recommended industry practice for piping identification states that pipe markers shall be placed adjacent to changes in direction.⁶⁰ MGPI selected a sleeve or wrap around marker for the sodium hypochlorite piping that attached loosely to the pipe. In addition, the text of the pipe marker appeared upside down from the vantage point of the fill line area (Figure 12, left). MGPI’s placement and orientation of the sodium hypochlorite pipe marker likely decreased its visibility and readability to the driver when he connected the sulfuric acid hose to the fill line.



Figure 12. Sodium hypochlorite pipe marker appearing upside down (left) and sulfuric acid piping mislabeled “hydrochloric acid” from a prior service (top). Both pipe markers are located several feet from the fill line and elbow (right) (Source: CSB).

After the incident, the sulfuric acid fill line was found to be incorrectly identified as “hydrochloric acid” from a prior service (Figure 12, top).⁶¹ Although the CSB found a damaged sulfuric acid pipe marker on the ground approximately 3 feet south of the unloading station and fill lines, it could not be determined whether this pipe marker was adhered to the sulfuric acid fill line prior to the incident.⁶²

By comparison, the CSB noted that the WWTP has a much simpler design and identification scheme than Mod B. For instance, the chemical fill lines at the WWTP are more clearly marked with labels above each connection point (Figure 13).

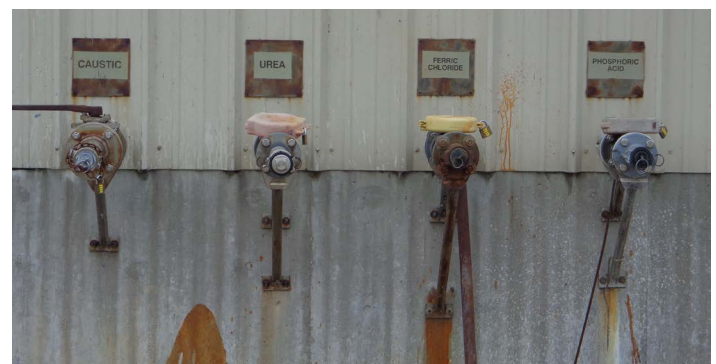


Figure 13. WWTP chemical fill lines (Source: CSB).

57 Crowl, D. *Human Factors Methods for Improving Performance in the Process Industries - 11. Labeling* [Online]; Center for Chemical Process Safety/AIChE: New York, NY, 2007. <http://app.knovel.com/hotlink/pdf/id:kt004M11B3/human-factors-methods/labeling> (accessed September 12, 2017).

58 American Society of Mechanical Engineers. A13.1 Scheme for the Identification of Pipes. ASME: New York, 2007.

59 American Society of Mechanical Engineers. A13.1 Scheme for the Identification of Pipes. ASME: New York, 2007.

60 American Society of Mechanical Engineers. A13.1 Scheme for the Identification of Pipes. ASME: New York, 2007.

61 The transfer system was modified in 2009 when MGPI permanently replaced hydrochloric acid with sulfuric acid for the modified starch process.

62 Prior to the incident, the adhesive pipe marker was affixed to the sulfuric acid line with tape directly on top of the hydrochloric acid marker from the previous service. According to MGPI, the water deluge system or water spray from the firetrucks and emergency response actions removed the pipe marker during the incident.

5.1.3 CHEMICAL UNLOADING PROCEDURES

To make processes safer, careful attention to human factors is necessary for procedures, just as it is for design and pipe markings. If the design and layout of procedures do not clearly indicate what should be done, the resulting confusion can increase the potential for error.⁶³ Accordingly, the inclusion of job aides, such as checklists, into procedures can help ensure critical steps are adhered to. The extent to which facility operators train their personnel on procedures, and verify knowledge and skills, can also affect the potential for error.⁶⁴ The CSB found that MGPI's unloading procedures were not aligned with work practices, and that the company lacked a rigorous process to ensure operators understood and could safely follow them. In addition, the CSB found that Harcros' procedures did not align with work practices and attributes those deficiencies, as well as others, to inadequate training.

5.1.3.1 MGPI

5.1.3.1.1 Procedures and Work Practices Not Aligned

As discussed in Section 3.1, after the operator signed the paperwork with the driver in the control room, the operator escorted the driver out to the unloading area. On the way, the operator pointed out the safety shower and then unlocked the sulfuric acid fill line. The operator reports that he pointed out the fill line to the driver and that the driver acknowledged the location; the driver, however, reports that the operator did not point out the location. The operator then returned the control room before the driver made the connection and opened the chemical transfer valve to discharge contents from the cargo tank. This work practice did not align with the Mod B sulfuric acid unloading procedure in two critical ways. First, the procedure states that operators must verify the connection: they are supposed to "have DOT-approved driver hook unloading hose to tank unloading station" and "not allow driver to connect hose to any other connection." Second, according to the procedure, when the driver is ready and the hose is connected,

the operator, not the truck driver, is supposed to open the sulfuric acid fill line valve. Adherence to either step would have required the operator to observe the connection between the discharge hose and fill line. Since the operator was more aware of the location of the sulfuric acid fill line valve than the truck driver, he likely would have noticed that the driver connected to the sodium hypochlorite line when he verified the correct connection or attempted to open the valve.

The CSB found that some operators were unfamiliar with these two steps in the unloading procedure. They indicated that the procedure did not state that a correct connection be verified, even though all Mod B unloading procedures include a step for verification. An operator reported to CSB investigators that it seemed logical, if they unlocked only one fill line (i.e., the correct fill line), that the truck driver would only be able to hook up to and discharge contents into that line. Operators also reported that it was their practice to have truck drivers open the fill line valve, in contrast to all other Mod B unloading procedures. They reasoned that it was safer for truck drivers to open the fill line valve because they had the appropriate PPE on in the event of a spill or leak from the fill line.

5.1.3.1.2 Training and Active Monitoring

The CSB reviewed both MGPI's training program and active monitoring process to determine if these were factors which led directly to the incident. With respect to training, DOT regulations provide requirements for hazardous materials (hazmat) employees. These regulations require that each hazmat employee be provided general awareness/familiarization training, as well as function-specific training, including training on unloading cargo tanks.⁶⁵ Training must be given at least once every three years after the initial training.⁶⁶ The CSB found that, as part of its training program, MGPI requires Mod B operators to review all procedures, including those for unloading, annually. In addition, MGPI asserts that "Toolbox Talks," where operators discuss, among other things, observations about the chemical deliveries and any changes necessary, are conducted regularly at Mod B. Mod B operators present on the day of the incident were current with all MGPI training requirements on the sulfuric

63 CCPS. *Inherently Safer Chemical Processes--A Life Cycle Approach: 6.4 Error Prevention* [Online], Center for Chemical Process Safety/AIChE: New York, NY, 2009. <http://app.knovel.com/hotlink/pdf/id:kt0068GRV3/inherently-safer-chemical/error-prevention> (accessed September 12, 2007).

64 CCPS. *Inherently Safer Chemical Processes--A Life Cycle Approach: 6.4 Error Prevention* [Online], Center for Chemical Process Safety/AIChE: New York, NY, 2009. <http://app.knovel.com/hotlink/pdf/id:kt0068GRV3/inherently-safer-chemical/error-prevention> (accessed September 12, 2007).

65 49 C.F.R. § 172.704(a) (2017).

66 49 C.F.R. § 172.704(c)(2) (2017).

acid unloading procedure.⁶⁷ Yet some stated that the procedure did not call for verification of the correct fill line and some were unaware that the procedure required operators, not truck drivers, to open the fill line valve. The CSB found these gaps to be indicative of the inadequacy of MGPI's training program.

In assessing MGPI's training program, the CSB also found it necessary to examine MGPI's active monitoring process. Active monitoring refers to all formal and informal checking activities carried out by line managers (i.e., personnel directly overseeing those performing the work in the field) to proactively ensure that barriers and risk controls are effective.⁶⁸ In contrast, auditing is typically carried out with a degree of independence from line management.⁶⁹ Active monitoring instead focuses responsibility on line management, who can more effectively implement safety systems that work.⁷⁰

The CSB found that, despite the existence of an active monitoring process at Mod B for unloading operations, the process did not identify that operators were not performing procedures as written. Operators deviated from the procedure to avoid chemical exposure by allowing the driver to open the facility transfer valve. This deviation, however, removed a crucial barrier that prevented drivers from mixing chemicals. Although the Mod B supervisor monitors the unloading practice by participating in and overseeing the majority of unloading transfers, the CSB found no records or accounts of operator deviations. Such records or accounts might have proven vital for active monitoring as they likely would have informed management how best to improve upon the unloading practices and/or procedures. For example, had a record been created for the operators' deviance from the requirement that operators, not drivers, open the facility transfer valve, operators, supervisors, and appropriate management personnel could have assessed the safety risks of such a deviance,

67 Mod B operators had most recently completed their sulfuric acid unloading procedure training in June/July 2016.

68 Wilkinson, P. *The role of "Active Monitoring" in Preventing Major Accidents*. [Online]; Noetic Group (Risk): Canberra, Australia and Washington, DC. http://www.csb.gov/assets/1/7/Wilkinson_Active_Monitoring.pdf (accessed September 12, 2017).

69 Wilkinson, P. *The role of "Active Monitoring" in Preventing Major Accidents*. [Online]; Noetic Group (Risk): Canberra, Australia and Washington, DC. http://www.csb.gov/assets/1/7/Wilkinson_Active_Monitoring.pdf (accessed September 12, 2017).

70 Wilkinson, P. *The role of "Active Monitoring" in Preventing Major Accidents*. [Online]; Noetic Group (Risk): Canberra, Australia and Washington, DC. http://www.csb.gov/assets/1/7/Wilkinson_Active_Monitoring.pdf (accessed September 12, 2017).

and adjusted the practice and/or procedure accordingly. The Mod B supervisor was off duty on the day of the incident; even so, the CSB found that MGPI did not provide him with the necessary training to properly oversee transfers, which requires more than correcting instances of nonconformance on a case-by-case basis.

Because systems and procedures do not always work as intended, it is critical for companies to regularly and effectively examine them through active monitoring.⁷¹ With meaningful employee participation, procedures can be written or updated to align with actual operator performance, where appropriate. When actual practice is found to deviate from procedures in an unsafe way, such as having truck drivers perform hose line hook-ups without operator verification, then supervisory instruction, training, and verification to adhere to the procedures is needed.

Alternatively, where actual operator practice may be safer than as instructed in procedures, management can incorporate these actions into updated procedures and provide training on them. The CSB found this aspect of active monitoring to be important because, although it could not be determined whether the sodium hypochlorite fill line dust cap was locked after the last shipment, none of the Mod B unloading procedures provided for verifying that dust caps on fill lines were locked after delivery. Despite the fact that two fill lines were incapable of being locked before the incident, operators reported to the CSB that their routine practice was to ensure that dust caps were locked. Unloading procedures should always include measures to ensure that fill lines are properly locked after delivery, a practice that should be checked periodically. Had MGPI conducted effective active monitoring for its unloading procedures, management might have been able to note instances of nonalignment, update the procedures, and train operators accordingly.

5.1.3.1.3 Comparison to Other Chemical Unloading Procedures at MGPI

Although not causal, the CSB nonetheless reviewed other MGPI chemical unloading procedures for comparison, including the Mod B sodium hypochlorite and WWTP chemical unloading procedures,

71 Wilkinson, P. *The role of "Active Monitoring" in Preventing Major Accidents*. [Online]; Noetic Group (Risk): Canberra, Australia and Washington, DC. http://www.csb.gov/assets/1/7/Wilkinson_Active_Monitoring.pdf (accessed September 12, 2017).

38. The Modified Starch Operator directs the supplier to the chemical unloading station. Verified: _____ Time: _____ Date: _____	3. Unlock gate by chemical unloading area.
39. VERIFY the vendor Bill of Lading and that the vendor is delivering Sodium Hypochlorite. Verified: _____ Time: _____ Date: _____	4. Have DOT-approved driver hook unloading hose to Bulk Tank Unloading station. Do not allow driver to connect this hose to any other connection. Consequence of Deviation from this: possibility of heavy reaction with any trace chemical in the wrong line. Heat reaction will occur, which may cause very hazardous situation in rest of tank yard.
40. VERIFY that the supplier is wearing the proper personal protective equipment. Verified: _____ Time: _____ Date: _____	5. Make sure valve #202 (Drain Valve) is closed.
41. Have supplier CONNECT vehicle transfer hose to the NaOCl fill line valve 176. Verified: _____ Time: _____ Date: _____	6. When driver is ready, and hose is connected, then open valve #203. Driver will send Sulfuric Acid through this valve to the tank.
42. OPEN the NaOCl Fill Line valve 176 to the Sodium Hypochlorite Bulk Tank NaOCl -BT. Verified: _____ Time: _____ Date: _____	7. Confirm liquid is transferring from the unloading truck to the tank, by observing level on tank.
43. Have supplier SLOWLY OPEN vehicle transfer valve. Verified: _____ Time: _____ Date: _____	8. When unloading is finished, close valve #203 at the unloading station.
44. Have supplier BEGIN to transfer of Sodium Hypochlorite from the chemical truck to the Sodium Hypochlorite Bulk Tank NaOCl -BT. Verified: _____ Time: _____ Date: _____	9. Have driver unhook Sulfuric Acid hose from station connection.
45. Have supplier MONITOR for leaks while unloading Sodium Hypochlorite. Verified: _____ Time: _____ Date: _____	10. Lock up gate at chemical unloading station, and complete paperwork for verification.

Figure 14. Part of the Mod B sodium hypochlorite unloading procedure (left) and sulfuric acid unloading procedure (right) (Source: MGPI).

and found that they lacked consistency. Consistency in procedures ensures that they are easy to follow and demands the use of, among other things, standard, effective formatting and page layout.⁷² Procedures must also be complete and accurate and include the appropriate level of detail.⁷³ This is particularly true for procedures involving critical tasks or activities. Procedures that are not followed due to obsolescence, inaccuracy, unavailability, or difficulty in implementation often present safety risks.⁷⁴

The CSB examined the unloading procedures at Mod B for sulfuric acid and sodium hypochlorite and found an inconsistent approach. While the sodium hypochlorite procedure included space for the operator to sign, date, and timestamp each step, the sulfuric acid procedure did not (Figure 14). Furthermore, the sodium hypochlorite procedure was more detailed and direct, especially with respect to ensuring that truck driver actions aligned with the procedure. For example, the sodium hypochlorite procedure states, "Have supplier slowly open vehicle transfer valve," while the sulfuric acid procedure does not mention the vehicle transfer valve. The CSB notes that the rigor applied to the sulfuric acid unloading procedure should have at least matched (or preferably

been greater than) that of the sodium hypochlorite procedure, especially since sulfuric acid is classified as an "Extremely Hazardous Substance" under the EPA's Emergency Planning and Community Right-to-Know Act (EPCRA), while sodium hypochlorite is not.⁷⁵

The CSB also found that the WWTP procedures employs a much different, more specific, approach to chemical unloading. Critical steps missing in the sulfuric acid unloading procedure are included, for example, in the WWTP's unloading procedure for caustic, a chemical delivered to Mod B. In terms of verifying a correct connection, the WWTP caustic unloading procedures states, "Verify the truck driver has his hose hooked to the correct fill line and that all connections are secured. Sign the truck driver[']s paper work that you verif[ied] correct connections [. . .] and then allow the driver to start unloading the caustic." Compared to the Mod B sulfuric acid procedure step for verification, this is much more specific. The procedure also calls for WWTP personnel to ensure the cap is locked after delivery. While including such steps in a procedure does not guarantee that the steps will be followed, including critical verification steps increases the likelihood that such steps are not overlooked.

5.1.3.2 HARCROS

5.1.3.2.1 Procedures and Work Practices Not Aligned

The CSB reviewed the Harcros CTMV unloading procedure and found that work practices did not align with the procedure in two critical ways. On the day of the incident, the truck driver

72 CCPS. *Guidelines for Writing Effective Operating and Maintenance Procedures* [Online]. Center for Chemical Process Safety/AIChE: New York, NY, 1996. <http://app.knovel.com/hotlink/toc/id:kpGWEOMP01/guidelines-writing-effective/guidelines-writing-effective> (accessed September 20, 2007).

73 CCPS. *Guidelines for Writing Effective Operating and Maintenance Procedures* [Online]. Center for Chemical Process Safety/AIChE: New York, NY, 1996. <http://app.knovel.com/hotlink/toc/id:kpGWEOMP01/guidelines-writing-effective/guidelines-writing-effective> (accessed September 20, 2007).

74 CCPS. *Inherently Safer Chemical Processes--A Life Cycle Approach: 6.4 Error Prevention* [Online]. Center for Chemical Process Safety/AIChE: New York, NY, 2009. <http://app.knovel.com/hotlink/pdf/id:kt0068GRV3/inherently-safer-chemical/error-prevention> (accessed September 12, 2007).

75 EPCRA requires industry to report on the storage, use, and release of hazardous substances to federal, state, and local governments. Sulfuric acid is on EPCRA's list of Extremely Hazardous Substances, with a reportable quantity of 1,000 pounds. 40 C.F.R. § 355 app. A (2017). For more information on EPCRA, see Section 5.5.2.



Figure 15. Post-incident photograph of Harcros CTMV connected to sodium hypochlorite fill line at Mod B unloading area, showing sodium hypochlorite tank and cab of CTMV (Source: MGPI).

connected his discharge hose to the first fill line he saw unlocked after the operator left the unloading area. He then opened the valves and returned to the cab of the truck. First, the procedure states that drivers must “carefully check to make certain that material to be transferred will be going into the correct vessel.” Second, the procedure states that drivers must “continuously monitor transfer.”⁷⁶ The CSB found, however, that the truck driver did not check to ensure the material in the truck would go into the correct vessel, such as by tracing the fill line with the operator or requesting confirmation of a correct connection from the operator before the operator left the unloading area. Furthermore, the truck driver did not continuously monitor the transfer, as he was in the cab of the truck facing away from the unloading area (Figure 15).⁷⁷ Had this second step in the procedure been followed, the driver likely would have monitored the unloading operations from an area closer to the back of the truck, thereby allowing him to immediately close either the fill line or truck valve to stop the flow of sulfuric acid.

⁷⁶ This step is a requirement of a U.S. Department of Transportation regulation, 49 C.F.R. § 177.834(i) (2017). 49 C.F.R. § 177.834(i)(2) (2017) states, in part, “A motor carrier who transports hazardous materials by a cargo tank must ensure that the cargo tank is attended by a qualified person at all times during unloading.” 49 C.F.R. § 177.834(i)(2) (2017).

⁷⁷ 49 C.F.R. § 177.834(i)(3) (2017) gives the conditions for which a qualified person “attends” the loading or unloading of a cargo tank. Attendance requires that (1) the qualified person is within 25 feet of the cargo tank, is alert, and has an unobstructed view of the cargo tank and delivery hose; (2) the qualified person observes by means of video cameras and the loading or unloading system is equipped with various safety safeguards; or (3) the hoses used in the loading or unloading are able to stop the flow of product from both source and receiving tank within 1 second without human intervention. 49 C.F.R. § 177.834(i)(3) (2017).

This in turn might have caused the chemical reaction to slow or stop much sooner and, as a result, mitigated the consequences of the incident. Although the truck driver attempted to shut off the truck valve, he could not safely do so because the cloud had developed and he was surrounded by toxic gas.

The CSB found that the driver was likely unfamiliar with these two steps in the tank truck unloading procedure. In fact, it is likely that the truck driver did not confirm a correct connection because he reasoned that if the operator unlocked only one fill line (i.e., the correct one), the fill line that the driver saw unlocked was the one and only, and correct, fill line to connect to. As the MGPI operator assumed, the truck driver also assumed that all other fill lines were properly secured. Furthermore, the driver reported to the CSB that he entered the cab to put away his paperwork. Harcros asserts that the driver could have continuously monitored the unloading operations, even from inside the cab, by maintaining an unobstructed view of the discharge hose and cargo truck through the truck’s side view mirrors.⁷⁸

⁷⁸ The Department of Transportation’s Pipeline and Hazardous Materials Safety Administration has investigated numerous incidents similar to the one at MGPI, including one in Holly Hill, Florida, in 2015 (Section 6.0). In the Holly Hill incident, the Department of Transportation cited the delivery company for violating the attendance requirement because the company’s procedures required the truck driver to enter the cab of the truck while unloading. The investigative team found that sitting in the cab of the tractor put the operator some 40 feet away from the rear of the cargo tank and delivery hose and would not provide an unobstructed view of the hose and activities occurring back there. Similar circumstances occurred with respect to the Harcros driver during the incident at MGPI.

5.1.3.2.2 Training

The CSB also examined Harcros' training program and determined that it was deficient in effectively communicating the importance of the critical safety steps that did not align with work practices on the day of the incident. As part of its training program, Harcros requires drivers to complete various tasks included on a tanker training log; the driver's trainer must observe and initial that they have been completed. Two of these tasks include ensuring "customer's piping is to the correct storage vessel" and "constant monitoring of the connections and tanker during the unloading process to abate leaks or any other malfunction that might arise." Although training records indicate that the truck driver was current on all Harcros training requirements,⁷⁹ he did not mention when interviewed by the CSB that the procedure called for checking to ensure a correct connection. Nor did he mention that he was responsible for continuously monitoring the unloading process.

In reviewing Harcros' training documentation, the CSB identified another area that may have contributed to the incident: the tanker training log indicated that the driver was aware of the location of a pneumatic⁸⁰ emergency shutoff switch for the internal valve that would stop the flow of product, at the front of the trailer⁸¹; however, the CSB found that the driver did not trigger the emergency shutoff switch, despite being in the cab at the time of the incident (Figure 16).

U.S. Department of Transportation (DOT) regulations for driver training require, in part, that for the operation of cargo tanks or vehicles with portable tanks with a capacity of 1,000 gallons or more, training include "operation of emergency control features of the cargo tank or portable tank."⁸² This training must occur once every three years per 49 C.F.R. § 177.816(d)



Figure 16. Harcros CTMV (right) and emergency shutoff switch (left) (Sources: Harcros and CSB).

and 49 C.F.R. § 172.704(c)(2). Accordingly, drivers should be intimately familiar with the location of emergency remote shutoffs, as well as with how they function. Had Harcros provided adequate training, such as by requiring its drivers to practice locating and triggering the emergency remote shutoff in simulations, the driver might have attempted to trigger the emergency shutoff switch, rather than attempt to close the valve at the back of the trailer. Without adequate training, no amount of reading or checking would be likely to produce the appropriate response reliably in a real emergency.

5.1.3.3 COLLABORATION IN PROCEDURE DEVELOPMENT

The CSB determined it is critical for facilities and chemical distributors to identify and assess risks associated with unloading operations and collaborate to develop and/or agree upon procedures that address those risks. Such collaboration ensures that responsibilities are clearly defined. For example, on the day of the incident, the truck driver opened the valve to the fill line although, according to MGPI's procedures, the operator was supposed to. This action conflicted with Harcros' procedure.

Facilities and chemical distributors should collaborate to develop, or agree upon, procedures for chemical unloading

Had the procedures been developed together, or agreed upon by both parties, the roles might not have been switched. Procedures should also establish a process that requires

79 The driver had most recently completed his training in 2016, as indicated on the tanker training log. The CSB also found that the driver was current with his Commercial Driver's License hazmat and tanker endorsements.

80 Pneumatic means containing or operated by air or gas under pressure.

81 The Harcros tank trailer was a Department of Transportation 412 version, which is required to have stop valves capable of closing the tank outlet within 30 seconds of actuation and of being remotely actuated. 49 C.F.R. § 178.345 and 178.348 (2017). According to Harcros, four devices on the Harcros cargo tank could have stopped the flow of material from the trailer: (1) a manual external main valve located at the rear of the cargo tank; (2) a manual internal valve located at the rear of the cargo tank; (3) the pneumatic emergency shut off at the front of the cargo tank; and (4) a manual valve on top of the cargo tank, near the dome.

82 49 C.F.R. § 177.816(b)(1) (2017).

facility personnel to be physically present during deliveries because they are more familiar with their equipment. Having both facility personnel and CTMV drivers monitor the chemical unloading process allows either party to identify concerns and increases the likelihood for safe execution.

As this incident demonstrates, both facility personnel and CTMV drivers should verify a correct connection before transferring chemicals. Using a checklist or other means, such as tips and reminders, is critical when coordinating a multi-person procedure to prevent the omission of steps, especially if the steps are critical to safety.⁸³ Verifying a proper connection should be both verbal and visual. The combination of verbal and visual confirmation is important because it makes it more likely that an individual will catch his own errors or omissions, including his understanding of what is happening. On the day of the incident, neither verbal nor visual verification was given nor requested; though the operator reported that he pointed out the correct connection, the driver did not recall hearing that information. Equipment walk-downs, where operators walk down fill lines from connection point to storage tank with drivers, may also be employed, where feasible. In addition, management of facilities and chemical distributors should provide effective training on unloading procedures, both periodically and when equipment or chemicals are modified. Finally, management and supervisory personnel must actively monitor procedures for conformance, and update them as necessary.

5.2 AUTOMATION AND REMOTE SHUTDOWN

At the time of the incident, MGPI did not have instrumentation in the Mod B process control system that would have automatically shut down the transfer of chemicals in the event of a process deviation, such as a temperature, pressure, or level exceedance, in the sodium hypochlorite bulk tank. Because the reaction generated significant pressure and the tank was 90% full prior to the delivery, an interlock on a pressure or level indicator would have signaled the transfer valve to automatically close, without requiring action from operators.

Alarms and interlocks are active safeguards that, when activated,

83 CCPS. *Guidelines for Writing Effective Operating and Maintenance Procedures--5.4 Procedure Checklist Elements* [Online], Center for Chemical Process Safety/AIChE: New York, NY, 1996. http://app.knovel.com/web/toc.v/cid:kpGWEOMP01/viewerType:toc/root_slug:guidelines-for-writing-effective-operating-and-maintenance-procedures (accessed September 12, 2017).

monitor process variables and function to eliminate or mitigate a hazard.⁸⁴ Process plants can configure instrumentation to automatically modify or shut down process equipment, without operator action, or signal operators to remotely mitigate a process deviation, such as a pressure increase, through the control system. MGPI has a sodium hypochlorite tank level indicator that signals an alarm in the control system when the level approaches tank capacity; however, it only notifies operators of the high level and does not automatically shut down the transfer, as MGPI did not configure the system to do that. At 7:59 AM on the day of the incident, the level indicator in the sodium hypochlorite bulk tank triggered an alarm after the sulfuric acid began flowing into the tank. Based on operator interviews, this was likely about the same time operators became aware of the reaction and began to evacuate the control building.

MGPI had two emergency stop buttons for the Mod B process, one in the control room, and the other in the indoor process area, that could remotely shut down equipment and processes downstream of the chemical unloading area. In addition, operators could remotely shut down equipment through the control system. One of the emergency stop buttons could stop the flow from the sodium hypochlorite tank to the day tank, but not from the chemical unloading area to the bulk tank. MGPI had a deluge system to mitigate propylene oxide releases in the unloading area, which emergency responders were able to manually activate to help suppress the cloud produced by the reaction.

The cloud entering the control room prevented operators from activating the emergency stop buttons for the chemical processes. Activating the emergency stop buttons would have halted the processes, but would not have mitigated the reaction, as there was no remote shutdown capability for the chemical unloading area.

Install or configure interlocks and mitigation measures to maintain safe operations during chemical unloading activities

84 CCPS. *Guidelines for Engineering Design for Process Safety - 5.1.7 Safeguard Stewardship*, 2nd ed. [Online], Center for Chemical Process Safety/AIChE: New York, NY, 2012. <http://app.knovel.com/hotlink/pdf/id:kt00A68RY1/guidelines-engineering/safeguard-stewardship> (accessed September 12, 2017).

Designing and installing automated systems for chemical unloading areas provides additional safeguards to unloading processes as the systems automatically shut down valves supplying chemicals to bulk or day tanks in the event of an unintended reaction or tank overflow. At MGPI, such an automatic shutoff device would have stopped the flow of sulfuric acid that was reacting with the sodium hypochlorite in the bulk tank long before emergency responders closed the discharge valve on the Harcros truck nearly 45 minutes later.

5.3 MOD B VENTILATION

The CSB found that the pre-incident design of the Mod B building and ventilation system allowed for the intake of the cloud produced by the reaction, which forced operators to evacuate. Because the gases produced by the reaction overwhelmed the operators in the control room, they were forced to evacuate and did not have time to retrieve their emergency escape respirators to protect them from respiratory hazards associated with even higher chemical concentrations outside.

The Mod B building has a positive pressure control room, designed only to prevent harmful gases from the adjacent indoor process area from entering the control room. Positive pressure is achieved by maintaining a higher air pressure in the control room than in the indoor process area. MGPI's heating, ventilation, and air conditioning (HVAC) system for Mod B has a 4-ton air handler with a high-speed motor that draws air from two intakes located on the exterior of the Mod B building. One of these intakes is located on the first level of the structure, adjacent to the tank farm and bulk chemical transfer area. A gauge constantly reads and compares the air pressure inside the control room to that in the production area. If the pressure in the control room drops below that in the production area, an alarm alerts operators to evacuate.

Although MGPI designed the control room to protect occupants from harmful vapors inside the production area, design considerations did not include protecting occupants from harmful gases or vapors from outside the building. Because MGPI received and stored a number of hazardous chemicals in the chemical unloading area and tank farm, any vapors from tank trucks unloading or from any vents or pressure release devices on the tanks could enter the control room through any doors, open crevices, or air intakes.

Other than a particulate filter, the fresh air intake that supplies air to the control room does not include filtration or cleaning systems to effectively remove the chlorine gas or other gases from the outside air. Though shutting off ventilation systems during a toxic release can reduce impact on control room occupants, the cloud had entered through the Mod B building intake before operators became aware of the release. MGPI had outdoor air monitors near the Mod B tank farm to detect concentrations of propylene oxide only. If the propylene oxide concentrations reached a predefined set point, an alarm would sound in the control room and operators were required to shut down the ventilation system per the emergency action plan. The HVAC intake system had no toxic gas alarms that would have warned operators to don escape respirators before the gases could enter through the vents.

In 2003 the CSB investigated a release of chlorine gas from the Honeywell International, Inc. (Honeywell) chemical plant in Baton Rouge, Louisiana, which resulted in injuries to seven workers and the issuance of a shelter-in-place advisory for residents within a 0.5-mile radius.⁸⁵ The chlorine was released from a failed coolant system and, as in the MGPI incident, entered an occupied control room through the ventilation system. The CSB found that the Honeywell release lasted 3.5 hours, partly because operators were forced to evacuate the area before they could diagnose the problem and isolate the source of the leak.

As with MGPI, the Honeywell control room was positive pressure and designed to prevent the infiltration of hazardous gases. However, unlike the Mod B building at MGPI, which only maintained positive pressure relative to the production area, the Honeywell control room was designed to maintain a higher pressure than the outside atmosphere. Because Honeywell attempted to prevent vapors from outside entering the control room, the ventilation system intakes were located at the highest point of the plant to pull in fresh air. The CSB found, however, found that the positive pressure control system did not protect personnel or equipment during the 2003 release. At Honeywell, the CSB observed holes and gaps in the HVAC intake ducts located on the roof, which allowed chlorine to be drawn into the building during the release. In addition, the Honeywell control

85 CSB. Honeywell Chemical Incidents. August 8, 2005. http://www.csb.gov/investigations/completed-investigations/?F_InvestigationId=54 (accessed October 3, 2017).

room ventilation system intake was not equipped with toxic gas alarms or an automatic shutoff, but with a manual shutoff device.

5.3.1 GUIDANCE AND STANDARDS

Standards and industry guidance for designing buildings and ventilation systems to protect occupants in buildings at facilities handling hazardous chemicals are limited. The American Petroleum Institute (API) develops standards for petroleum refineries and API Recommended Practices 550, 551, and 752 provide direction around positive pressure control rooms that may be helpful to other industries. The Chlorine Institute (CI) also provides guidance on designing building and ventilation systems for facilities handling sodium hypochlorite. Although MGPI is not a member of the CI (Section 7.1), Pamphlet 64 provides guidance on designing ventilation systems, which can be useful to industries and facilities that handle sodium hypochlorite.

Pamphlet 64 (Section 7.1) covers emergency response plans for sodium hypochlorite and suggests that facilities consider designing building and ventilation systems to minimize the impact of a release on building occupants.⁸⁶ This includes elevated air intakes, because chlorine gas is heavier than air and tends to accumulate at lower elevations.⁸⁷ The intakes on the first floor of the Mod B building likely allowed for greater concentrations of chlorine in the cloud to enter the building shortly after the chemical reaction began. In addition, Pamphlet 64 recommends chlorine monitors with alarms that automatically trigger ventilation system shutdown and filtration equipment to remove chlorine from supply air to keep building occupants safe during a chlorine release. Without these controls, operators must rely on respiratory protection that, in the case of MGPI, was not readily accessible during the release, given that the cloud entered the control room without warning (Section 5.4).

Although it does not include specific design requirements for control rooms, the U.S. Occupational Safety and Health Administration (OSHA) Process Safety Management of Highly

86 The Chlorine Institute. *Emergency Response Plans for Chlor-Alkali, Sodium Hypochlorite and Hydrogen Chlorite Facilities. Pamphlet 64; 7th ed.*; The Chlorine Institute: Arlington, VA, November 2014.

87 The Chlorine Institute. *Emergency Response Plans for Chlor-Alkali, Sodium Hypochlorite and Hydrogen Chlorite Facilities. Pamphlet 64; 7th ed.*; The Chlorine Institute: Arlington, VA, November 2014.

Hazardous Chemicals standard (PSM) requires facilities to perform a process hazard analysis (PHA) on processes covered by the PSM standard.⁸⁸ PSM is a performance-based standard that includes requirements for preventing or minimizing the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals that are covered under the standard (Section 8.1).⁸⁹ The PSM standard applies to processes that involve certain chemicals at or above specified threshold quantities.⁹⁰ PSM requires employers to perform an initial PHA on covered processes to identify, evaluate, and control the hazards involved in the process.⁹¹ Specifically, the PHA shall address, among other things, facility siting.⁹² When evaluating siting, facilities should consider whether toxic or flammable gases from releases are able to enter control rooms.

In 2008, OSHA, under the PSM standard, cited Kuehne Chemical, a chlor-alkali plant in South Kearney, New Jersey,⁹³ for failing to accurately address the ingress of chlorine gas due to a catastrophic release from chlorine lines into the control room. Chlorine is a chemical that falls under the PSM standard if held in sufficient quantities. Although chlorine gas in addition to other toxic compounds entered the Mod B building on the day of the MGPI incident, the chlorine was a byproduct of a reaction between sulfuric acid and sodium hypochlorite, neither of which is covered by PSM.

However, other processes and chemicals at Mod B are covered by the PSM standard, including two chemicals stored above threshold quantities at Mod B: propylene oxide (received at the unloading area) and phosphorous oxychloride (not received at the unloading area). Because of the MGPI incident, OSHA initially issued citations to MGPI for 12 violations.⁹⁴ One was for not appropriately performing a PHA that addressed the hazard of toxic and flammable

88 29 C.F.R. § 1910.119(e) (2017).

89 29 C.F.R. § 1910.119 (2017).

90 19 C.F.R. § 1910.119(a)(1) (2017).

91 29 C.F.R. § 1910.119(e)(1) (2017).

92 29 C.F.R. § 1910.119(e)(3)(v) (2017).

93 Kuehne Company. <http://www.kuehnecompany.com/history/> (accessed November 27, 2017).

94 OSHA and MGPI entered an Informal Settlement Agreement on May 10, 2017, which reduced the number of violations and penalty. See Section 8.1.

vapors entering the control room through the pressurized air handling equipment. MGPI was also specifically cited for not adequately addressing hazards related to facility siting. OSHA reasoned that "Employees were exposed to [a] release of volatile organic compounds (VOC)s to atmosphere that historically result in explosion, fire and health hazards leading to injury and death to employees in the workplace."⁹⁵ Had the hazard of toxic vapors entering the control room been recognized prior to the incident, the ventilation system at Mod B may have been modified or designed to prevent ingress.

Commonly referenced texts briefly cover positive pressure control rooms and ventilation systems. *Lees' Loss Prevention in the Process Industries* (4th Edition) discusses the need for an airtight design, positive pressure requirements, and the possible use of toxic gas detectors and alarms in the control building that shut off normal ventilation air.⁹⁶ Design of control rooms for protection against toxic releases is also discussed in the Chemical Industry Association's (CIA) *Process Plant Hazard and Control Building Design* (1979).⁹⁷ Specifically it states, "Normal external ventilation

Evaluate building design and ventilation systems near chemical unloading stations to ensure occupants are protected in the event of a spill or chemical reaction

air supplies, liable to be contaminated, must be capable of being sealed off... [and] control building occupants must be supplied in an emergency with clean air for the length of the emergency or alternatively

for the time necessary to shut the plant down."⁹⁸ Alternatively, CIA acknowledges that it may be possible for ducted air to be supplied from a sufficient distance "that it is uncontaminated

under the wind condition that put the building itself at risk."⁹⁹ As explained in Section 3.1 and Section 5.4 of this Case Study, Mod B operators were forced to evacuate the building without shutting down any other processes due to the toxic gas entering the building through the vents directly adjacent to the tank farm and the lack of access to appropriate respirators.

The Center for Chemical Process Safety (CCPS) *Guidelines for Facility Siting and Layout* (2003) discusses control building siting and placement of building HVAC intakes. CCPS recommends that vents and relief vents on equipment be located to vent to a safe location, specifically a safe distance from building HVAC intakes.¹⁰⁰ CCPS also suggests that consequence analyses per API RP 752 be conducted to address potential toxic impacts to control buildings. If the control building is shown to be impacted, mitigation measures, such as supplied air, HVAC pressurization, or shutdown, should be provided.¹⁰¹

5.3.2 PREVIOUS RECOMMENDATION TO ASHRAE

Had the Mod B building and ventilation system been designed to prevent the infiltration of, or automatically respond to, releases from the outdoor tank farm, operators likely would have had more time to safely shut down processes, retrieve their emergency escape respirators, and evacuate. Because of the lack of U.S. standards and guidance for how to specifically design building ventilation systems to protect against different types of potentially hazardous chemicals from various sources, in 2005, at the conclusion of the Honeywell investigation, the CSB issued recommendation [2003-13-I-LA-R22](#)¹⁰² to the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). The CSB recommended that ASHRAE "Develop guidance on the effective design and maintenance of HVAC systems and other necessary control room components designed to protect employees and equipment in the event of a release of hazardous

95 OSHA Inspection 1186824, Citation 1 Item 7. This violation was amended in the Informal Settlement Agreement and combined with the general PHA violation, Citation 1 Item 6.

96 Mannan, S. *Lees' Loss Prevention in the Process Industries*, Vols. 1-3, 4th ed.; [Online]; Elsevier: Waltham, MA, 2012. <http://app.knovel.com/hotlink/toc/id:kpLLPPIVH2/lees-loss-prevention/lees-loss-prevention> (accessed September 13, 2017).

97 Chemical Industry Association. (1979). An approach to the categorization of process plant hazard and control building design. London, England, 1979.

98 Chemical Industry Association. (1979). An approach to the categorization of process plant hazard and control building design. London, England, 1979. Appendix III.6.

99 Chemical Industry Association. (1979). An approach to the categorization of process plant hazard and control building design. London, England, 1979. Appendix III.6.

100 CCPS. *Guidelines for Facility Siting and Layout*. [Online] Center for Chemical Process Safety/AIChE: New York, NY, 2003. <http://app.knovel.com/hotlink/toc/id:kpGFSL0005/guidelines-facility-siting/guidelines-facility-siting> (accessed September 13, 2017).

101 CCPS. *Guidelines for Facility Siting and Layout*. [Online] Center for Chemical Process Safety/AIChE: New York, NY, 2003. <http://app.knovel.com/hotlink/toc/id:kpGFSL0005/guidelines-facility-siting/guidelines-facility-siting> (accessed September 13, 2017).

102 Recommendation Status Change Summary, 2003-13-I-LA-R22. [http://www.csb.gov/assets/recommendation/Status_Change_Summary_ASHRAE_\(Honeywell_R22\)_O-ARAR1.pdf](http://www.csb.gov/assets/recommendation/Status_Change_Summary_ASHRAE_(Honeywell_R22)_O-ARAR1.pdf) (accessed September 13, 2017).

materials.” In 2015 the CSB updated the Recommendations Status to “Open–Acceptable Response or Alternate Response.”¹⁰³ At that time, ASHRAE had expressed support for the recommendation and provided the CSB with an outline of a new guidance document, “Heating, Ventilation & Air Conditioning of Hazardous Spaces,” proposed as either an ASHRAE handbook chapter or standard or design guide. ASHRAE also indicated that it planned to begin drafting the guidance document in February 2016.

ASHRAE is a global, nonprofit organization that develops and publishes voluntary consensus standards for the HVAC industry.¹⁰⁴ The standards define minimum values for acceptable performance, whereas its other documents encourage enhanced performance.¹⁰⁵ ASHRAE is accredited by the American National Standards Institute (ANSI) and follows ANSI requirements for due process and standards development.¹⁰⁶ OSHA recognizes both ANSI and ASHRAE standards as national consensus standards for purposes of identifying recognized hazards that do not have a specific OSHA standard and thus fall under the General Duty Clause.¹⁰⁷ In addition, model building and energy codes have adopted some ASHRAE standards and are required to be strictly adhered to in some jurisdictions.¹⁰⁸

In 2014, ASHRAE provided the CSB a proposed draft outline for a chapter or standard titled “Heating, Ventilation & Air Conditioning of Hazardous Spaces.” The outline is broken into eleven sections; the first few cover the purpose, scope, definitions, and applicable standards and the eleventh provides

103 An “Open–Acceptable Response or Alternate Response” designation means a response by a recipient that indicates a planned action that would satisfy the objective of the recommendation when implemented, including a written timetable for completion.

104 ASHRAE. About ASHRAE. <https://www.ashrae.org/about-ashrae> (accessed September 13, 2017).

105 ASHRAE. Standards and Guidelines. <https://www.ashrae.org/standards-research-technology/standards-guidelines> (accessed September 13, 2017).

106 ASHRAE. Standards and Guidelines. <https://www.ashrae.org/standards-research-technology/standards-guidelines> (accessed September 13, 2017).

107 Section 5(A)(1) of the Occupational Safety and Health Act requires that employers provide employment and place of employment free from recognized hazards that are causing or are likely to cause death or serious physical harm. This provision affords OSHA the ability to issue citations when the four components of this provision are met: 1) the employer failed to keep his/her workplace free of a “hazard,” 2) the hazard was “recognized” either by the cited employer individually or by the employer’s industry generally, 3) the recognized hazard was causing or was likely to cause death or serious physical harm, and 4) there was a feasible means available that would eliminate or materially reduce the hazard.

108 ASHRAE Standard 90.1 *Energy Standard for Buildings Except Low-Rise Residential Buildings*; ASHRAE: Atlanta, GA, 2016.

references. Other sections provide guidance on, among other topics, applicable hazardous substances, sources of hazards in relation to work spaces, principles of protection, and equipment selection and installation. Of note, under sources of hazards in relation to work spaces, ASHRAE distinguishes among external sources, internal sources, and combined sources. MGPI protected the occupants of the Mod B building from internal sources that were in the processing area inside the Mod B building; however, the toxic cloud that entered the Mod B building was the result of external sources and, more specifically, combined sources. Additionally, the section on hazards covers hazardous conditions normally and abnormally present (e.g., as the result of a release from an inadvertent chemical reaction).

The section on equipment selection proposes to cover, among other things and in conjunction with other standards, ventilation equipment, pressurization equipment, and filtration. Ventilation is further outlined under the principles of protection section, which distinguishes between positive and negative ventilation. It also covers other principles of protection such as pressurization, containment, isolation and removal, and filtration. The rest of the standard or chapter will help facilities select and install the correct equipment to protect occupants.

ASHRAE has not yet provided the CSB with a draft of the standard or chapter nor a timetable for its completion. The incident at MGPI highlights the need for ASHRAE to continue developing the dedicated guidance as proposed to the CSB in 2014. The CSB found that existing standards and guidance for addressing building ventilation at chemical facilities lack specific information for designing and maintaining HVAC systems to control hazards from a variety of chemicals and sources. If ASHRAE issues this guidance, facilities can apply it to the design or modification of occupied buildings and chemical processes, or when evaluating the effectiveness of their engineering controls to handle contaminants from inside or outside sources.

5.4 ACCESS TO EMERGENCY ESCAPE RESPIRATORS

MGPI’s Emergency Response Plan calls for shutting off the source of a release if safe to do so and evacuating the area. As described in Section 5.2, operators could not stop the release by shutting down the transfer from a safe location because the toxic cloud

entered the control room. Accordingly, operators immediately evacuated the building; however, the CSB found that Mod B operators did not have immediate access to escape respirators for the evacuation.¹⁰⁹ Mod B did have mobile escape bottles with breathing air, intended to be used for a short duration during emergency egress in hazardous atmospheres but, while they were readily accessible during the incident, the respirator face pieces that attached to them were not. According to Mod B operators, the operators' practice was to lock respirator face pieces in their lockers at the end of each shift and remove them at the start of shift. Because the incident occurred at shift change, the oncoming day shift operator's respirator remained locked. Further complicating matters is that these lockers are equipped with combination locks, requiring additional time in an emergency to attempt to unlock.

According to records from MGPI's respiratory training program, the company instructs employees to properly store respirators when not in use to prevent damage.¹¹⁰ Although proper storage is key to prevent damage to this equipment, respirators should never be secured such that immediate access is impeded. The OSHA Respiratory Protection Standard requires that emergency respirators be kept accessible in the work area and stored in compartments or covers that are clearly marked as containing emergency respirators.¹¹¹ Immediate accessibility was vitally important at MGPI where operators had to rely on respiratory protection to protect themselves from an outdoor chemical release. As discussed, the Mod B area was not equipped with automatic controls to immediately stop the transfer of sulfuric acid or shut down the building's ventilation system; therefore, had MGPI provided Mod B operators with easily accessible storage areas for respiratory equipment, including face pieces and mobile escape bottles, the Mod B operators might have been able to don their escape respirators before evacuating, thereby reducing the severity of the injuries they suffered.

The CSB also found that the truck driver did not have access to

109 Escape respirators are hoods or face pieces attached to a supply of breathing air and are intended to be used only for emergency exit.

110 The operators inside the control room on the day of the incident had most recently completed respiratory protection training in April 2016.

111 OSHA. Respiratory Protection Standard. 29 C.F.R. § 1910.134(h)(2)(ii) (2017). MGPI immediately addressed this issue by ensuring the accessibility of emergency respirators at Mod B post-incident. See Section 9.0 for a description of post-incident changes.

respiratory protection during the incident. Harcros did not provide a respirator for the truck driver because Harcros does not require delivery drivers to wear respirators unless its customers require them.¹¹² Because of this, Harcros drivers are generally not trained under the Respiratory Protection Standard. According to Harcros, MGPI did not have a respirator requirement; no indication was made for such a requirement when receiving verbal delivery instructions from the company. As such, Harcros operated under the assumption that MGPI did not have known workplace hazards that would have caused Harcros drivers delivering chemicals to MGPI to wear respirators. The CSB found, however, that the sulfuric acid Safety Data Sheet (SDS), produced by Harcros, provides that chemical respirators with organic vapor cartridges and full face pieces be worn for individual protection. As such, MGPI operated under the assumption that Harcros drivers had access to respirators in their trucks. The CSB also found that Harcros' tanker training log states that all proper PPE must be donned according to the SDS for the chemical being delivered. The CSB determined that this type of respirator was not provided to the driver on the day of the incident. Although a chemical respirator with organic vapor cartridge and full face piece would not have provided the driver with clean breathing air, it would have afforded the driver at least some protection, which might have allowed him to escape with less severe injuries.

In reviewing regulations regarding the provision of respiratory protection on CTMVs, the CSB found that the U.S. Pipeline and Hazardous Materials Safety Administration (PHMSA) Hazardous Materials Regulations (HMR)s require respiratory protection be provided during the shipment of CTMVs for certain chemicals. For example, chlorine CTMVs must be shipped only when equipped with a gas mask of a type approved by the National Institute of Occupational Safety and Health (NIOSH) for chlorine service.¹¹³ Also, carriers of carbon monoxide, cryogenic liquid must provide drivers with self-contained air breathing apparatuses that are approved by NIOSH.¹¹⁴ Although there is no similar regulation for the shipment of sulfuric acid, such requirements establish that it is critical for chemical distribution companies to provide drivers

112 Harcros indicated that two of its customers require Harcros drivers to have respiratory protection readily accessible when making deliveries to their sites because of potential respiratory hazards that could be encountered. Harcros delivers diatomaceous Earth to one customer, and caustic soda and caustic potash to the other. Both require air purifying respirators.

113 49 C.F.R. § 177.840(e) (2017).

114 49 C.F.R. § 177.840(k) (2017).

with respiratory protection when the circumstances warrant it. As such, chemical distribution companies should conduct evaluations to determine the need to train drivers to don appropriate PPE and respond to chemical spills or releases during unloading operations. Where mitigating incidents is feasible, chemical distributors should provide the appropriate PPE for doing so on CTMVs. Where mitigating incidents is not feasible, chemical distributors should ensure that drivers have access to, and are properly trained to wear, emergency escape respirators on CTMVs to safely evacuate in the event of an incident. Furthermore, in addition to chemical distribution companies supplying respirators on CTMVs, facilities can also store emergency respiratory protection near unloading areas. If properly trained, drivers can access emergency respirators to safely escape in the event of an accidental release.

The CSB found Harcros' respiratory protection policy for drivers to be inadequate in part because, as described, Harcros relies on communications made by its customers to determine workplace hazards. Such reliance may prove misplaced, however, where parties do not actively establish who is responsible for making the communication; an omission on the part of one may be interpreted as a commission by the other. As described, there must be shared responsibility between chemical distribution companies and facility management to ensure chemicals are unloaded safely. Accordingly, the CSB recommends that Harcros establish a process whereby the respiratory hazards associated with chemical unloading at each customer's site are proactively evaluated. The evaluations should determine whether drivers might need emergency escape respirators in the event of an accidental reaction and/or release of chemicals. Equipment and training for such protection should be provided, as appropriate, in accordance with OSHA's Respiratory Protection Standard. Finally, so as to avoid the problems faced by MGPI operators, the equipment should be stored in an area of the CTMV that allows for immediate access.

5.5 EMERGENCY PLANNING AND RESPONSE ANALYSIS

5.5.1 INCIDENT AFTER ACTION REVIEW AND IMPROVEMENTS

Following the October 2016 incident, city and county emergency responders conducted a post-incident critique to examine issues identified during the response. Though the response was largely viewed as a success by responders, the After-Action Report and Improvement Plan (AAR & IP), issued by the Atchison County

Department of Emergency Management (ACDEM), identified several issues and areas for improvement. Most responders agreed that interagency communication and coordination went well on the day of the incident, but they identified some challenges communicating the incident to the public as well as updating the local hospital. The report identified issues with the CodeRED® community notification system. CodeRED is a mass notification system provider that can alert and inform subscribers of emergencies or severe weather through a variety of methods (e.g., voice, text, email, mobile alerts).¹¹⁵ Although Atchison County uses CodeRED, notifications did not go out at the time of the incident. In the absence of CodeRED functioning, ACDEM and local emergency responders utilized social media and local radio and television to communicate details about the emergency. As identified by ACDEM in the AAR & IP, CodeRED notifications did not go out due to a lack of training on the system. Progress has been made with respect to CodeRED since the incident. ACDEM has completed additional training on the CodeRED system to ensure it will work correctly and has increased efforts to publicize the notification system.

Though some emergency responders quickly became aware of the chemicals involved in the reaction, the exact chemicals and concentration of chemicals contained in the cloud, as well as the exposure effects on the community, remained largely unknown throughout the incident. As part of the after-action review, hospital staff reported that they were not kept informed of the status of potential victims and decontamination procedures for the chemicals. In addition, incident command did not directly communicate information regarding the released chemicals to the hospitals until about 1 and a half to 2 hours after the incident began. The emergency responders set up triage stations in town to evaluate members of the public prior to hospital transport. Atchison Hospital, though overwhelmed initially, was able to decontaminate and treat all arriving patients. According to ACDEM, after the incident, it set up a plan with local hospitals to have a representative at the emergency operations center or command post, depending on the size of the event. This is meant to ensure that the representative is up-to-date on all information to relay back to the hospital.

¹¹⁵ Onsolve Code Red Product Description. <https://www.onsolve.com/solutions/products/codered/> (accessed October 30, 2017).

During the incident, the Kansas Department of Health and Environment (KDHE) initiated syndromic surveillance through the National Syndromic Surveillance Program (NSSP).¹¹⁶ The NSSP system enables public health agencies at all levels to immediately communicate and share health information to increase awareness of, and respond to, hazardous events and outbreaks.¹¹⁷ Epidemiologists at KDHE used the system to search the health effects associated with the chemicals involved in the reaction and, within two hours of the incident, began sharing information with state and local health departments and hospitals.¹¹⁸

Following the incident, the AAR & IP identified the need for more operational coordination and a liaison to communicate exposure information during similar incidents. Less than two months after the incident, MGPI hosted training with local emergency responders, including a representative from Atchison Hospital, to discuss the hazards of the chemicals used at Mod B (Section 5.5.2.1).

5.5.2 STATE AND LOCAL EMERGENCY PLANNING

Intended to address concerns about local preparedness for chemical emergencies and to ensure public access to information, the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986, established a framework for states to organize resources to pre-plan for chemical accidents.¹¹⁹ EPCRA is divided into four parts: (1) emergency planning (§§ 301-303), (2) emergency release notification (§ 304), (3) hazardous chemical inventory reporting (§§ 311-312), and (4) toxic chemical release reporting (§ 313).¹²⁰ The chemicals covered by each section of EPCRA are different, as are the quantities that trigger reporting.¹²¹

116 National Syndromic Surveillance Program. Chemical Spill in Kansas: Importance of Sharing Information across Sites. CDC February 2017. <https://www.cdc.gov/2Fnssp/2Fdocuments/2Fsuccess-story-chemical-spill-20170201.pdf&usg=AOvVaw2QLzSqjBWPItpKez3akXCg> (accessed October 30, 2017).

117 <https://www.cdc.gov/nssp/overview.html>

118 National Syndromic Surveillance Program. Chemical Spill in Kansas: Importance of Sharing Information Across Sites. CDC February 2017. <https://www.cdc.gov/2Fnssp/2Fdocuments/2Fsuccess-story-chemical-spill-20170201.pdf&usg=AOvVaw2QLzSqjBWPItpKez3akXCg> (accessed October 30, 2017).

119 EPA. The Emergency Planning and Community Right-to-Know Act. https://www.epa.gov/sites/production/files/2015-05/documents/epcra_fact_sheet.pdf (accessed November 2, 2017).

120 EPA. The Emergency Planning and Community Right-to-Know Act. https://www.epa.gov/sites/production/files/2015-05/documents/epcra_fact_sheet.pdf (accessed November 2, 2017).

121 EPA. The Emergency Planning and Community Right-to-Know Act. https://www.epa.gov/sites/production/files/2015-05/documents/epcra_fact_sheet.pdf (accessed

EPCRA Section 301 requires each state to create a State Emergency Response Commission (SERC) composed of individuals with expertise in emergency response.¹²² It also requires each SERC to set forth emergency planning districts, each of which must have a Local Emergency Planning Committee (LEPC).¹²³ LEPCs must be composed of elected state and local officials; police, fire, civil defense, public health, transportation, and environmental professionals; representatives of facilities subject to EPCRA emergency planning requirements; community groups; and the media.¹²⁴ While SERCs supervise and coordinate the activities of LEPCs, establish procedures for receiving and processing public requests for information, and review local emergency response plans, LEPCs develop community emergency response plans, review the plans annually, and provide information to the public.¹²⁵

Community emergency response plans are developed by LEPCs with stakeholder participation.¹²⁶ The plans must (1) identify facilities and transportation routes of extremely hazardous substances; (2) describe emergency response procedures, onsite and offsite; (3) designate a community coordinator and facility coordinators to implement the plan; (4) outline emergency notification procedures; (5) explain the means to determine the probable area and population affected by chemical releases; (6) describe local emergency equipment and facilities and the people responsible for them; (7) outline evacuation plans; (8) provide a training program for emergency responders (including schedules); and (9) detail methods and schedules for exercising emergency response plans.¹²⁷ Facilities covered by Section 311 must also submit Emergency and Hazardous Chemical Inventory forms to their SERCs, LEPCs, and local fire

October 31, 2017).

122 42 U.S.C. § 11001 (1986).

123 42 U.S.C. § 11001 (1986).

124 EPA. The Emergency Planning and Community Right-to-Know Act. https://www.epa.gov/sites/production/files/2015-05/documents/epcra_fact_sheet.pdf (accessed November 2, 2017).

125 EPA. The Emergency Planning and Community Right-to-Know Act. https://www.epa.gov/sites/production/files/2015-05/documents/epcra_fact_sheet.pdf (accessed November 2, 2017).

126 EPA. Local Emergency Planning Committee. <https://www.epa.gov/epcra/local-emergency-planning-committees> (accessed November 2, 2017).

127 EPA. Local Emergency Planning Committee. <https://www.epa.gov/epcra/local-emergency-planning-committees> (accessed November 2, 2017).

departments annually.¹²⁸ Facilities provide either Tier I or Tier II inventory forms.¹²⁹ Tier I inventory forms include the following information for each applicable hazard category: (1) an estimate (in ranges) of the maximum amount of hazardous chemicals for each category present at the facility at any time during the preceding calendar year; (2) an estimate (in ranges) of the average daily amount of hazardous chemicals in each category; and (3) the general location of hazardous chemicals in each category.¹³⁰ Tier II inventory forms contain much of the same information, but list the information by chemical (rather than by hazard category).¹³¹ Information submitted under Sections 311 and 312 is available to the public from SERCs and LEPCs.¹³²

While EPCRA provides an essential function to emergency planning and management, funding deficiencies have often caused shortfalls. A 2008 survey by EPA found that the majority of LEPCs were not receiving technical assistance or guidance from the federal government, although a majority of them reported that federal support “plays a significant role” in directing their activities.¹³³ Although grants are occasionally made for LEPC activity with federal funding such as the Department of Transportation (DOT) Hazardous Materials Emergency Preparedness (HMEP) Grants, many LEPCs only receive direct funding through state fees from EPCRA report submissions or are unfunded.¹³⁴ Accordingly, it is critical that LEPCs take advantage of grants and resources, when available, in order to ensure the full success of their capabilities.

128 EPA. The Emergency Planning and Community Right-to-Know Act. https://www.epa.gov/sites/production/files/2015-05/documents/epcra_fact_sheet.pdf (accessed October 31, 2017).

129 EPA. The Emergency Planning and Community Right-to-Know Act. https://www.epa.gov/sites/production/files/2015-05/documents/epcra_fact_sheet.pdf (accessed October 31, 2017).

130 EPA. The Emergency Planning and Community Right-to-Know Act. https://www.epa.gov/sites/production/files/2015-05/documents/epcra_fact_sheet.pdf (accessed October 31, 2017).

131 EPA. The Emergency Planning and Community Right-to-Know Act. https://www.epa.gov/sites/production/files/2015-05/documents/epcra_fact_sheet.pdf (accessed October 31, 2017).

132 EPA. The Emergency Planning and Community Right-to-Know Act. https://www.epa.gov/sites/production/files/2015-05/documents/epcra_fact_sheet.pdf (accessed October 31, 2017).

133 EPA. 2008 Nationwide Survey of Local Emergency Planning Committees (LEPCs): Final Report. https://www.epa.gov/sites/production/files/2013-08/documents/2008_lepcsurv.pdf (accessed December 5, 2017).

134 EPA. 2008 Nationwide Survey of Local Emergency Planning Committees (LEPCs): Final Report. https://www.epa.gov/sites/production/files/2013-08/documents/2008_lepcsurv.pdf (accessed December 5, 2017).

In the state of Kansas, the Commission on Emergency Planning and Response (CEPR) serves as the state emergency response commission. The CEPR implements federal EPCRA provisions and works to enhance state and local emergency response and preparedness capabilities.¹³⁵ This is achieved by assisting with the development of local hazard mitigation plans, training and exercises, and reviewing responses to emergencies and recommending improvements.¹³⁶ The CEPR, among other duties, designates emergency planning districts, oversees 105 LEPCs within the state, and coordinates proposals for training grant funds.¹³⁷

The Kansas Department of Emergency Management (KDEM) provides administrative support to the CEPR, and together, these organizations work to provide information and training to LEPCs within the state. The CEPR and KDEM published an LEPC handbook to provide information on LEPC duties and responsibilities as well as example activities, exercises and potential sources for additional LEPC funding.¹³⁸ In addition, the CEPR has multiple resources available to LEPCs including conference presentations and regional training activities.

5.5.2.1 ATCHISON COUNTY LEPC

When examining emergency planning and response, the CSB noted that, though there were no issues with the response that resulted in additional consequences to emergency responders or members of the public, neither the city nor the county trained for such an event. With respect to the Atchison Fire Department (AFD), the CSB found that AFD had conducted annual tours of MGPI as well as annual fire extinguisher training for MGPI employees. In addition, AFD performs annual inspections of the facility's sprinklers, safety showers/eye wash stations, emergency lighting, and hydrants. In terms of the Atchison County LEPC,¹³⁹

135 Kansas Department of Emergency Management. Commission on Emergency Planning and Response. <http://www.kansastag.gov/KDEM.asp?PageID=408> (accessed December 4, 2017).

136 Kansas Department of Emergency Management. Commission on Emergency Planning and Response. <http://www.kansastag.gov/KDEM.asp?PageID=408> (accessed December 4, 2017).

137 Kansas Department of Emergency Management. Commission on Emergency Planning and Response. <http://www.kansastag.gov/KDEM.asp?PageID=408> (accessed December 4, 2017).

138 Kansas Department of Emergency Management. Kansas LEPC Handbook. http://kansastag.gov/AdvHTML_doc_upload/2014%20LEPC%20Handbook%209%20apr%2014.pdf (accessed October 30, 2017).

139 The Atchison County LEPC is administered by ACDEM.

the CSB found that the LEPC, together with ACDEM, holds training and table-top exercises for area emergency responders throughout the year. The LEPC organizes full-scale exercises every three years. More recent exercises, however, were largely focused on infectious diseases, active shooter situations, and severe weather events prior to the October 2016 incident. These training exercises did not include incidents at chemical facilities, or more specifically, incidents involving accidental releases of unknown chemicals in the community. A functional hazmat exercise is scheduled for the second quarter of 2019.

Following the incident, MGPI has increased its involvement with local emergency planners and responders. During the week of December 12, 2016, MGPI invited emergency responders to Mod B for training on the chemicals used and stored there, as well as for a discussion on the properties and hazards of those chemicals. Three separate sessions were held, with attendees from AFD, Atchison County LEPC, and Atchison Hospital. MGPI provided copies of a non-compatible chemical matrix for all chemicals used at Mod B, its Emergency Response Plan, and maps of its facility, including the locations of all bulk tanks and chemicals stored therein. It also demonstrated new PPE installed at Mod B since the incident during these sessions. Additionally, on October 6, 2017, MGPI attended and participated in a Tabletop Exercise in Hiawatha, Kansas, facilitated by KDEM, where a chlorine gas release resulting from a railcar derailment was simulated. Members of the Atchison County LEPC also participated in that exercise.

Just as MGPI increased its involvement with local emergency planners and responders, emergency responders and facilities have also increased participation in the Atchison County LEPC. In April 2016, 20 members were listed on the LEPC roster. The most recent LEPC roster from March 2017 lists 26 members, including representatives from law enforcement/EMS/firefighting and MGPI. During an LEPC meeting held on March 22, 2017, committee members conducted a tabletop exercise of the incident that occurred at MGPI. Local emergency response departments discussed the events of that day, as well as successes and improvements that could be made in the future. MGPI also requested that its Emergency Response Plan be discussed at the end of each year. LEPC meetings were also held in May, July, and August 2017.

The CSB found that the Atchison LEPC does not review, or train on, EPA Risk Management Plans submitted by facilities that produce or store extremely hazardous chemicals. Further, the CSB concluded that besides MGPI, there are four other facilities in Atchison County that store sufficient quantities of hazardous chemicals to be covered under the EPA Risk Management Program (RMP). The LEPCs are encouraged by KDEM to request facility Risk Management Plans from the state for preplanning and training.¹⁴⁰ Atchison County, however did not obtain or review Risk Management Plans prior to the incident. The Risk Management Plan submitted for MGPI did not include sodium hypochlorite and sulfuric acid as those chemicals are not covered under the EPA RMP. The CSB still found, however, that LEPCs can gain useful information by reviewing facility Risk Management Plans and training for offsite releases involving chemicals processed and stored at those sites.

5.5.3 THE HMEP GRANT PROGRAM

Because LEPCs generally only receive funding through the state fees or other private sources, LEPCs and SERCs must take advantage of federal grant opportunities to support and enhance their emergency planning and training programs.¹⁴¹ The HMEP grant program, offered by PHMSA, provides financial and technical assistance and guidance to enhance hazardous materials emergency planning and training.¹⁴² The HMEP comprises two allocations: planning and training.¹⁴³ The purpose of the planning grant is to develop, improve, and implement emergency plans under EPCRA. The training allocation funds public sector employee training for hazmat incidents. States, territories and tribal nations can designate an agency to receive HMEP grant funds.¹⁴⁴ In Kansas, KDEM requests project proposals from active and eligible

140 Kansas Department of Emergency Management. Kansas LEPC Handbook, pp 35. http://kansastag.gov/AdvHTML_doc_upload/2014%20LEPC%20Handbook%209%20apr%2014.pdf (accessed October 31, 2017). How LEPCs can use RMP tools when planning for chemical accidents. KDEM July 2016 http://kansastag.gov/AdvHTML_doc_upload/Risk%20Management%20Program-EPA%20Ndiaye%20and%20Brewer.pdf (accessed October 31, 2017)

141 EPA. 2008 Nationwide Survey of LEPCs, pp26. https://www.epa.gov/sites/production/files/2013-08/documents/2008_lepcsurv.pdf (accessed November 1, 2017).

142 The Hazard Grants Programs are funded by registration fees collected by DOT from hazmat shippers and carriers. PHMSA Hazardous Materials Grants Program. <https://www.phmsa.dot.gov/grants/hazmat/hazardous-materials-grants-program> (accessed October 31, 2017).

143 PHMSA Hazardous Materials Grants Program. <https://www.phmsa.dot.gov/grants/hazmat/hazardous-materials-grants-program> (accessed October 31, 2017).

144 PHMSA Hazardous Materials Grants Program. <https://www.phmsa.dot.gov/grants/hazmat/hazardous-materials-grants-program> (accessed October 31, 2017).

LEPCs, and submits grant applications to PHMSA.¹⁴⁵ Once PHMSA awards the grants, KDEM distributes grant awards and monitors how award funds are used.¹⁴⁶ In FY 2014-2015, Kansas received \$368,000 in grant funding.¹⁴⁷ KDEM can distribute funds directly to LEPCs; fund exercise and training initiatives that benefit local responders; or fund state and regional hazardous materials training through universities and training institutes.¹⁴⁸ The HMEP grant program designates funding priorities for training and planning to prevent hazmat transportation incidents.¹⁴⁹ Among other priorities, the program includes conducting appropriate hazard assessments to determine the level of hazmat risks within a jurisdiction, and conducting drills and exercises to test county emergency response capabilities and identify gaps in training and planning.¹⁵⁰ Eligible training activities can include chemical specific response training, such as a toxic chemical release.¹⁵¹ Planning activities can include hazmat tabletop exercises and hazmat preparedness activities for fixed facilities.¹⁵²

Funding is provided to the Atchison County LEPC from local tax dollars. The CSB learned that the Atchison County LEPC has not directly applied for or received HMEP grant funding for planning or training since 2007. In 2007, the LEPC received grant funds to update the county emergency operations plan. In 2013, it was included in an application submitted by another county to conduct a 12-county regional commodity flow study to identify

145 Kansas HMEP Grant Guideline. KDEM: 2016; pp 3, 5. http://www.kansastag.gov/AdvHTML_doc_upload/HMEP%202015-2016%20Grant%20Guide%20.pdf (accessed November 1, 2017).

146 Kansas HMEP Grant Guideline. KDEM: 2016; pp 5, 17. http://www.kansastag.gov/AdvHTML_doc_upload/HMEP%202015-2016%20Grant%20Guide%20.pdf (accessed November 1, 2017).

147 Kansas HMEP Grant Guideline. KDEM: 2016; pp 5. http://www.kansastag.gov/AdvHTML_doc_upload/HMEP%202015-2016%20Grant%20Guide%20.pdf (accessed November 1, 2017).

148 Kansas HMEP Grant Guideline. KDEM: 2016; pp 5. http://www.kansastag.gov/AdvHTML_doc_upload/HMEP%202015-2016%20Grant%20Guide%20.pdf (accessed November 1, 2017).

149 Kansas HMEP Grant Guideline. KDEM: 2016; pp 5. http://www.kansastag.gov/AdvHTML_doc_upload/HMEP%202015-2016%20Grant%20Guide%20.pdf (accessed November 1, 2017).

150 Kansas HMEP Grant Guideline. KDEM: 2016; pp 7. http://www.kansastag.gov/AdvHTML_doc_upload/HMEP%202015-2016%20Grant%20Guide%20.pdf (accessed November 1, 2017).

151 Kansas HMEP Grant Guideline. KDEM: 2016; pp 9. http://www.kansastag.gov/AdvHTML_doc_upload/HMEP%202015-2016%20Grant%20Guide%20.pdf (accessed November 1, 2017).

152 Kansas HMEP Grant Guideline. KDEM: 2016; pp 10-11. http://www.kansastag.gov/AdvHTML_doc_upload/HMEP%202015-2016%20Grant%20Guide%20.pdf (accessed November 1, 2017).

hazmat transportation flow patterns throughout the state. Though KDEM uses HMEP grant funds for state and regional activities through which LEPCs and emergency responders can participate, the CSB found that the Atchison County LEPC can benefit from applying for grants to fund additional planning and training activities. Therefore, the CSB concludes that the Atchison LEPC should better utilize the training and information resources available at a state and regional level, and work with the state to apply for grants that will provide funding specifically directed at preparing for emergencies involving hazardous materials. In addition the LEPC should conduct more pre-planning and training with chemical facilities in the county to ensure the community is prepared for future incidents.

6.0 SIMILAR INCIDENTS DURING UNLOADING OPERATIONS

The CSB found that over the years a number of injuries have occurred as a result of similar incidents involving inadvertent mixing during unloading. PHMSA reviewed incident data from 2003-2007 and found that a significant number of highway incidents¹⁵³ subject to mandatory reporting¹⁵⁴ occurred during loading and unloading incident to movement of a hazardous material.¹⁵⁵ The CSB requested and received, information regarding similar incidents from PHMSA. One such event in Holly Hill, Florida, was similar to the MGPI incident and involved a carrier delivering sodium hypochlorite.

The CSB reviewed PHMSA incident data from 2014 through 2017 and found that unloading incidents involving hose connections to incorrect tanks occur frequently but most commonly involve compatible materials and result in tank overfills. Less common are incidents similar to the MGPI incident where two incompatible materials are inadvertently mixed due to incorrect tank connections. However, since

153 PHMSA's regulations apply to the transportation of hazardous materials in commerce, including loading, unloading, and storage incidental to transportation. See 49 C.F.R. § 171.1(c) (2017), which separates transportation functions into four areas: (1) movement, (2) loading incidental to movement of a hazardous material, (3) unloading incidental to movement of a hazardous material, and (4) storage incidental to movement of a hazardous material.

154 PHMSA's regulations require detailed written reports for hazardous materials incidents as described in 49 C.F.R. § 171.16 (2017) and mandate immediate reporting for serious incidents that meet thresholds described in 49 C.F.R. § 171.15 (2017).

155 See Section 8.2.1 PHMSA Guidance for further discussion of PHMSA data and guidance.

January 1, 2014,¹⁵⁶ eight incidents similar to the MGPI incident have occurred involving incompatible materials and resulting in a chemical reaction. These incidents resulted in 44 injuries and the evacuation of 846 individuals (Table 3).

Table 3. Incidents involving inadvertent mixing from PHMSA Database (Source: CSB).

PHMSA Totals: (January 1, 2014 through June 9, 2017)	
Incidents:	8
Injuries:	44
Hospitalizations:	2
Individuals Evacuated:	846

Analysis of the data reveals that these incidents occur periodically and are not tied to specific industries; for instance, incidents have occurred at water treatment plants, generation plants, public and private swimming pools, as well as at other industrial facilities. These incidents can lead to injuries and evacuations due to potentially violent chemical reactions and harmful gases entering the air. Inadvertent mixing during unloading can occur at any facility that receives more than one type of chemical. The CSB concludes that adopting key lessons and recommendations resulting from this Case Study, in addition to recognized industry and regulatory guidance, can prevent similar incidents.

7.0 INDUSTRY ASSOCIATIONS AND GUIDANCE

7.1 CHLORINE INSTITUTE

The Chlorine Institute (CI) is a technical trade association that focuses on the production, distribution, and use of chlor-alkali¹⁵⁷ chemicals.¹⁵⁸ CI members include chlorine producers, packagers, distributors, users, and suppliers, and its North American producer members account for a majority of the total chlorine production capacity of the United States and Canada.

As part of its chlorine stewardship program, the CI requires its members that produce, distribute, or use chlorine to sign

¹⁵⁶ Up to and including June 9, 2017.

¹⁵⁷ Chlor-alkali products refer to chlorine, sodium hydroxide, potassium hydroxide, sodium hypochlorite, anhydrous hydrogen chloride, and hydrochloric acid collectively.

¹⁵⁸ The Chlorine Institute. <https://www.chlorineinstitute.org/about-us/> (accessed September 12, 2017).

Holly Hill Incident

The Pipeline and Hazardous Materials Safety Administration (PHMSA) investigated a similar incident to the MGPI incident in 2015 that occurred in Holly Hill, Florida. PHMSA found that the driver of the tank truck connected a delivery hose from a truck filled with sodium hypochlorite to a fill line to two storage tanks containing sulfuric acid. The mixture of the two materials caused a release of gas that overcame the operator and several local residents.

The DOT investigative team found that the “company’s SOP and related training for unloading of cargo tanks violated the attendance requirement during unloading as stipulated by 49 C.F.R. § 177.834(i), in that the process is to open valves on the cargo tank and fixed storage tanks to begin flow of liquid then leave the rear of the cargo tank to climb into the cab of the tractor to start the engine and build up air pressure.” The DOT investigative team found that sitting in the cab of the tractor put the operator some 40 feet away from the rear of the cargo tank and delivery hose and would not have provided an unobstructed view of the hose and activities during the unloading operation. As a result, the operator would be unaware of any abnormalities occurring at the connection until he returned. In the Holly Hill incident, the driver apparently walked into the chemical gas cloud when returning to the rear of the vehicle after the situation was out of control.

a Member Safety and Security Commitment and Pamphlet Certification annually, certifying that they will promote and demonstrate safety and security and that they have implemented and comply with stewardship policies, which include safety and security audits and hazard evaluations of chlor-alkali operations.¹⁵⁹ Additionally, the CI has developed many safety resources and technical pamphlets that provide guidelines, recommended practices, and other information for the chlor-

¹⁵⁹ The Chlorine Institute. <https://www.chlorineinstitute.org/hess/hess-overview/> (accessed November 15, 2017).

alkali industry and emergency responders. The CSB reviewed pamphlets related to the equipment and processes at MGPI and concluded that voluntary adherence to the information in these pamphlets could have prevented or mitigated the incident.

CI Pamphlet 96, "Sodium Hypochlorite Manual," is a guidance document intended to provide information about sodium hypochlorite, its properties, manufacture, safe handling, packaging, transportation and uses, and the regulations affecting these areas.¹⁶⁰ A critical part of Pamphlet 96 is Appendix D, "Guidance to Avoid Accidental Mixing," a new addition to the prior edition. Recommended procedural steps for unloading in Appendix D include "verify[ing] that the unloading connections/piping are correct (check labels, routing, etc.) [,] verify[ing] connections by a second person, [and] follow[ing] applicable regulations for monitoring/attendance."¹⁶¹ Appendix D also recommends:

- Locating sodium hypochlorite unloading connections away from incompatible product loading/unloading connections;
- Ensuring sodium hypochlorite piping is short, visible, and marked as best as possible so that the unloader can trace the product piping from the connection point to the receiving tank;
- Dedicating sodium hypochlorite unloading lines to avoid any compatibility issues; and
- Considering the use of lockout systems to prevent unloading into tanks prior to proper verification.

As discussed, MGPI's sodium hypochlorite fill line was located only 18 inches from the sulfuric acid fill line, although the chemicals are incompatible. In addition, the closest sodium hypochlorite pipe marker to the fill line connection point was loosely attached to the line and appeared to be upside down. It was not placed at the connection point or immediately adjacent to the downstream elbow, which would have made the line much easier to trace. Furthermore, while not identified by Pamphlet 96, neither the sodium hypochlorite fill line

160 The Chlorine Institute. Pamphlet 96, Sodium Hypochlorite Manual, 4th ed.; The Chlorine Institute: Arlington, VA, October 2011.

161 The Chlorine Institute. Pamphlet 96, Sodium Hypochlorite Manual, 4th ed.; The Chlorine Institute: Arlington, VA, October 2011.

connection point nor the CTMV hose receptacle had a unique size or shape to prevent incorrect connections. And, although MGPI used padlocks and keys to open the caps on the fill lines in the unloading area, the sodium hypochlorite fill line was unlocked at the time of the incident. Finally, neither MGPI nor Harcros verified that the connection was correct. Had MGPI voluntarily followed Pamphlet 96 before the incident, the incident might have been prevented or the likelihood reduced.

CI Pamphlet 64, "Emergency Response Plans for Chlor-Alkali, Sodium Hypochlorite, and Hydrogen Chloride Facilities," provides the basics of an emergency response plan to be used, for example, during an accidental release of chlor-alkali products.¹⁶² Among other things, the CI advises that employers provide escape respirators and consider steps to minimize the consequences of a release on a building's occupants in the design and operation of the building ventilation system.¹⁶³ As described in Section 5.4, ease of access to escape respirators became an issue for operators during the incident, which meant that operators had to evacuate without respiratory protection. Furthermore, as described in Section 5.3, the Mod B control room ventilation system did not protect occupants from the plume. Had MGPI voluntarily followed Pamphlet 64 before the incident, the severity of consequences that followed the inadvertent mixture might have been lessened. Because sodium hypochlorite is one of the chemicals handled by CI member companies, the CSB intends to work with the CI to communicate the key lessons from this Case Study at the completion of its investigation.

7.2 NATIONAL ASSOCIATION OF CHEMICAL DISTRIBUTORS

The National Association of Chemical Distributors (NACD) is an international association of chemical distributors and their supply-chain partners.¹⁶⁴ Members consist of companies that process, formulate, blend, re-package, store, transport, and market

162 The Chlorine Institute. *Emergency Response Plans for Chlor-Alkali, Sodium Hypochlorite and Hydrogen Chlorite Facilities. Pamphlet 64; 7th ed.*; The Chlorine Institute: Arlington, VA, November 2014.

163 The Chlorine Institute. *Emergency Response Plans for Chlor-Alkali, Sodium Hypochlorite and Hydrogen Chlorite Facilities. Pamphlet 64; 7th ed.*; The Chlorine Institute: Arlington, VA, November 2014.

164 National Association of Chemical Distributors. <https://www.nacd.com/about/about/> (accessed December 4, 2017).

chemical products for over 750,000 customers.¹⁶⁵ NACD's nearly 450 members and affiliate companies represent more than 85% of the chemical distribution capacity in the United States.¹⁶⁶

To become a member company of NACD, companies must meet certain requirements, one of which is participation in NACD's Responsible Distribution® Program.¹⁶⁷ The program requires members to work continuously to improve performance in protecting health, safety, and the environment.¹⁶⁸ NACD accomplishes this through a mandatory third-party verified environmental, health, safety & security program.¹⁶⁹ NACD's Responsible Distribution Program verification is required of each NACD member and chemical handler affiliate¹⁷⁰ at a 20% sampling of company facilities.¹⁷¹ On-site program verification is conducted by an independent, third-party verifier(s) against a specifications document based on the Responsible Distribution Program's Guiding Principles and a Code of Management Practice.¹⁷² Successful completion, at least once every three years, is a condition of continued membership in NACD.¹⁷³ Harcros Chemicals Inc. is a verified member of the NACD Responsible Distribution Program.¹⁷⁴ Therefore, Harcros manufacturing and distribution facilities are subject to Responsible Distribution on-site verification.¹⁷⁵

In 2002, the CSB issued a recommendation to NACD following its Improving Reactive Hazard Management investigation study.¹⁷⁶ In the study, the CSB found that, of the 167 serious incidents involving

165 National Association of Chemical Distributors. <https://www.nacd.com/about/about/> (accessed December 4, 2017).

166 National Association of Chemical Distributors. <https://www.nacd.com/about/about/> (accessed December 4, 2017).

167 National Association of Chemical Distributors. <https://www.nacd.com/about/about/> (accessed December 4, 2017).

168 National Association of Chemical Distributors. <https://www.nacd.com/about/about/> (accessed December 4, 2017).

169 National Association of Chemical Distributors. Responsible Distribution. <https://www.nacd.com/rd/about/> (accessed December 4, 2017).

170 Examples of CHAs include public warehouses and carriers.

171 National Association of Chemical Distributors. Third Party Verification. <https://www.nacd.com/rd/about/verification/> (accessed December 4, 2017).

172 National Association of Chemical Distributors. Third Party Verification. <https://www.nacd.com/rd/about/verification/> (accessed December 4, 2017).

173 National Association of Chemical Distributors. Third Party Verification. <https://www.nacd.com/rd/about/verification/> (accessed December 4, 2017).

174 Harcros Distribution. <http://harcros.com/distribution> (accessed December 4, 2017).

175 Harcros Distribution. <http://harcros.com/distribution> (accessed December 4, 2017).

176 CSB. Improving Reactive Hazard Management. <http://www.csb.gov/assets/1/19/ReactiveHazardInvestigationReport.pdf> (accessed September 19, 2017).

reactive hazards between 1980 and 2001, more than 50% of the incidents involved chemicals not covered under existing OSHA and EPA process safety standards, and 30% occurred at facilities that use or consume bulk quantities of chemicals.¹⁷⁷ As a result, the CSB recommended NACD "Expand the existing Responsible Distribution Process to include reactive hazard management as an area of emphasis" and, "at a minimum, ensure that the revisions address storage and handling, including the hazards of inadvertent mixing of incompatible chemicals."¹⁷⁸ In response to the recommendation, NACD updated its Responsible Distribution Program Code of Management Practice in 2003 to ensure procedures for loading and unloading chemicals at member company facilities include, among other things, an increased awareness of hazards from the inadvertent mixing of incompatible chemicals. At the time of the 2016 incident at MGPI, the Harcros unloading procedure required verifications to ensure correct connections to minimize the risk of inadvertent mixing from improper loading and unloading.

NACD's modifications to procedural verification only extended to the member companies and their chemical handler affiliates within the Responsible Distribution Program. NACD, however, also modified the Code of Management Practice to verify member companies have a process in place to ensure that customers, such as the facilities that receive chemicals, also receive information to increase awareness of inadvertent mixing hazards. As part of that verification process, member companies must describe how guidance and information regarding loading and unloading, chemical storage, and the hazards of incompatible mixtures, are shared with downstream users, such as customers, warehouses and carriers.

Though downstream users are not subject to the Responsible Distribution Program, NACD holds various events, meetings, and webinars through which downstream users can also benefit from information sharing and lessons learned. As such, the CSB intends to work with NACD following the publication of this Case Study to ensure lessons and recommended practices are shared with NACD member companies, as well as non-member distributors and downstream users that participate in NACD activities.

177 CSB. Improving Reactive Hazard Management. <http://www.csb.gov/assets/1/19/ReactiveHazardInvestigationReport.pdf> (accessed September 19, 2017).

178 CSB. Improving Reactive Hazard Management. <http://www.csb.gov/assets/1/19/ReactiveHazardInvestigationReport.pdf> (accessed September 19, 2017).

8.0 REGULATORY OVERSIGHT AND GUIDANCE

The CSB reviewed various regulations from different agencies to determine their applicability to this incident. Regulations from two agencies, OSHA and PHMSA, are included in this Case Study for discussion. OSHA conducted and completed an investigation that arose out of this incident. Many of the violations for which OSHA cited MGPI and Harcros correspond to the CSB's investigation and findings. While other violations are outside the scope of the CSB's investigations in that they involve chemicals other than 30% sulfuric acid and sodium hypochlorite, they are included here because they provide insight into a voluntary Process Hazard Analysis (PHA) conducted by MGPI before the incident. As discussed, PHAs are required under OSHA's PSM standard; the one conducted by MGPI for the two chemicals involved in the incident, however, was voluntary because the chemicals are not covered under the standard. The CSB also collaborated with and reviewed PHMSA regulations. With respect to these, the CSB looked into PHMSA's HMRs, as well as their history, and found them to be pertinent, particularly so far as inadvertent mixing of incompatible materials is concerned. Accordingly, the CSB reviewed the HMRs, as well as relevant PHMSA guidance, for connection to this incident.

8.1 OSHA

Though OSHA does not have a specific standard for bulk unloading activities, it has a number of regulations that apply to the safe handling of chemicals. For example, the OSHA Hazard Communication standard requires employers to provide employees with effective communication and training on hazardous materials handled or stored in the workplace.¹⁷⁹ This includes chemical properties, such as reactivity, and measures for employees to protect themselves from chemical exposure.¹⁸⁰

The Mod B process uses two chemicals, propylene oxide and phosphorous oxychloride, which are covered under the OSHA PSM standard. The standard contains requirements for managing hazards associated with handling highly hazardous chemicals. Though sodium hypochlorite and 30% sulfuric acid are not covered chemicals, MGPI voluntarily applied a number of PSM elements to the entire Mod B process, which included unloading

equipment and operations for non-covered chemicals. One key provision of PSM is the PHA, which requires employees to identify potential process risks and safeguards in place to mitigate hazards. In the most recent PHA for Mod B before the incident from March 2015, MGPI identified the potential for the wrong chemical to be transferred into the sodium hypochlorite bulk tank due to operator error or a "bad shipment" of a chemical. MGPI included mostly generic administrative safeguards, such as training and procedures, to prevent the transfer of a wrong chemical; most of which failed to prevent or mitigate the October 2016 incident as described in this Case Study.

Following the incident, OSHA inspected MGPI for compliance with regulations that covered processes and activities involved in the incident, as well as the application of PSM for covered chemicals at Mod B. OSHA also conducted a compliance inspection of Harcros in relation to all applicable requirements while at the MGPI facility. On April 19, 2017, OSHA issued citations to MGPI and Harcros for violations. Some of the violations issued to MGPI pertained to OSHA's PSM standard and were covered under OSHA's National Emphasis Program (NEP) for PSM Covered Chemical Facilities.¹⁸¹ As discussed in Section 5.3, one of the PSM violations pertained to a PHA requirement for facility siting, specifically regarding occupied structures including, but not limited to, the control room inside the Mod B building.

The remaining OSHA violations included not having adequate emergency exits in the Mod B control room; violating requirements for emergency action plans, as MGPI operators were unable to retrieve respirators per the written plan; and not providing employees with the required hazard communication training to follow standard operating procedures to unload sulfuric acid. On May 10, 2017, OSHA and MGPI entered an Informal Settlement Agreement, whereby certain citations and penalties were amended and/or withdrawn.

Harcros was cited for failing to ensure employees were not exposed to the hazards of chemicals due to the lack

179 29 CFR 1910.1200(h).

180 29 CFR 1910.1200(h)(3)(ii) 1910.1200(h)(3)(iii).

181 As mentioned, OSHA's PSM applies to two chemicals stored above threshold quantities in the Mod B area: (1) propylene oxide and (2) phosphorous oxychloride. For more information on OSHA's PSM standard: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9760. For information on OSHA's NEP, including the NEP for PSM Covered Chemical Facilities, see: <https://www.osha.gov/dep/neps/nep-programs.html>.

of training under OSHA's hazard communication training requirement. The violation stated that the Harcros driver had not been trained on the appropriate actions to take to prevent cross contamination of chemicals while unloading (work practices), as well as emergency procedures to follow in the event of a chemical release. Harcros entered an Informal Settlement Agreement with OSHA May 8, 2017.

8.2 PHMSA

PHMSA was created in 2004 as a DOT agency tasked with protecting people and the environment by advancing the safe transportation of hazardous materials.¹⁸² PHMSA establishes national policy, sets and enforces standards, educates, and conducts research to prevent incidents.¹⁸³ The Office of Hazardous Materials Safety within PHMSA enforces the HMRs,¹⁸⁴ which generally apply to hazardous materials being transported via interstate, intrastate, and foreign carriers by rail car, aircraft, motor vehicle, and vessel.¹⁸⁵ Harcros is subject to the HMRs because it delivers hazardous materials to MGPI and other facilities via motor vehicle. PHMSA also regulates the transportation of hazardous materials in commerce, including loading, unloading, and storage incidental to transportation.¹⁸⁶

PHMSA provided the CSB documentation of recent PHMSA investigations of similar incidents, published guidance documents related to offloading incidents, and other information that has allowed the CSB to conduct a thorough examination of offloading incidents. A similar incident involving offloading and the inadvertent mixture of incompatible materials is discussed in Section 6.0.

8.2.1 PHMSA GUIDANCE

As discussed in Section 6.0, similar incidents involving the inadvertent mixture of incompatible materials during unloading have occurred somewhat frequently. PHMSA reviewed serious incident data involving bulk loading and unloading of hazardous

materials transported via highway and rail occurring between 2003 and 2007 and found that, of the incidents that reported a failure cause, 33% can be attributed to incorrect operation when performing a loading or unloading function. Examples of these incident causes include "failure to attend or monitor the operation, leaving valves in the wrong position, or improperly connecting hoses and other equipment."¹⁸⁷ PHMSA also found that "90% of the serious incidents occurred during highway loading or unloading operations and approximately 75% of those incidents involved CTMVs."¹⁸⁸

Because of the frequency of bulk unloading incidents and safety recommendations made by the CSB and NTSB, in 2011 PHMSA issued a Notice of Proposed Rulemaking (NPRM) to amend the HMRs.¹⁸⁹ The amendments would have required each person who engages in CTMV loading or unloading to perform a risk assessment and develop and implement safe operating procedures based on the results of the risk assessment.¹⁹⁰ PHMSA also proposed additional personnel training and qualification requirements for persons who perform those operations.¹⁹¹ In addition, the rule would have required facilities like MGPI to implement maintenance and inspection programs consistent with existing standards for hoses carried aboard CTMVs.¹⁹² After receiving comments and conducting a supplementary policy analysis, PHMSA reconsidered its approach to addressing the safety risks of bulk loading and unloading operations through rulemaking. Instead, PHMSA decided to conduct outreach and issue a guidance document¹⁹³ that, together with current regulations, provide direction on bulk loading and unloading.

187 Hazardous Materials: Cargo Tank Motor Vehicle Loading and Unloading Operations, 76 Fed. Reg. 13313, 13315 (Mar. 11, 2011). Analysis reflects failure causes reported on incident reports. Not all incident reports reported a failure cause and PHMSA did not assume the cause of the failure if a failure cause was not indicated on the report; approximately 39% did not include a failure cause.

188 Hazardous Materials: Cargo Tank Motor Vehicle Loading and Unloading Operations, Section III, A, 76 Fed. Reg. 13313, 13315 (Mar. 11, 2011).

189 Hazardous Materials: Cargo Tank Motor Vehicle Loading and Unloading Operations, Section II, 76 Fed. Reg. 13313, 13315 (Mar. 11, 2011).

190 Hazardous Materials: Cargo Tank Motor Vehicle Loading and Unloading Operations, 76 Fed. Reg. 13313, 13313 (Mar. 11, 2011).

191 Hazardous Materials: Cargo Tank Motor Vehicle Loading and Unloading Operations, 76 Fed. Reg. 13313, 13313 (Mar. 11, 2011).

192 Hazardous Materials: Cargo Tank Motor Vehicle Loading and Unloading Operations, 76 Fed. Reg. 13313, 13313 (Mar. 11, 2011).

193 Guidance is not legally binding and may not mandate or require a particular action; its intent is to provide helpful information, clarify a rule or statute's meaning, or communicate PHMSA's policy for implementing requirements. Hazardous Materials: Cargo Tank Motor Vehicle Loading and Unloading Operations, 76 Fed. Reg. 13313, 13315 (Mar. 11, 2011).

182 PHMSA. Mission, Vision and Goals. <https://www.phmsa.dot.gov/about/mission> (accessed September 13, 2017).

183 PHMSA. Mission, Vision and Goals. <https://www.phmsa.dot.gov/about/mission> (accessed September 13, 2017).

184 49 C.F.R. Parts 171-180 (2017); for a more in-depth discussion of HMR, specifically the attendance requirement, see Section 5.1.3.

185 49 C.F.R. § 171.1(c) (2017).

186 49 C.F.R. § 171.1(c) (2017).

In 2014, with input from OSHA and EPA, PHMSA issued the “Cargo Tank Motor Vehicle (CTMV) Loading/Unloading Operations: Recommended Best Practices Guide” (PHMSA Guide).¹⁹⁴ PHMSA, at the same time, published a two-page companion pocket guide (PHMSA Companion Guide) to serve as a reference for chemical delivery drivers.

The PHMSA Guide provides various best practices for training, conducting risk assessments and audits, and implementing clear operating procedures based on those assessments and audits.¹⁹⁵ PHMSA recommends that all hazmat employees, whether employed by a carrier or facility, be evaluated annually to gauge their understanding of safe loading/unloading procedures.¹⁹⁶ Employees should also be observed and evaluated and feedback provided on the performance of their duties.¹⁹⁷ The CSB found that neither MGPI nor Harcros had a program or process for evaluating and providing feedback to Mod B employees performing unloading operations or Harcros drivers. Had MGPI and Harcros actively monitored operators while unloading, the companies may have become aware that operators and drivers were not adhering to unloading procedures as written and could have provided appropriate feedback and training to correct deficiencies.¹⁹⁸

PHMSA also recommends that parties who load or unload CTMVs perform a risk assessment of the operation, including clearly identifying whether facility personnel or the CTMV operator is responsible for each loading/unloading activity. Procedures used to ensure safe loading/unloading should also be assessed to identify areas for improvement. Had MGPI management completed a risk assessment prior to the incident,

194 Cargo Tank Motor Vehicle (CTMV) Loading/Unloading Operations: Recommended Best Practices Guide, https://hazmatonline.phmsa.dot.gov/services/publication_documents/CTMV%20Guidelines.pdf (accessed December 7, 2017).

195 Cargo Tank Motor Vehicle (CTMV) Loading/Unloading Operations: Recommended Best Practices Guide, https://hazmatonline.phmsa.dot.gov/services/publication_documents/CTMV%20Guidelines.pdf (accessed December 7, 2017).

196 Cargo Tank Motor Vehicle (CTMV) Loading/Unloading Operations: Recommended Best Practices Guide, pp 5. https://hazmatonline.phmsa.dot.gov/services/publication_documents/CTMV%20Guidelines.pdf (accessed December 7, 2017).

197 Cargo Tank Motor Vehicle (CTMV) Loading/Unloading Operations: Recommended Best Practices Guide, pp 5. https://hazmatonline.phmsa.dot.gov/services/publication_documents/CTMV%20Guidelines.pdf (accessed December 7, 2017).

198 Post-incident, MGPI changed its unloading procedure and, among other changes, now requires a salaried employee to observe operators during unloading. See Section 5.1.3 for a discussion of procedural deficiencies and Section 9.0 for an analysis of MGPI's updated procedures.

roles and responsibilities for valve operation might not have been switched between facility personnel and CTMV drivers, and critical steps missing from the procedures could have been identified and corrected.¹⁹⁹ In addition, MGPI might have identified the incorrect pipe marking at Mod B and lack of signs or pipe markers at the connection points.²⁰⁰ PHMSA states that employers should use these risk assessments to implement new, or enhance existing, operating procedures.²⁰¹

Prior to the incident, both Harcros' and MGPI's procedures required verification that material is being transferred into the appropriate tank and that the tank has sufficient room to receive the chemical; however, both procedures relied on oral communication between the driver and operator. Certain design issues, such as adding distance between incompatible connections, selecting unique fittings, and applying clearer pipe markings, could greatly reduce the likelihood of incorrect connections. The PHMSA Guide also suggests implementing engineering controls to avoid the mixture of incompatible materials (Figure 17). Had these suggested engineering controls been implemented, the incident may have been avoided.²⁰² The PHMSA Guide also recommends that facility operators provide oversight of carrier personnel during unloading operations, including supervision during unloading, and providing carriers with written instructions, or at least sufficient information, to allow carriers to comply with unloading procedures.

Ideas for ensuring proper connections and use of transfer equipment include color-coding components and/or receiving containers or introducing specially designed connections/couplings that only link with other components intended for use in the transfer of a specific material.

Figure 17. Excerpt from “CTMV Loading/Unloading Operations: Recommended Best Practices Guide” (Source: PHMSA).

199 See Section 5.1.3 for a discussion of Operating Procedures.

200 See Section 5.1.2 for an analysis of MGPI's labelling deficiencies.

201 Cargo Tank Motor Vehicle (CTMV) Loading/Unloading Operations: Recommended Best Practices Guide, https://hazmatonline.phmsa.dot.gov/services/publication_documents/CTMV%20Guidelines.pdf (accessed December 7, 2017).

202 See Section 5.1.1 for an analysis of MGPI's design of chemical transfer equipment.

8.2.2 SHARED RESPONSIBILITY

PHMSA's mission to protect people and the environment by advancing the safe transportation of energy and other hazardous materials is accomplished, in part, by enforcing the HMRs and issuing guidance. Although PHMSA's mandate focuses on the transportation aspect of hazardous materials, PHMSA concludes, like the CSB, that safe loading/unloading of hazardous materials is a shared responsibility between the carrier and facility.²⁰³ The PHMSA Guide provides practical applications of best practices to clarify where facility personnel should play a primary role, such as in training and evaluation, risk assessment, emergency response, and operating procedures. The CSB concludes that facilities also play a vital role in ensuring chemicals are unloaded safely and that lessons learned and recommendations in this Case Study will augment PHMSA and other agency guidance and regulations to prevent similar incidents.

The two-page PHMSA Companion Guide provides questions, mostly geared toward carrier personnel, to ask before loading/unloading. Facilities receiving chemicals will benefit from not only existing PHMSA guidance, but also a shorter reference guide that facility personnel can refer to before loading/unloading chemicals. As such, the CSB has developed "Recommended Practices for Facilities Receiving Chemicals by CTMVs" (Appendix B) that will be published as a companion document to this Case Study.

9.0 MGPI AND HARCROS POST-INCIDENT CHANGES

Immediately following the incident, MGPI made some temporary changes to its transfer equipment and unloading area to reduce the potential for a similar incident, until more permanent changes could be made. These included placing dedicated locks with separate keys on the different fill line caps, replacing the caps on the fill lines with caps that use a different locking mechanism, placing new (or more securely affixing existing) pipe markers closer to fill line connection points and elbows, placing new color-coded tags on the fill lines, and updating the chemical unloading procedures. Additionally, Harcros worked with MGPI to select and install new couplings on the Mod B

sulfuric acid fill line and Harcros sulfuric acid delivery hoses. These couplings share the same unusual size and shape, such that only the correct delivery hose can be connected to the sulfuric acid fill line. The couplings are also colored differently from all other couplings at the Mod B unloading area (Figure 18).



Figure 18. New coupling on the Mod B sulfuric acid fill line (Source: MGPI).

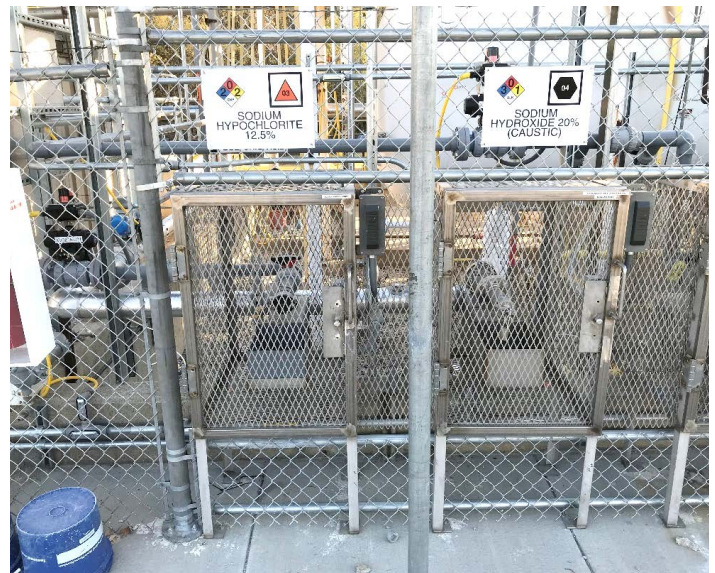


Figure 19. Separation of unloading connections with secure cages around connection points at Mod B (Source: MGPI).

After making the immediate modifications described above, MGPI also made a number of other engineering and process safety changes at Mod B, including:

- Chemical unloading connection adjustments (a minimum of three-foot separation between each unloading connection with a secure cage around each

203 Cargo Tank Motor Vehicle (CTMV) Loading/Unloading Operations: Recommended Best Practices Guide, pp 13. https://hazmatonline.phmsa.dot.gov/services/publication_documents/CTMV%20Guidelines.pdf (accessed December 7, 2017).

connection point with card reader access and related administrative controls on access) (Figure 19);

- Engineering system interlocks that correspond to additional alarm-state situations;
- Additional monitoring and emergency shutdown devices;
- Design changes to the operator control room and air handling equipment; and
- Emergency response and preparedness modifications, including the water sprinkler deluge system.

Both MGPI and Harcros revised their chemical unloading practices and procedures as well. MGPI now prohibits unloading to start within 20 minutes of shift change and requires that a safety observer be present when connecting and disconnecting a cargo tank hose to a chemical fill line. Procedures also require operators to inspect fill lines to ensure all dust caps are secured and locked prior to, and following, deliveries. Harcros created a new sulfuric acid unloading procedure specific to MGPI and now requires its drivers to complete a tanker pre-unloading checklist with customers.

Apart from the changes to practices and procedures MGPI and Harcros made independently, they also made changes to promote greater coordination between operators and drivers. For example, operators and drivers must complete written verification forms to ensure that procedural steps are followed and to certify a correct connection prior to unloading a chemical. MGPI also requires its operators to ensure drivers can identify the CTMV emergency stop button.

Following the incident, MGPI also modified the storage and accessibility of the Mod B emergency respirators. Instead of storing emergency respirator face pieces separately from escape bottles, the Mod B control room is now equipped with a cabinet containing both supplied air bottles and hoods²⁰⁴ that are easily accessible to protect operators in the event of a similar incident.

MGPI continued to receive active participation from Mod

204 A hood is a respiratory inlet covering that completely covers the head and neck and may also cover portions of the shoulders and torso. Instead of face pieces, hoods are also used with escape bottles.

B employees, including represented employees, in the development and implementation of modifications to equipment and processes following the incident. For example, represented employees were consulted on desired changes to their work area post-incident, and were involved in reviewing all Management of Change²⁰⁵ documentation for all Mod-B modifications. In addition, MGPI received input from represented employees on the revision of unloading procedures and the development of new procedures. Represented employees have participated in facility walkthroughs with procedures in hand, and have provided recommendations on the frequency with which operators should be retrained on procedures, which has been accepted and integrated into company practice.

The CSB concludes that many of the post-incident changes implemented by MGPI address a number of human factors and design issues presented in this Case Study. In addition, MGPI and Harcros worked together to develop and agree upon procedures and design changes to reduce the likelihood of similar incident. Modifications to unloading equipment and processes as exemplified in this section, and in accordance with the investigation key lessons, can greatly reduce the opportunities for inadvertent mixing during chemical unloading operations.

10.0 KEY LESSONS

For fixed facilities that receive chemicals:

1. When assessing risks associated with chemical unloading process and equipment, apply the hierarchy of controls when evaluating controls and safeguards for preventing inadvertent mixing. For all chemical unloading activities that require human interaction, either by facility personnel or CTMV drivers, identify and address human factors issues that may increase the potential for an incorrect connection.
2. Evaluate chemical transfer equipment and processes (e.g., fill lines, transfer valves, piping and receiving tanks) and, where feasible, install and configure safeguards, such as interlocks and mitigation

205 Management of change is a process for evaluating and controlling modifications to equipment, processes and organizations, to identify and address hazards that may be introduced by that change.

measures, in the process control system that will maintain safe operations during chemical unloading activities. The control system should monitor and respond to hazardous process conditions (e.g., temperature, level, pressure, or airborne concentrations) and automatically shut down the transfer of chemicals and other processes in the event of an unintended reaction or release during chemical unloading. Where automated process control and safety systems are not feasible, configure transfer valves and equipment, as well as ventilation, deluge, and other mitigation systems, so that they can be activated remotely to stop the flow of chemicals into facility piping or receiving tanks during an emergency.

3. Design or modify chemical transfer equipment to ensure fill lines for incompatible materials are physically separated by a discernable distance (e.g., acids delivered to an unloading area separate from bases) to avoid reactive incidents resulting from inadvertent mixing.
4. Work with chemical distributors to select hose couplings and fill line connections with uniquely shaped and color-coded fittings for each chemical or class of chemicals, especially where several chemicals are unloaded in close proximity. This can include a combination of accepted fittings with unique shapes (e.g., square for acids, hexagon for bases) or different sized diameters (e.g., 2-inch or 3-inch round) for each fill line.
5. Ensure pipe marking and identification of transfer equipment (e.g., fill lines, valves, transfer piping, and tanks) identification are clear and accurately represent the material contained in the equipment in accordance with accepted industry standards, such as ASME A13.1-2007 Scheme for the Identification of Piping Systems. Affix pipe markers as close to fill line connection points as possible so that personnel involved in unloading activities can easily identify equipment and chemicals prior to making a connection. This is particularly important when there are multiple fill lines for different chemicals in one area.
6. Work with chemical distributors to conduct a risk assessment and, based on the results of the

assessment, develop and/or agree upon procedures for chemical unloading and emergency operations to ensure responsibilities are clearly defined.

Procedures should establish a process that requires facility personnel to be physically present during deliveries. Both facility personnel and drivers should verify (i.e., verbally and visually, through written checklists, and/or during equipment walk-downs) a correct connection before discharging chemicals. Management of both facilities and chemical distributors should provide effective initial and refresher training on the procedures periodically, or when equipment or chemicals are modified. In addition, management should actively monitor procedures to ensure conformance.

7. Evaluate building design and ventilation systems for occupied structures near chemical unloading stations to ensure occupants are protected in the event of a spill or chemical reaction. Design considerations should include positive-pressure ventilation systems, makeup air-cleaning and filtration systems, sensors and alarms that automatically shut down HVAC systems in the event of a release, and the careful selection of intake locations to prevent chemicals from entering the supply. These systems should be checked regularly to ensure they are functioning properly.
8. For all occupied buildings near chemical unloading areas and bulk storage tanks, evaluate the accessibility of emergency respirators and escape bottles in the event of a toxic release. Avoid locking emergency respirator components in lockers, even between shifts, to ensure that workers can immediately access the equipment at all times. Conduct reviews of control rooms and emergency evacuation routes to determine the most accessible location of employee respirators near escape bottles and update emergency response and respiratory protection procedures and training accordingly.
9. Provide emergency escape respirators near chemical unloading areas for drivers and personnel in the event of a spill or unintended reaction and release during unloading operations.

For chemical distribution companies:

10. Ensure drivers are fully aware of the location and use of all CTMV emergency shutoff mechanisms.
11. Evaluate the need to train drivers to don appropriate PPE and respond to chemical spills or releases during unloading operations. Where mitigating incidents is feasible, chemical distributors should provide the appropriate PPE for doing so on CTMVs. Where mitigating incidents is not feasible, chemical distributors should ensure that drivers have access to, and are properly trained to wear, emergency escape respirators on CTMVs to safely evacuate in the event of an incident.

11.0 CONCLUSION

According to the National Association of Chemical Distributors (NACD), whose membership represents more than 85% of U.S. chemical distributors, in 2016, more than 39.9 million tons of product were delivered to customers every 8.4 seconds. The incident at MGPI highlights that, even though unloading operations are relatively simple, the consequences can greatly impact workers and surrounding communities due to the large amount of chemicals transferred during deliveries. Because chemical deliveries are so common at fixed facilities, the CSB urges facilities and chemical distributors to adopt the Key Lessons and Recommended Practices from this Case Study and work collaboratively to implement controls and practices that prevent or reduce the opportunity for inadvertent mixing incidents. Following the issuance of this Case Study, the CSB will work with the Chlorine Institute, NACD, and unions representing chemical facility and chemical transport workers to communicate the Key Lessons and Recommended Practices to their membership.

12.0 RECOMMENDATIONS

TO THE AMERICAN SOCIETY OF HEATING REFRIGERATION AND AIR CONDITIONING ENGINEERS (ASHRAE):

The CSB reiterates the following recommendation originally issued to ASHRAE in 2005 as part of the Honeywell International chlorine release investigation:

2003-13-I-LA-R22:

Develop guidance on the effective design and maintenance of HVAC systems and other necessary control room components designed to protect employees and equipment in the event of a release of hazardous materials.

As a result of its investigation, the CSB makes the following safety recommendations:

TO MGPI PROCESSING, INC.:

2017-01-I-KS-R1:

Commission an independent engineering evaluation of the Mod B building and ventilation system and, based on the results of that evaluation, implement design changes and controls to protect occupants from a chemical release. At a minimum, the evaluation should assess the effectiveness of the building ventilation system, indoor and outdoor sources of chemicals, air intake locations, contaminant control methods such as filtration and removal, contaminant monitoring devices, and automation. The engineering evaluation of the ventilation system should consider airborne contaminants during normal operations as well as spills, releases, and chemicals produced from unintended reactions and inadvertent mixing.

2017-01-I-KS-R2:

Conduct an evaluation of the Mod B chemical transfer equipment (e.g., fill lines, transfer valves, transfer piping, tanks and other associated equipment) and install appropriate engineering safeguards to prevent and mitigate an unintended reaction, chemical release, or spill during bulk unloading. Where feasible, install safeguards, such as alarms and interlocks, to prevent personnel from opening the incorrect chemical transfer valves during deliveries. In addition, install mitigation measures to automatically shut down the transfer of chemicals into the facility based on process deviations or abnormal conditions (e.g.,

pressure, temperature, flow or level indications; gas detection).

TO HARCROS CHEMICALS:

2017-01-I-KS-R3:

Establish a refresher training program to ensure drivers know the location of various CTMV emergency shut-off devices, when to use them, and the effectiveness of those devices to stop the flow of chemicals during emergencies. The refresher training program should include drills for drivers to simulate the activation of all shut-off devices in defined incident scenarios (e.g., inadvertent mixing, chemical releases, etc.) during unloading operations. Establish a process to evaluate the effectiveness of the refresher training program.

2017-01-I-KS-R4:

Establish a process whereby the respiratory hazards associated with chemical unloading at customer sites are evaluated. The evaluations should, at a minimum, determine whether drivers need emergency escape respirators in the event of an accidental reaction and/or release of chemicals. If the results of the evaluations indicate that respiratory protection is needed, provide the equipment and training for such protection as appropriate. The equipment and training should be provided in accordance with OSHA's Respiratory Protection Standard (29 C.F.R § 1910.134). The equipment should also be stored in an area that allows for immediate access.

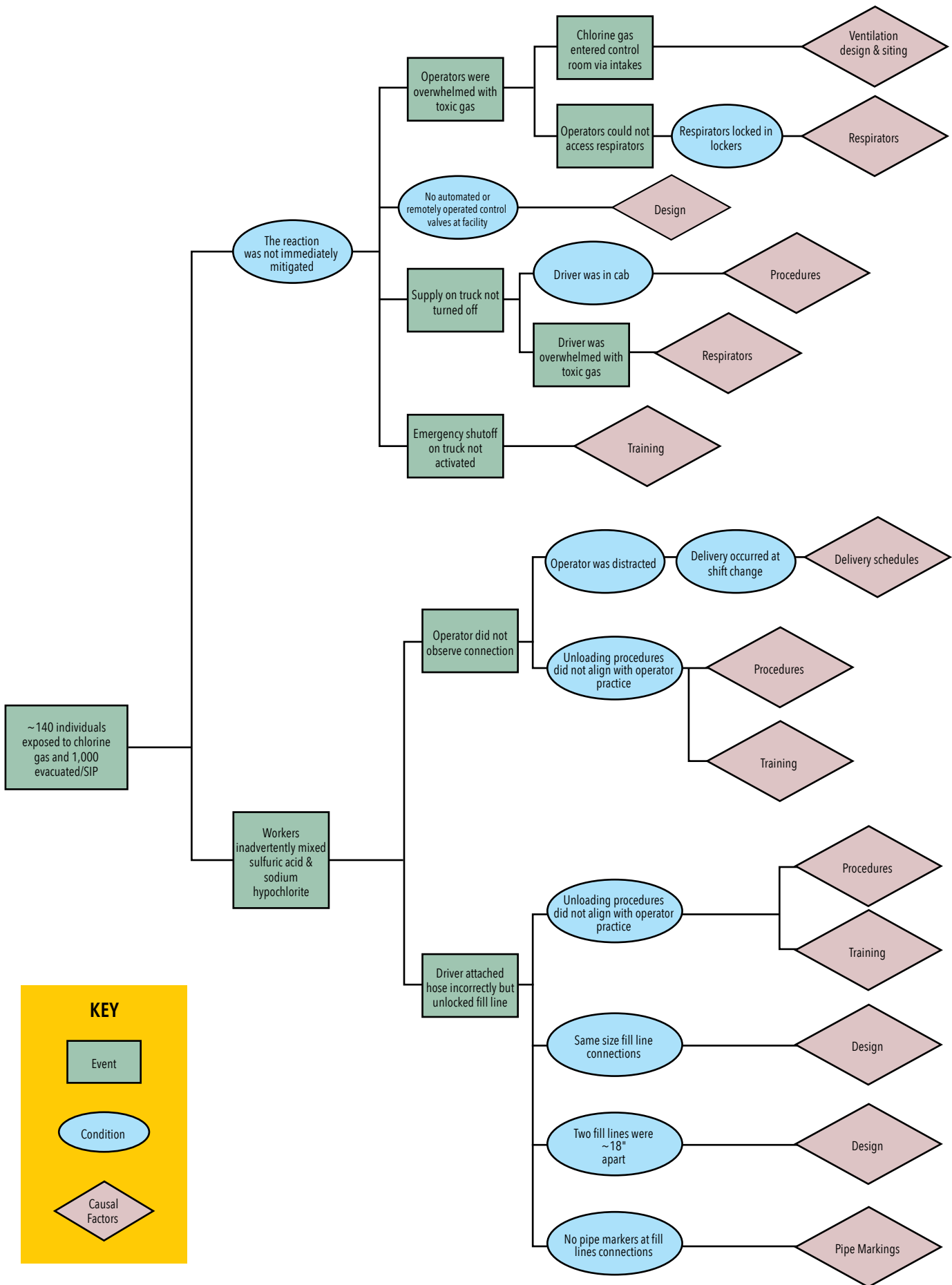
**TO THE ATCHISON COUNTY DEPARTMENT
OF EMERGENCY MANAGEMENT:**

2017-01-I-KS-R5:

Coordinate planning and training activities to ensure emergency responders within Atchison County are prepared for future incidents involving hazardous materials. The Atchison County Local Emergency Planning Committee should do the following:

- a) Review facility Risk Management Plans as they are submitted or revised and conduct pre-planning at Risk Management Program covered facilities and all other facilities within the county that, based on annual Tier II reporting forms, store large amounts of hazardous chemicals.
- b) Conduct a full-scale hazardous materials exercise that involves an offsite chemical release scenario within the next three years. The exercise should include participants from local emergency response organizations, hospitals, schools, and fixed facilities. Identify and resolve coordination or communication issues identified during the exercise.
- c) Increase participation in state and regional emergency response training and programs. Work with the Kansas Department of Emergency Management to submit a Hazardous Materials Emergency Preparedness (HMEP) grant proposal to assist in funding additional training and pre-planning activities within the county.

APPENDIX A - SIMPLIFIED CAUSAL ANALYSIS



KEY

- Event
- Condition
- Causal Factors

APPENDIX B - RECOMMENDED PRACTICES FOR CHEMICAL UNLOADING OPERATIONS

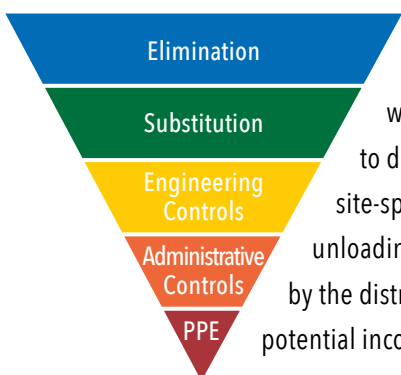
This Page Intentionally Left Blank

Facilities are strongly encouraged to consider the following questions when evaluating the potential for inadvertent mixing incidents during chemical deliveries, and when there are modifications to chemicals, chemical unloading equipment, or chemical distributors:¹

Design

- When applying the hierarchy of controls to unloading equipment and processes, are there more protective safeguards (e.g., inherently safer strategies or design controls) that can be implemented or installed to avoid mixing?
- When examining how workers and drivers interface with equipment, what human factors issues increase the opportunity for inadvertent mixing?
- Can fill lines or receiving vessels for incompatible materials be isolated or separated by distance?
- Is it possible to select unique fittings on fill lines to prevent incorrect connections?
- Does your facility have an automation that can stop the flow of chemicals from CTMVs into facility piping and equipment during an emergency (i.e. transfer valve)? Can those controls be activated remotely through the control system or an emergency switch?
- Is the chemical transfer equipment appropriately labeled so that drivers can easily locate corresponding fill lines? Are labels affixed to the fill lines to avoid the need for tracing piping prior to making a connection?

Hierarchy of Controls



Pipe Markings

- Did your facility work with the chemical distributor to develop and/or agree upon site-specific procedures for unloading each chemical delivered by the distributor? Did you review potential incompatible mixtures and

Inadvertent Mixing Incident

The CSB investigated an incident involving the inadvertent mixture of sulfuric acid from a CTMV into a sodium hypochlorite tank at a facility in Atchison, Kansas. The mixture of the two materials resulted in a chemical reaction that produced a dense, green-yellow cloud containing chlorine gas. Thousands of community members were ordered to shelter-in-place and some areas were evacuated. Over 140 individuals, including members of the public and company employees, sought medical attention; some required hospitalization.

The CSB found that this and similar incidents could have been prevented through improved design of the chemical unloading area to prevent incorrect connections of incompatible materials. In addition, clear pipe markers at fill line connection points also decrease the opportunity for error when connections are made between the CTMV and facility fill line.

Preventing incidents during chemical unloading operations is a *shared responsibility* between chemical distributors and facilities receiving chemicals. Therefore, facilities and distributors must work together to develop and agree upon procedures that clearly define roles and responsibilities and ensure safe execution of unloading operations.

emergency action plans? Are those procedures and plans being periodically updated and shared with one another whenever changes are made?

Procedures

- Does your unloading process include verification steps to ensure both facility personnel and drivers work together to ensure a correct connection is made?
- Are responsibilities for unloading operations clearly defined and understood?
- Is personal protective equipment (PPE), such as respirators and escape packs, readily accessible at all times for all facility personnel and drivers in the event of a spill or release?
- Have you worked with chemical distributors to define actions for drivers during a chemical delivery emergency? Do you know if drivers are trained to activate emergency shutoff devices on CTMVs?

¹ The Pipeline and Hazardous Materials Safety Administration (PHMSA) developed guidance for CTMVs, which can be found here: https://www.phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Files/ctmv_pocket_guide_short_09212015.pdf.

CASE STUDY



U.S. Chemical Safety and Hazard Investigation Board

Key Lessons for Preventing Inadvertent Mixing During Chemical Unloading Operations

Chemical Reaction and Release in Atchison, Kansas

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

Vanessa Allen Sutherland, J.D./M.B.A.

Chairperson

Manuel Ehrlich

Member

Richard Engler

Member

Kristen Kulinowski, Ph.D.

Member

