U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD

INVESTIGATION REPORT

CHLORINE RELEASE
July 20, 2003
(7 Injured)

CONTAMINATED ANTIMONY PENTACHLORIDE EXPOSURE
JULY 29, 2003
(1 Killed)

HYDROGEN FLUORIDE RELEASE
August 13, 2003
(1 Exposed, 1 Injured)

HONEYWELL INTERNATIONAL, INC.

BATON ROUGE, LOUISIANA

KEY ISSUES:

- HAZARD ANALYSIS
- NONROUTINE SITUATIONS
- OPERATING PROCEDURES

REPORT NO. 2003-13-I-LA

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Acronyms and Abbreviations

ACC	American Chemistry Council
AIChE	American Institute of Chemical Engineers
API	American Petroleum Institute
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
CAL	Community alert system
CCPS	Center for Chemical Process Safety (AIChE)
CFR	Code of Federal Regulations
CMA	Chemical Manufacturers Association
C&MI	Chemical and Metal Industries
CSB	U.S. Chemical Safety and Hazard Investigation Board
DOT	U.S. Department of Transportation
EMS	Emergency medical services
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
G-143a	Genetron 143a refrigerant
HazCom	Hazard Communication Standard (OSHA)
HAZOP	Hazards and operability

HF	Hydrogen fluoride
HFIPI	Hydrogen Fluoride Industry Practices Institute
HVAC	Heating, ventilating, and air conditioning
ISA	Instrumentation, Systems, and Automation Society
LADEQ	Louisiana Department of Environmental Quality
LEPC	Local emergency planning committee
MOC	Management of change
MSDS	Material safety data sheet
NDT	Nondestructive testing
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NRC	U.S. Nuclear Regulatory Commission
OHSEP	Office of Homeland Security and Emergency Preparedness (East Baton Rouge Parish)
OSHA	U.S. Occupational Safety and Health Administration
PHA	Process hazard analysis
PPE	Personal protective equipment
ppm	Parts per million
psig	Pounds per square inch gage
PSM	Process Safety Management (OSHA)
RMP	Risk Management Program (EPA)
SCBA	Self-contained breathing apparatus
SOCMA	Synthetic Organic Chemical Manufacturers Association

Executive Summary

On July 20, 2003, a release of chlorine gas from the Honeywell International, Inc. (Honeywell) chemical plant in Baton Rouge, Louisiana, resulted in injuries to seven plant workers and issuance of a shelter-in-place advisory for residents within a 0.5-mile radius. On July 29, 2003, a 1-ton cylinder at the same plant released its contents to the atmosphere, fatally injuring a plant worker by exposing the worker to contaminated antimony pentachloride. On August 13, 2003, two workers at the plant were exposed to hydrogen fluoride requiring hospitalization for one of those workers.

The U.S. Chemical Safety and Hazard Investigation Board (CSB) incident investigation determined root and contributing causes for the three incidents. An overall analysis revealed common deficiencies in the following management systems:

- Hazard analyses did not ensure a review of all equipment, procedures, and likely scenarios. The safeguards listed were generic and, in many cases, relied too heavily on administrative procedures.

- Nonroutine situations were not always recognized and reviewed to ensure that work could proceed safely.

- Work practices at the plant did not always strictly follow written operating procedures.

CSB determined that guidance and standards for design and maintenance of positive pressure control room systems were lacking in the U.S. chemical industry. CSB also found that manufacturers and users of hydrogen fluoride could benefit from sharing of best practices on draining equipment and maintenance operations for hydrogen fluoride.

CSB makes recommendations to Honeywell International, Inc.; the Baton Rouge facility; Chemical and Metal Industries; American Society of Heating, Refrigeration, and Air Conditioning Engineers; East

Baton Rouge Parish Office of Homeland Security and Emergency Preparedness; Baton Rouge Fire Department; and Hydrogen Fluoride Industry Practices Institute.

1.0 Introduction

1.1 Background

On July 20, 2003, release of chlorine gas from the Honeywell International, Inc. (Honeywell) chemical plant in Baton Rouge, Louisiana, resulted in injuries to seven plant workers and issuance of a shelter-in-place advisory for residents within a 0.5-mile radius. On July 29, 2003, a 1-ton cylinder at the same plant released its contents to the atmosphere, fatally injuring a plant worker by exposing the worker to contaminated[1] antimony pentachloride. On August 13, 2003, two workers at the plant were exposed to hydrogen fluoride (HF) requiring hospitalization for one of those workers.

Because the July 20 incident was serious enough to result in employee injuries and a shelter-in-place advisory, the U.S. Chemical Safety and Hazard Investigation Board (CSB) launched an investigation to determine the root and contributing causes and to issue recommendations to help prevent similar occurrences. The July 29 incident happened during the early phases of this investigation, and because that second incident resulted in a fatality, CSB extended its investigation. Although the consequences of the August 13 incident were not as severe, CSB decided that—since the three incidents occurred in less than 4 weeks—all three would be investigated to determine if there was a relationship among them.

1.2 Investigative Process

CSB investigated independently each of the three Honeywell Baton Rouge plant incidents. During its investigations, CSB:

- Interviewed plant personnel, emergency responders, and neighbors.
- Examined physical evidence.

[1] The material involved in this incident contained a mixture of antimony pentachloride and unknown materials. At least one of the mixture's components had a high vapor pressure.

- Reviewed relevant documentation.

- Reviewed technical and industry guidance, standards, and regulations.

- Discussed relevant issues with the East Baton Rouge Parish Office of Homeland Security and Emergency Preparedness (OHSEP) and the local emergency planning committee (LEPC).

- Entered into joint protocol agreements with Honeywell and the Occupational Safety and Health Administration (OSHA) to test physical evidence.

On March 30, 2004, CSB held a public meeting in Baton Rouge to present initial factual evidence and to hear public comments and concerns.

CSB conducted an independent investigation of these three incidents. Other governmental organizations, including OSHA, the Louisiana Department of Environmental Quality (LADEQ), and the U.S. Environmental Protection Agency (EPA) have conducted their own investigations. Safety investigations conducted by the Board are undertaken for the specific and distinct purposes set forth in the Clean Air Act, 42 U.S.C. 7412(r)(6)(C), and are fundamentally different than those of other Federal or State agencies with civil and/or criminal enforcement responsibilities. (S. Rept, 101-228 (1989), page 232.)

1.3 Honeywell International, Inc.

Honeywell International, Inc. is a multinational company. Its major business groups are Aerospace, Automation and Control Solutions, Specialty Materials, and Transportation Systems. The Baton Rouge plant is part of the Specialty Materials group.

1.4 Honeywell Baton Rouge Plant

The Honeywell Baton Rouge plant began operation in 1945 as General Chemical. Allied Chemical Corporation, which became AlliedSignal Corporation, operated the plant for much of its history. In 1999, AlliedSignal bought Honeywell International, Inc. and took the Honeywell name.

The Baton Rouge plant has over 200 full-time employees. It produces fluorocarbon-based refrigerants (brand named Genetron) and calcium chloride. The site also operates a reclamation and recycling facility for Genetron refrigerants and their shipping containers. The International Brotherhood of Teamsters represents the plant's hourly employees.

Hydrogen fluoride and chlorine are two of the primary raw materials used at the facility. The facility handled enough chlorine and hydrogen fluoride to be covered by the OSHA Process Safety Management (PSM) Standard and the EPA Risk Management Program (RMP) Standard.

2.0 July 20 Chlorine Release

On July 20, a chlorine cooler at the Baton Rouge plant failed, leaking chlorine into the Genetron 143a refrigerant (G-143a) coolant system.[2] The coolant system itself then failed, releasing chlorine to the atmosphere, which overwhelmed operators located both inside and outside the control room and caused them to leave the area. Seven plant workers were injured.

The entire plant was evacuated, and authorities were notified. Because chlorine had been released to the atmosphere, the East Baton Rouge OHSEP initiated its community notification system and issued a shelter-in-place advisory for residents within a 0.5-mile radius. The release lasted approximately 3.5 hours, largely because:

- Operators were forced to evacuate the area before they could diagnose the problem and isolate the source of the leak.
- Chlorine entered the control room and damaged process control equipment.
- Unit emergency shutdown procedures did not completely isolate the chlorine supply.

2.1 Background

2.1.1 Process Description

The Baton Rouge plant operates several processes that manufacture refrigerants. Several of these processes combined form what Honeywell calls the Omni unit, which operates out of the Omni control room.

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[2] Genetron 143a, Honeywell's product name for 1,1,1-trifluoroethane, is a specialty chemical used in refrigerant blends for high-capacity cooling systems.

Honeywell uses chlorine as a raw material to make G-143a.[3] The July 20 leak occurred in the system that feeds chlorine to the G-143a reactor. In this process—depicted in Figure 1—chlorine is fed to the reactor from a railcar through a cooler designed to ensure that the chlorine remains in the liquid phase.[4] The railcar has an emergency shutdown system capable of isolating[5] the railcar.

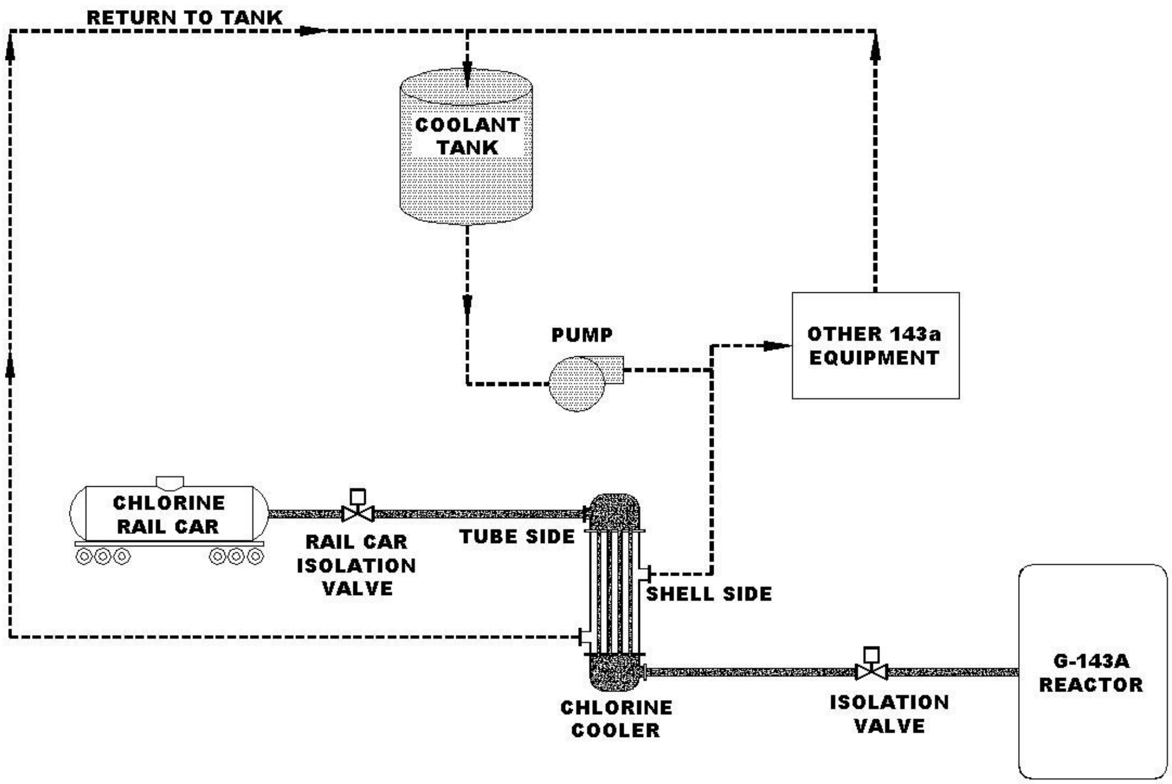

Figure 1. Simplified chlorine feed and coolant systems.

[3] Nomenclature for the numbering of refrigerants (e.g., 143a) is defined in ASHRAE 34 – 2004, Designation and Safety Classification of Refrigerants.

[4] Chlorine is a gas at normal atmospheric conditions. It boils at –29 degrees Fahrenheit.

[5] All valves connecting the chlorine railcar to equipment or processes would be closed for the shutdown, thus preventing further chlorine flow from the railcar.

The chlorine cooler is a carbon steel vertical shell and tube heat exchanger[6] 6 inches in diameter and 8 feet tall. As shown in Figure 2, a shell and tube exchanger consists of a bundle of tubes placed inside an outer shell. In this case, the chlorine flowed inside the tubes (tube side), and coolant flowed over the outside of the tubes within the shell (shell side).

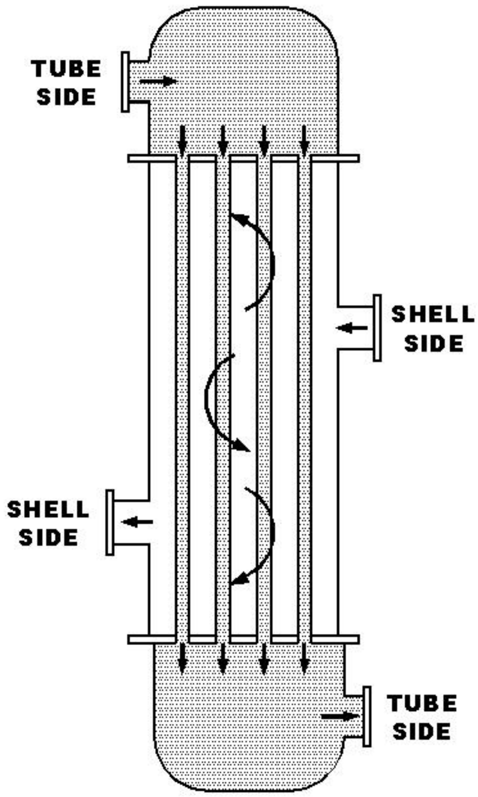

Figure 2. Typical shell and tube heat exchanger.

The coolant—a chlorofluorocarbon refrigerant manufactured at the Baton Rouge facility—is continuously circulated in a loop through various pieces of equipment, including the chlorine cooler. A photograph of the cooler is shown in Figure 3.

[6] This exchanger has a fixed tube sheet, which is welded in place so that individual tubes cannot be removed (i.e., TEMA-type BEM).

Liquid chlorine from the cooler flows through an isolation valve to the G-143a reactor. The reactor isolation valve is normally open when the plant is running. At the time of the incident, both the process automated shutdown sequence and manual shutdown procedures relied on this isolation valve to stop the flow of chlorine to the process. The shutdown system on the railcar was not part of the G-143a shutdown procedures.

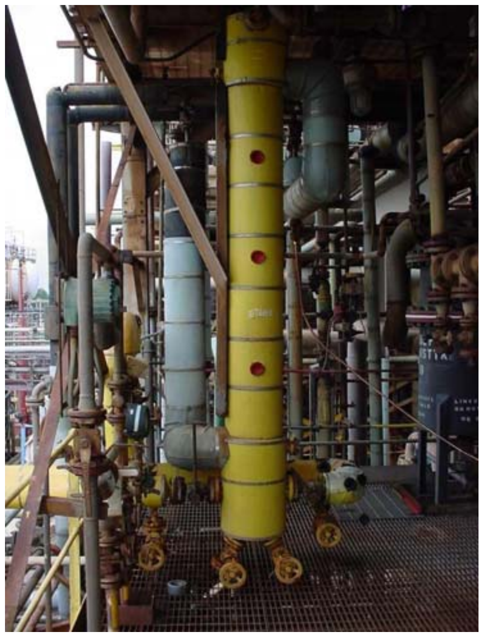

Figure 3. Vertical chlorine cooler in G-143a process.

2.1.2 Chlorine

Chlorine is used to produce many products, including household bleach, water disinfectants, pesticides, medicines, plastic piping, silicon chips, and automotive parts. At room temperature, chlorine is a greenish-yellow gas 2.5 times heavier than air. Its odor is easily recognizable and noticeable at concentrations as low as 0.2 parts per million (ppm).

Because of chlorine’s many uses, considerable data exist on its health effects (Table 1). Chlorine exposure occurs through inhalation or skin or eye contact. Inhalation irritates the mucous membranes of the nose, throat, and lungs. Direct skin contact with gaseous or liquid chlorine may result in chemical burns.

Table 1

Health Effects of Chlorine Inhalation

Concentration (ppm)	Health Effects
1–3	Mild mucous membrane irritation
5–15	Moderate irritation of upper respiratory tract
30	Immediate chest pain, vomiting, dyspnea, and coughing
40–60	Toxic pneumonitis and pulmonary edema
430	Death within 30 minutes
1,000	Death within a few minutes

Source: Ellenhorn and Barceloux, 1988.

Both OSHA and EPA have regulations that require the use of certain management systems for companies that manufacture, store, and use chlorine. The OSHA PSM Standard requires companies to implement management systems to protect workers at facilities that handle extremely hazardous chemicals, including chlorine[7] (29 *Code of Federal Regulations* [CFR] 1910.119). Similarly, the EPA RMP regulation requires companies to develop management systems and assess public risk at facilities that handle specified chemicals including chlorine[8] (40 CFR 68.130).

2.1.3 Industry Trade Associations

Professional and trade associations such as the American Institute of Chemical Engineers (AIChE), the American Chemistry Council (ACC), the Synthetic Organic Chemical Manufacturers Association (SOCMA), the Chlorine Institute, Inc., and the American Society for Nondestructive Testing (ASNT) provide voluntary safety guidance to members. Much of this guidance is also available to the public.

[7] Processes containing chlorine at levels of 1,500 pounds or greater are covered by the OSHA PSM Standard.

[8] Processes containing chlorine at levels of 2,500 pounds or greater are covered by the EPA RMP Standard.

In 1985, AIChE established the Center for Chemical Process Safety (CCPS), which is sponsored by manufacturers, government agencies, and scientific research groups. CCPS has published extensive industry guidance in the areas of process safety technology and management.

ACC and SOCMA have their own programs to promote good chemical process safety practices among member companies.

The Chlorine Institute, Inc. supports the safe production, use, and distribution of chlorine and is a source of guidelines for manufacturers and users (www.chlorineinstitute.org).

Honeywell is a member of CCPS, ACC, SOCMA, and the Chlorine Institute.

ASNT is the world's largest technical society for nondestructive testing (NDT) professionals. It promotes the discipline of NDT as a profession and facilitates NDT research and technology applications. The organization provides a forum for exchange of technical information as well as educational materials and programs, and standards and services for the qualification and certification of NDT personnel.

2.2 Incident Description

2.2.1 Chlorine Release

At 3:10 am on July 20, 2003, Omni unit operators inside the control room noticed a chlorine odor. One operator went outside to investigate and observed a leak near the G-143a coolant system pumps. Because the leak appeared to be coming from the coolant pumps, operators initially believed the leak was confined to the coolant system. Plant personnel outside the control room quickly realized the need for additional help and protective equipment to stop the leak. However, before they could take action, chlorine concentration inside and outside the control room became overwhelming. Operators experienced difficulty breathing and were forced to evacuate the area before they could determine why chlorine was leaking from the coolant pumps. The G-143a process was still running when they left.

2.2.2 Incident Response

By 3:25 am, plant personnel had evacuated to the main plant gate. A level II incident (i.e., one with effects inside the plant and potential for offsite effects)[9] was reported to local authorities through the East Baton Rouge I-notification system. By 3:29 am, Honeywell raised the incident to level III (i.e., one with effects outside the plant).

Several operators who were exposed to chlorine during the release were given oxygen in the first-aid building. The site water deluge towers (Figure 4)[10] were turned on to suppress chlorine vapor, and off-duty plant personnel were called into the plant to help stop the release.

Figure 4. Typical water deluge tower.

Plant emergency response personnel activated the incident command system and began attempts to stop the leak. However, because the chlorine that entered the control room had corroded the process control system, rendering it inoperable, plant response personnel had to manually shut down the G-143a process.

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[9] See section 2.3.6 for further explanation of the incident notification system.

[10] Water deluge towers spray water from a nozzle. Studies indicate that the water spray can suppress chlorine vapors, reducing the concentration of chlorine outside the area of release (the Chlorine Institute, Inc., 1990).

Once that process was shut down, personnel realized that the chlorine was still being released, and that the railcar would have to be isolated to stop the leak (Figure 6).

The chlorine leak was finally stopped at approximately 6:46 am, when the railcar valve was manually closed by Honeywell's emergency response team. Eight employees were transported to the hospital for medical evaluation and treatment following the July 20 incident.[11] Table 2 shows the timeline for events from 3:10 am until the release was brought under control approximately 3.5 hours later.

Table 2

July 20 Incident Timeline

Time (am)	Activity
3:10	Operators notice chlorine release in unit.
3:25	Honeywell reports level II incident to Baton Rouge Fire Department.
3:29	Honeywell reports level III incident to Baton Rouge Fire Department.
3:30–3:40	Plant emergency responders turn on water deluge towers.
3:35	Baton Rouge Fire Department units are dispatched.
3:35–4:00	Emergency responders notice odor at Plank and Prescott Roads 1.5 miles away.
4:00	Siren system activated for 0.5-mile-radius shelter-in-place.
4:03	Auto dialer is used to notify residents within 0.5-mile radius.
4:05	Employees are transported to hospital.
5:35	Chlorine reading at main gate is 1.5 ppm.
6:46	Chlorine railcar is isolated by closing all valves.
7:09	Fire department downgrades incident to level I.

The exact amount of chlorine released could not be determined. However, Honeywell reported to the Louisiana Department of Public Safety and Corrections, Office of the State Police a maximum estimated release of 14,400 pounds, an estimate calculated from pre- and post-incident chlorine railcar weight. The amount released to the atmosphere may have been less if some chlorine dissolved in the coolant or remained in the system piping. Additionally, the amount of chlorine that drifted offsite may have been less than what was released onsite because of mitigation by the deluge tower water spray.

2.2.3 Community Impact

At 4:00 am, the local fire department issued a shelter-in-place advisory for residents within a 0.5-mile radius of the plant (Figure 5). Community sirens were activated, and an auto dialer was used to notify these residents. The advisory remained in effect for 3 hours. At 7:09 am, the fire department downgraded the incident to level I (i.e., one with effects inside the plant only).

At the time of the release, the predominate wind speed was 3 to 5 miles per hour from the southwest. Chlorine concentrations in the air were not measured until 5:30 am—at which time, Honeywell recorded a concentration of 1.5 ppm at the main gate. At 7:13 am, LADEQ arrived and sampled air near the facility; these measurements showed less than 0.35 ppm chlorine outside the plant fence line.[12] [13]

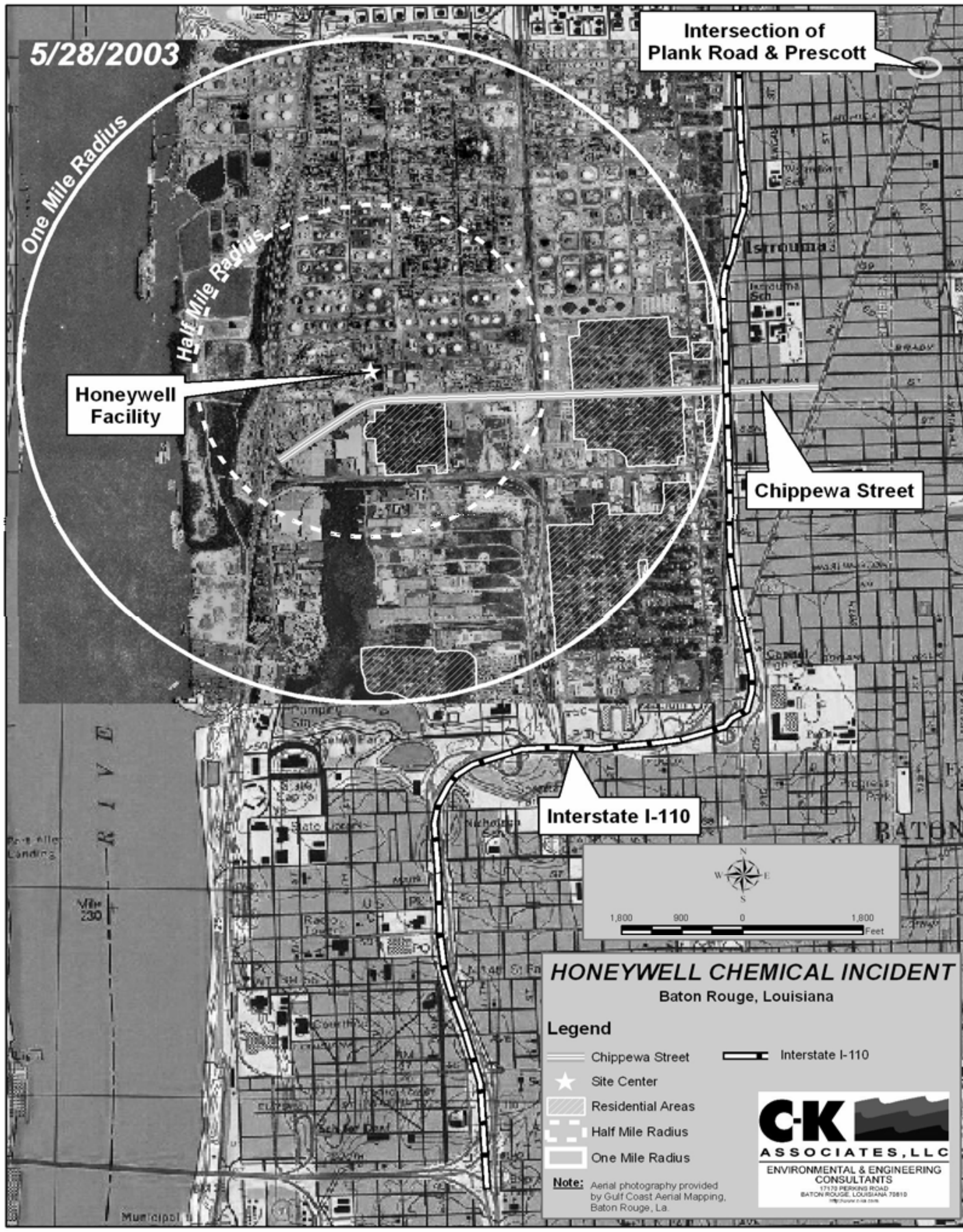
CSB interviewed emergency responders, who reported a strong chlorine odor more than 1.5 miles away in the vicinity of Plank and Prescott Roads. These responders stated that as they proceeded west on Chippewa Street toward the site, the odor was much less pronounced. A few citizens also noticed a strong chlorine odor on Interstate 110 north of the Honeywell facility. Ten members of the general public sought treatment at a local emergency room—three initially and seven throughout the day. They complained of headaches and sore throats and were either treated or observed, then released from the emergency room.

[11] Seven of the employees fell under OSHA's definition for recordable injuries.

[12] Table 1 lists the health consequences of chlorine exposure at these concentrations.

[13] These measurements are indicators of concentrations at a specific location and time and do not necessarily represent concentrations at other locations and times.

Although the shelter-in-place advisory was issued for residents within a 0.5-mile radius, residents outside this radius reported to CSB that they also heard the siren and were confused about what to do because they did not receive a call from the auto dialer.



The star in the center of this overhead picture represents the Honeywell facility. The two circles indicate a 0.5- and 1-mile radius from the plant. Residential areas are shown, as well as Interstate 110 and the intersection of Plank and Prescott Roads.

Figure 5. Overhead view of Honeywell facility and surrounding area.

2.3 Incident Analysis

2.3.1 Mechanical Integrity

As depicted in Figure 6, the immediate cause of the July 20 release was a failure in the chlorine cooler, which allowed chlorine to enter the coolant system. Because Honeywell did not anticipate the coolant pumps coming into contact with chlorine, their materials of construction were not compatible with it. The pumps failed, releasing chlorine to the atmosphere.

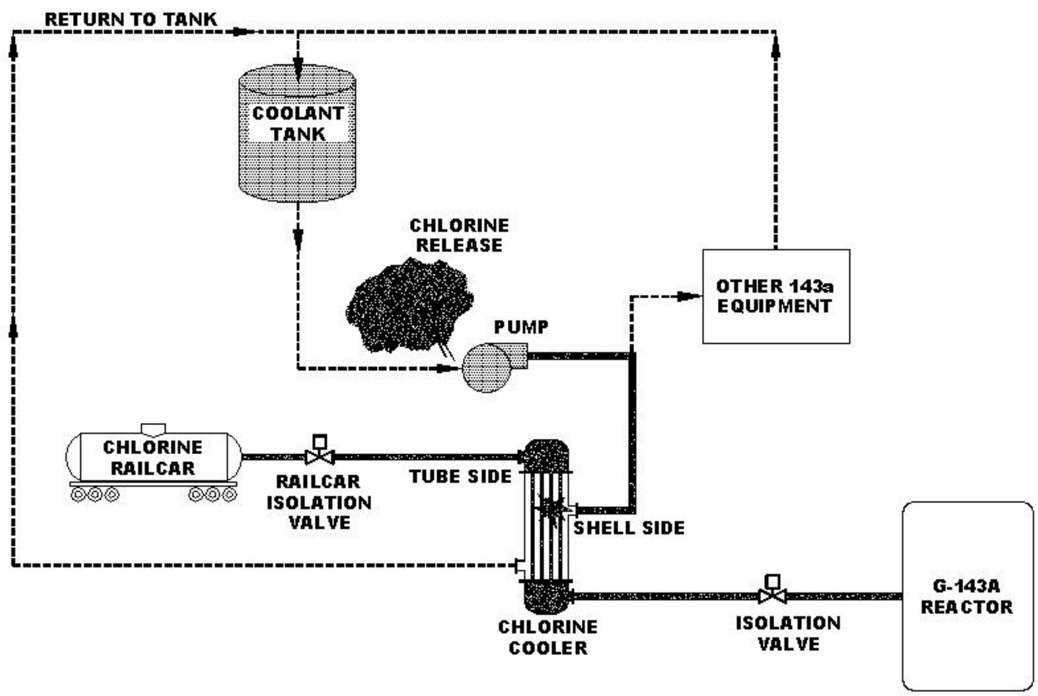


Figure 6. Failure of chlorine cooler, causing release at coolant pumps.

The OSHA PSM standard and EPA RMP regulation both require that covered processes have mechanical integrity programs—a step also considered good practice in the chemical industry. A mechanical integrity program ensures that process equipment is designed, constructed, installed, and maintained to minimize likelihood of an accidental chemical release (Chemical Manufacturers Association [CMA], 1984).

Testing is a critical part of such a program. CSB reviewed Honeywell's mechanical integrity testing program for the chlorine cooler and found that, although Honeywell routinely inspected, tested, and maintained the cooler, the plant's testing program likely could not have identified or prevented problems that caused this failure.

2.3.1.1 Cooler History

The vertical chlorine cooler was an American Society of Mechanical Engineers (ASME)-code certified pressure vessel[14] built and installed in 1986. It had a fixed tube design with 0.109-inch-thick tube walls. Figure 7 shows key milestones in the history of the chlorine cooler.

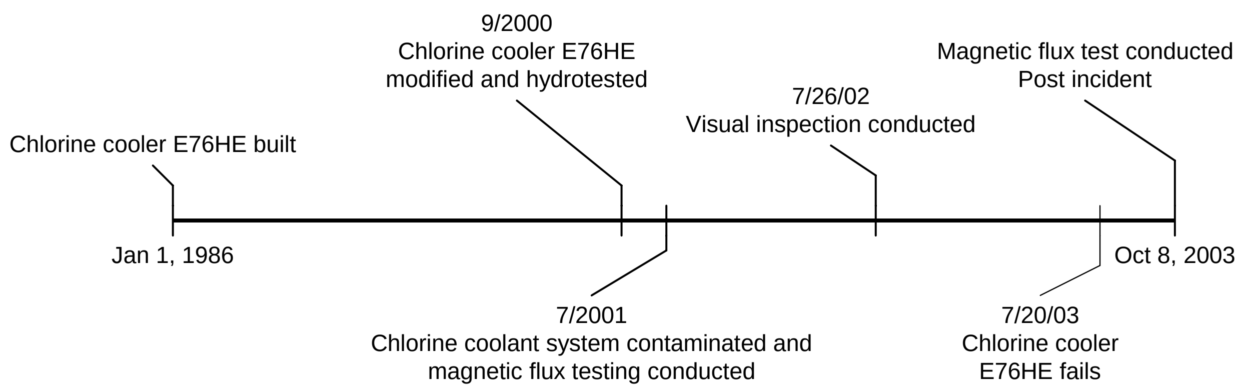


Figure 7. Chlorine cooler history.

[14] The vessel was certified in accordance with the ASME Boiler and Pressure Vessel Code.

In September 2000, modifications were made to the exchanger shell side vents and drains. These modifications, which were made in accordance with the National Board of Boiler and Pressure Vessel Inspectors and ASME code requirements, were certified and inspected by qualified contractors.

In July 2001, an incident in the G-143a reactor contaminated the coolant system with catalyst and other reactor contents. The system was then drained and refilled, and all associated equipment was tested to determine if the contamination caused any damage. No damage was found in the chlorine cooler.

As a part of the Honeywell mechanical integrity program, the chlorine cooler was inspected every year using visual external inspection and inspected every two years using magnetic flux leakage testing. Magnetic flux leakage is an NDT method that relies on magnetism to inspect ferromagnetic materials such as carbon steel.[15] External visual and magnetic flux leakage inspection of the cooler in 2001 revealed no plugged tubes, measurable defects, or wall thinning.

2.3.1.2 Post-Incident Testing

Following the July 20 incident, the chlorine cooler was cut open and inspected. Visual inspection revealed three holes in the tubes and a buildup of corrosion products at the bottom (two holes are shown in Figure 8). All corrosion products and the holes were found in the lower section of the cooler; the holes originated on the outside surface of the tubes (refer to Figure 2). One hole was crescent shaped and about 0.5 inch long, while the two other holes were about 0.25 inch in diameter and approximately 5 inches higher on adjacent tubes. After the visual inspection, two holes were confirmed by magnetic flux testing performed by a Honeywell contractor; however, the third hole's test results showed only significant wall thinning.

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[15] A magnetic field is applied to the material to be inspected. Surface and near-surface flaws disturb the magnetic flux (energy density) in the inspection area. The test device detects this disturbance, providing the approximate size and location of the flaw.

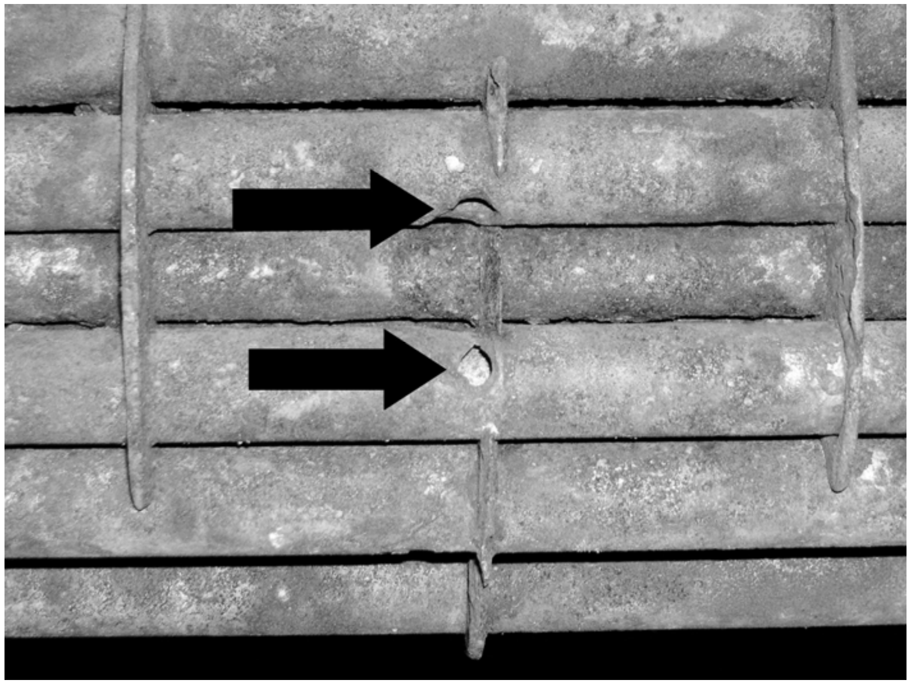

Figure 8. Chlorine cooler tube bundle showing two holes.

Following agreement with CSB and OSHA on testing protocols, Honeywell hired a laboratory to conduct additional failure mode testing of the chlorine cooler. The laboratory was unable to determine conclusively what the failure mechanism was, based on physical evidence alone. After further study, the laboratory proposed that damage on one tube might have been caused by the September 2000 modifications and exacerbated by the July 2001 contamination incident. Appendix A provides additional details on this failure theory.

2.3.1.3 Analysis

Upon referral by ASNT, CSB contacted the Electric Power Research Institute (EPRI).[16] EPRI has studied several NDT methods—magnetic flux, remote field eddy current, and magnetically biased eddy current—and demonstrated that the different NDT techniques have different strengths and weaknesses for given

[16] EPRI has a large NDT research facility. Although its work is not specific to the chemical industry, it is applicable in this case and recognized within the NDT field.

applications. Specifically, EPRI has concluded that magnetic flux may not detect all defects in thick carbon steel tubes (such as the 0.109-inch tube walls in the chlorine cooler).[17] EPRI cautions that tube thickness and material of construction should be considered in choosing the most appropriate NDT method (Dau and Kryzywosz, 1990).

A magnetic flux leakage inspection in October 2003 followed the July 20, 2003 incident. Two of the three holes were identified by that inspection, but the third showed only as wall thinning. This finding suggests that either the methodology or the testing apparatus is less than adequate to positively detect thinning and failure of the 0.109-inch tube walls.

In light of this incident and CSB findings, NDT programs should be periodically reviewed and modified based on experience and advances in NDT technology. Although many companies use magnetic flux testing, this incident showed that in cases involving coolers such as the chlorine cooler in the Baton Rouge plant, this testing method does not appear to be the best choice.

2.3.2 Hazard Analysis

CCPS defines hazard analysis as: "the analysis of the significance of hazardous situations associated with a process or activity" (CCPS, 1992). A typical process hazard analysis (PHA) uses qualitative techniques to identify specific process hazards and corresponding consequences and possible safeguards. As required by the OSHA PSM Standard, Honeywell conducted PHAs of the G-143a process. However, the PHAs identified only nonspecific leaks in the chlorine system—rather than identifying problems with specific equipment such as the chlorine cooler. The PHA did not consider utility systems, such as the coolant system, and relied on generic and administrative safeguards.

[17] The post-incident magnetic flux testing report also notes that magnetic flux is not the best method for testing the chlorine cooler.

The hazards and operability (HAZOP)[18] and "what if"[19] methods were used to complete a PHA on the G-143a process in September 1994. For this PHA, the team did not consider a chlorine leak, analyze the effects of deviations in the G-143a process utilities, or identify the possibility of a tube leak in the chlorine cooler.

As required by OSHA PSM, the G-143a PHA was revalidated in January 2000—again using the HAZOP and "what-if" methodologies. This second PHA specifically identified the possibility of a leak in the chlorine feed system, but still did not look at leaks in individual pieces of equipment such as the chlorine cooler. At this time, it was thought that the consequences of a leak in the chlorine system would be minor injuries with no effects outside the facility boundaries. As with the 1994 PHA, the revalidation did not investigate the G-143a process utility systems.

In June 2002, a revalidation PHA was conducted on another Omni unit refrigerant process (G-113 R-1) that used the same chlorine feed and coolant systems as G-143a. During this PHA, Honeywell looked at the possibility of a tube leak in the chlorine cooler and identified the possibility of chlorine getting into the coolant system. "Design, inspection, and testing" were listed as safeguards and deemed adequate by Honeywell. In the PHA, Honeywell recognized that failure of the chlorine cooler could lead to contamination of the chlorine coolant system. However, it did not evaluate the consequences of this contamination or the need for prevention and mitigation measures.

In the 1994 PHA, the 2000 revalidation for G-143a, and the 2002 G-113 R-1 PHA, the PHA team relied on generic administrative safeguards in their analyses. For example, "standard operating procedures," "design," "proper emergency response procedures," and "testing and inspection" were listed as safeguards

[18] With this method, an interdisciplinary team uses a "creative, systematic approach to identify hazard and operability problems resulting from deviations from the process design intent that could lead to undesirable consequences." (CCPS, 1992)

[19] "The what-if technique is a brainstorming approach in which a group of experienced people familiar with the subject process ask questions or voice concerns about possible undesired events." (CCPS, 1992)

against a leak in the chlorine feed system. None of the analyses listed procedures for specific operations that could be analyzed for adequacy. For example, if a “chlorine shutdown” procedure had been specified, that procedure could have been reviewed to ensure it contained specific steps to mitigate a chlorine release.

In a typical hazard analysis, the consequences of hazards are reviewed to determine if existing safeguards provide adequate protection against risk. Hazards with a higher degree of risk generally require a higher level of safeguards. Administrative protections—such as operating and maintenance procedures—are typically viewed as lower-level safeguards (Bird and Germain, 1985). For many of these hazard analyses, a “layer of protection” approach is used to ensure that should one safeguard fail, others would would provide protection. This approach is an example of a simplified risk analysis.[20]

When Honeywell conducted its 1994 HAZOP, the PHA procedure did not include guidelines for risk analysis to determine appropriate levels of safeguards. Later versions were updated to include some risk analysis guidelines. However, in both cases, administrative protection measures—such as operating procedures, and testing and inspection—were deemed appropriate safeguards for the level of risk presented by deviations such as a chlorine release. The 2002 G-113 R-1 PHA also used risk analysis guidelines. However, this PHA failed to fully identify that consequences of contaminating the coolant system with chlorine could include chlorine release to the atmosphere. Therefore, the severity of the coolant system contamination was ranked as relatively low-level, and a lower level of safeguards was judged to be sufficient.

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[20] “Risk analysis is the process of estimating the magnitude of risk arising from a potentially hazardous activity.” (CCPS, 1995)

Honeywell investigated the July 2001 incident (Section 2.3.1.1) that resulted in contamination of the G-143a coolant system. However, the investigation recommendations focused on equipment integrity but did not reconsider what would happen if the coolant system was contaminated.

Overall, the Honeywell PHAs did not effectively identify the likelihood or consequences of chlorine entering the coolant system. In addition, the safeguards that were identified as necessary were inadequate to prevent, contain, or mitigate a large-scale chlorine release.

2.3.3 Management of Change and Chlorine System Shutdown

Management of change (MOC) programs are used to evaluate the safety of changes in processes. The OSHA PSM Standard requires that processes it covers have MOC programs, a step also considered good practice throughout the chemical industry.

When the G-143a process was originally built, 1-ton cylinders supplied chlorine to the plant. In the late 1990s, the chlorine feed system was modified to feed chlorine from an existing railcar system equipped with its own transfer shutdown system. The shutdown system included remotely operated valves that operators could close manually from the control room, but not chlorine monitors that automatically close the valves and isolate the railcar. The change to railcars increased the volume of chlorine available. (A full railcar holds 180,000 pounds, 90 times the capacity of a 1-ton cylinder.) An MOC analysis was done before the railcar was used to supply chlorine to the G-143a process.

Because the chlorine railcar system was already in use elsewhere at the Baton Rouge plant at the time of the change, its transfer shutdown control system was separate from the G-143a shutdown system. Normally, when the G143a process is shut down—using either the standard operating procedure or the automated shutdown sequence—it does not shut off the chlorine feed from the railcar. However, video cameras in the Omni control room monitored the chlorine railcars,[21] and operators in the control room are trained to remotely isolate the railcars if they notice one leaking, though there are no formal procedures for this activity.

System isolation is more critical for a railcar because it has a much higher volume of chlorine than a 1-ton cylinder. The MOC included a brief "what-if" analysis that deemed the existing railcar shutdown system an adequate safeguard for chlorine release. It did not recommend integrating procedures for isolating the railcar and shutting down the G-143a process. Having integrated procedures in place likely would have precluded the release of significant amounts of chlorine in this incident and resulted in less severe consequences.

2.3.4 Design and Maintenance of Positive Pressure Control Rooms

Honeywell converted the Omni control room into a positive pressure control room in 1998 after plant personnel complained of odors getting into the control room and an engineering study identified potential infiltration of the highly hazardous substance hydrogen fluoride.

A Honeywell divisional engineering group[22] managed the control room conversion project. The control room was designed to provide short-term protection for personnel during a chemical release so that they could safely shut down processes before evacuating. Operators were to use escape respirators, located in the control room, to evacuate after shutting the process down.

The design of the positive pressure control room included the following features:

- Air intake piped to pull air from the highest point in the plant.

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[21] U.S. Department of Transportation (DOT) regulations mandate continuous monitoring of unloading of a hazardous material such as chlorine. If the railcar is monitored remotely, it also must be capable of remote isolation.

[22] The divisional engineering group provides engineering support to Baton Rouge and other facilities within Honeywell.

- Sealing of the room to allow the heating, ventilating, and air conditioning (HVAC) system to maintain positive pressure.

- Manual shutoff of the HVAC system intake.

- Audible alarms to indicate low pressure.

During the July 20 release, chlorine entered the control room. CSB investigators found that it was drawn into the building through holes and gaps in the HVAC intake ducts located on the roof. Some holes appeared to have been drilled in the duct and not plugged, while others resulted from gaps in joints. Duct tape was used to seal some gaps, but the tape became dry and brittle over time. Figures 9 and 10 show this deterioration. Figure 11 shows the proximity of the coolant system chlorine leak in relation to the HVAC system.

Figure 9. Condition of duct tape used to seal gaps.

Figure 10. Hole in ductwork.

Figure 11. HVAC intake system on control roof (foreground).

Arrow points to location of coolant system chlorine leak.

The positive pressure control room system did not protect personnel or equipment during the July 20 chlorine release. The following deficiencies in the positive pressure control room system contributed to its failure:

- There was no maintenance program for the control room, including HVAC ductwork.[23]

- Duct tape used to seal some joints in HVAC ductwork eventually became brittle and exposed gaps in the joints.

- There were numerous entrances and exits from the control room—none of which had a double door air lock system.

- There were no toxic gas alarms on the HVAC intake system. Alarms could have warned operators to use the escape respirators and exit the control room.

- Although the positive pressure control room system was listed as a safeguard in a hazard analysis, it was not designated as critical equipment or maintained as such.[24]

When interviewed by CSB, Honeywell engineers stated they were unaware of any standards for design and maintenance of control rooms to withstand toxic gas releases. CSB researched available industry standards and guidance for control rooms, and found that existing standards aimed at the chemical manufacturing industry do not adequately address design and maintenance for protection against toxic chemical releases. Current guidance is summarized below:

- ***American Petroleum Institute (API) Recommended Practices***: API develops standards for petroleum refineries. However, API Recommended Practices 550, 551, and 752 provide direction in the area of positive pressure control rooms that also can be helpful to the chemical industry (API, 1977; 1995; 1999).

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[23] When asked, Honeywell indicated that there was no preventive maintenance on the positive pressure control room system, including ductwork.

[24] In its citations, OSHA considered the positive pressure control room to be covered by the PSM Standard.

- ***National Fire Protection Association (NFPA)***: NFPA 496, Standard for Purges and Pressurized Enclosures for Electrical Equipment (1998), contains only a few recommendations for pressure and air velocities. It was not intended to address the protection of personnel.

- ***Instrumentation, Systems, and Automation Society (ISA)***: Several ISA standards include design recommendations to protect process measurement and control systems; however, none of the standards address protection of personnel.

- ***U.S. Nuclear Regulatory Commission (NRC)***: Although NRC regulatory guides are not intended for the chemical industry, they may provide relevant information in the area of positive pressure control room design and maintenance (USNRC, 2003a; 2003b; 2001). NRC staff use the guides to implement specific regulations, to evaluate specific problems or postulated accidents, and to review applications for permits and licenses.

The United Kingdom Chemical Industries Association provides guidance on control room design and maintenance, including recommendations for inspecting and maintaining HVAC systems and for entrance and exit design. In *Loss Prevention in the Process Industries*, Lees (1996) briefly covers topics such as the need for an airtight design, positive pressure requirements, and possible use of toxic gas monitors.

As outlined above, U.S. guidance and standards for designing control rooms in chemical manufacturing facilities to protect against toxic releases are limited. If the Omni positive pressure control room system had been better designed, documented, and maintained, operators likely would have been better protected and could have stopped the July 20 chlorine leak more expeditiously, and the chlorine would not have damaged the control system.

2.3.5 Previous Incidents of Chlorine in Omni Control Room

Employee interviews indicated that on several occasions Honeywell personnel noticed chlorine odors in the Omni control room. Actions were taken to eliminate the source of the odors, but no formal investigation was conducted of how the chlorine entered the positive pressure control room.

As required by the OSHA PSM Standard and EPA RMP regulation, Honeywell has a procedure for investigating incidents and near misses. Its procedure defines an incident "as an unplanned event that occurs outside the guidelines of normal operating procedures that creates the potential for injury, equipment damage, or environmental impacts."

The positive pressure control room system was not documented in Honeywell procedures or identified as critical equipment. Procedures did not include warnings that odors in the control room are not expected and need to be investigated. With specific written guidance, employees might have recognized odor in the control room as an "incident." If such incidents had been investigated, it is likely that Honeywell would have determined that the positive pressure control room was compromised.

2.3.6 Community Notification Systems

An effective community notification system alerts people to the fact that an incident has occurred and informs them when the situation is over. As a part of the notification system, people are instructed on appropriate steps to protect themselves.

The East Baton Rouge OHSEP manages the community notification system in East Baton Rouge Parish, and the Baton Rouge Fire Department operates the system. During investigation of an unrelated October 13, 2002 incident in Pascagoula, Mississippi, CSB had surveyed several industrial areas with residential neighbors (including East Baton Rouge) to determine good practices for community notification and emergency response. At that time, CSB determined that East Baton Rouge OHSEP had a good community notification system containing several components comparable to other large municipalities. (CSB, 2003)

Baton Rouge industry, including Honeywell, own and operate an I-notification system they use to electronically alert authorities of an incident. Companies classify incidents according to their effects on the community, as outlined in Table 3.

Table 3

East Baton Rouge Incident Classification

Classification	Type of Incident	Incident Effects
Level I	Unusual event	Inside plant only
Level II	Site emergency	Inside plant with potential for offsite
Level III	General emergency	Areas outside plant

In the event of a Level III release, the Baton Rouge Fire Department standard procedure is to issue a 0.5-mile-radius shelter-in-place advisory and to begin public notification. As emergency responders approach the scene, they assess the situation and decide whether to change the initial advisory or to recommend evacuation. The community alert system (CAL) offers several means of public notification, which include:

- ***Telephone***: CAL automatically dials the telephone numbers in the area of an emergency and plays a prerecorded message on where the incident is and what steps to take. CAL can call all telephone numbers in East Baton Rouge Parish or target specific areas.

- ***Sirens and loudspeakers***: CAL also can activate sirens and loudspeakers in the emergency area. The sirens emit a loud warning tone first, followed by an emergency message from a loudspeaker. Nineteen sirens are located in the East Baton Rouge industrial corridor.

- ***Emergency alert system:*** This system uses local commercial radio and television broadcast services. In the event of an emergency, citizens are advised to monitor their local radio and television stations for instructions and updates on conditions.

- ***Mobile sirens***: When feasible and where there are no fixed sirens, government vehicles equipped with sirens or loudspeakers provide emergency information.

- ***Door-to-door***: If required, emergency response and public safety personnel will deliver door-to-door emergency warnings.

Because of the impact of the July 20 release, CSB investigated the effectiveness of East Baton Rouge's community notification system during this incident. CSB found that some local residents were confused and frustrated by a lack of information.

The shelter-in-place advisory should have been immediately activated, according to the Baton Rouge Fire Department written procedures for level III incidents. However, incident timelines show a 31-minute delay between the Honeywell report of a level III incident and activation of the shelter-in-place alert system. Following the incident, the fire department reviewed its community notification procedures and retrained personnel, emphasizing the importance of timely notification.

At the public meeting in Baton Rouge on March 30, 2004, CSB presented preliminary findings and gathered additional information. One community concern that came out at the meeting was that the broadcast via the community loudspeaker was garbled. Also, residents outside the 0.5-mile zone did not receive telephone notification because they were not included in the shelter-in-place advisory. Additional concerns raised at the meeting focused on the structural integrity of the houses where residents are asked to shelter in place. Many attendees felt their housing was inadequate for protection during a toxic gas release. Residents also were concerned about the delay in monitoring chlorine levels in the air.

In response to issues raised by the community, OHSEP is currently evaluating its procedures regarding community shelter-in-place. The LEPC reviewed shelter-in-place at its April and June 2004 meetings and the Baton Rouge Fire Department conducted research on the effectiveness of shelter-in-place. The LEPC reached consensus that shelter-in-place is still the best protective action for a "rapidly propagating event with expected short-term duration." OHSEP is working through the LEPC and the Public Information Coordinating Council to further develop public education programs relating to shelter-in-place.

2.4 Regulatory Analysis

2.4.1 OSHA Process Safety Management

The OSHA PSM Standard (29 CFR 1910.119) requires employers to prevent or minimize the consequences of catastrophic release of highly hazardous chemicals and mandates that 14 elements of a management system be used towards that purpose.

The standard covers processes if they contain OSHA-defined minimum threshold quantities of listed chemicals. Chlorine is a listed chemical, and the Honeywell G-143a unit had sufficient quantities to be covered.[25] The elements of OSHA's PSM Standard include many of the issues discussed in this report's analysis, and these elements provide appropriate coverage for processes such as G-143a.

In a post-incident inspection, OSHA issued citations for numerous violations of the PSM Standard in the following areas:

- Process hazards analysis (which requires employers to evaluate hazards of the processes covered by this standard).

[25] Processes containing chlorine are covered if they contain more than 1,500 pounds of chlorine.

- Process safety information (which requires employers to compile information pertaining to the highly hazardous chemicals in a process).
- Standard operating procedures (which requires employers to develop and implement written procedures for safely conducting activities involved in each covered process).
- Management of change (which requires employers to establish and implement written procedures to manage changes that affect a covered process).
- Incident investigations (which requires employers to investigate each incident that resulted in or could reasonably have resulted in a catastrophic release of highly hazardous chemicals in the workplace).
- Compliance audits (which requires employers to evaluate compliance with OSHA PSM at least every 3 years).
- Mechanical integrity (which requires employers to establish, maintain, and implement procedures to maintain the ongoing integrity of process equipment including inspection and testing).

Honeywell did not consider the coolant system or the positive pressure control room to be covered by the OSHA PSM Standard, nor did the company apply the principles of process safety management to those areas. However, OSHA considers utilities that serve a PSM-covered process also covered by the standard: "where they can impact on, or affect a release of a highly hazardous chemical in the process" (USOSHA, 1995). If Honeywell had applied these principles to the coolant system, it likely would have identified the need for more appropriate protections against the possibility of leaking chlorine to the atmosphere.

In discussions with CSB, ACC and SOCMA stated that many members conduct hazard analyses to determine the effects of utility systems on PSM-covered processes. Analysis results are used to determine whether the utility is covered under the facility's PSM program and to what extent management systems will be applied.

Because the positive pressure control room system was relied upon as a safeguard in the Honeywell PHA, OSHA considered the system part of the covered process. If it had been included in the Honeywell PSM program, routine maintenance more likely would have been carried out, incidents of odors would have been formally investigated, and the operators would have been better protected during the July 20 chlorine leak.

2.4.2 EPA Risk Management Program

The EPA RMP regulation is similar to the OSHA PSM Standard except that it is designed to protect the public and the environment from releases of highly hazardous chemicals, while OSHA's standard is designed to protect employees. RMP contains a list of regulated chemicals and requirements for facilities possessing more than a threshold quantity of a listed chemical. Facilities that are covered are required to implement a risk management program containing elements similar to those required by OSHA's PSM regulation. Companies also are required to identify a worst-case release and alternative scenarios,[26] and to estimate the potential offsite effects of each.

Honeywell identified an HF release as its worst-case scenario. For its alternative scenario, Honeywell identified a chlorine release; however, the company predicted no effect on the public. There is no evidence that failure to identify the July 20 release scenario made a difference in the community response during this incident. However, these scenarios can help communities prepare for incidents such as the July 20 chlorine release.

2.5 Key Findings

1. The G-143a chlorine cooler tubes failed, releasing chlorine into the G-143a coolant system.

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[26] The alternative case uses more realistic failure mechanisms and safeguards than the worst-case scenario.

2. The materials of construction for the G-143a coolant system pump were not compatible with chlorine; therefore, system components failed, releasing chlorine to the atmosphere.

3. Incident timelines show a 31-minute delay between the Honeywell report of a level III incident and the Baton Rouge Fire Department activation of the shelter-in-place alert.

4. Although the chlorine cooler was constructed of materials suitable for its intended use, inspection and testing were the only layers of protection against failure.

5. The chlorine cooler had been inspected in 2001 using the magnetic flux NDT method. Test results then showed no flaws. Magnetic flux testing done after the incident, when three holes were present, showed two complete holes through walls, but only wall thinning at the location of the third hole.

6. EPRI has demonstrated that magnetic flux testing may not be the best NDT method for ferrous (such as carbon steel) coolers with tube walls as thick as those in the chlorine cooler (.109 inches).

7. The G-143a PHA did not identify the potential for chlorine leaking into the coolant system.

8. The PHA on a similar process in the same facility (G-113 R1) identified the possibility of chlorine leaking into the coolant system but did not evaluate the consequences.

9. The MOC review (including the associated hazard analysis) conducted when the chlorine feed system was modified to allow use of railcars (at a capacity of 180,000 pounds) in addition to ton cylinders (at a capacity of 2,000 pounds) did not identify a need to integrate the chlorine railcar and G-143a shutdown procedures.

10. The G-143a shutdown sequence and procedures did not include isolation of the chlorine railcar.

11. Chlorine released from the cooler entered the positive pressure control room through holes or gaps in the HVAC ductwork.

12. The design of the positive pressure control room system was not adequate for protecting operators long enough to allow them to identify the source of the chlorine leak and shut down the G-143a process.

13. The Omni unit control room was designed to be positive pressure, but the positive pressure system was not routinely inspected or maintained.

14. Previous incidents of chlorine entering the Omni control room had occurred. In those cases, actions were taken to eliminate the source of odors; however, no formal investigation was conducted to determine how the chlorine entered the positive pressure control room.

15. There are no standards or guidance applicable specifically to design and maintenance of positive pressure control rooms for the U.S. chemical industry.

2.6 Root and Contributing Causes

2.6.1 Root Causes

1. **The Honeywell Baton Rouge plant management systems did not protect against failures in the chlorine cooler.**

   The Honeywell mechanical integrity system failed to identify problems with the chlorine cooler prior to its failure. Annual inspections prior to the incident did not show any flaws in the cooler tubes.

   Honeywell had no additional measures in place to protect against cooler failure, such as monitoring for chlorine leaks. Because the mechanical integrity system was relied upon exclusively, a failure in the cooler resulted in chlorine contacting incompatible materials in the coolant system and releasing chlorine to the atmosphere.

2. The consequences of chlorine entering the coolant system were not fully evaluated.

The Honeywell G-143a PHA was too general and did not identify the potential for chlorine leaking into the coolant system. The chlorine feed system was considered as a whole. However, because there was no consideration of potential hazards in individual pieces of equipment, the possible failure of the chlorine cooler was not evaluated. Although the possibility of a leak in the chlorine feed system was considered, general safeguards such as design, maintenance, and procedures were listed as adequate to prevent or respond to a leak.

Furthermore, the potential impact of contamination of the coolant system was never fully evaluated—neither during the G-113 R-1 PHA that did identify the possibility of coolant system contamination nor after a July 2001 incident that contaminated the system.

2.6.2 Contributing Causes

1. The positive pressure control room system was not adequately designed and maintained to provide short-term protection against the infiltration of chlorine.

Honeywell intended that the positive pressure system would prevent the entry of toxic gases into the control room. Improper materials of construction, inadequately protected entrances, and lack of toxic gas sensors, interlocks, and alarms rendered the system incapable of protecting employees. Additionally, deficiencies were not found prior to the July 20 release because the system was not identified as critical equipment and put on a preventive maintenance plan.

2. The need to integrate existing railcar shutdown procedures with G-143a unit shutdown procedures was not identified.

Chlorine from the railcar continued flowing into the failed cooler even after the process was shut down, resulting in a release of additional chlorine into the atmosphere.

The MOC that was conducted when Honeywell began using railcars as the chlorine feed source included a brief “what-if” analysis that deemed the existing railcar shutdown system as an adequate safeguard for a chlorine release. It did not recommend the integration of procedures for isolating the railcar when shutting down the G-143a process. Integrated procedures likely would have resulted in a more rapid shutdown and less severe consequences.

Although the G-143a PHA completed in 2000 identified a chlorine leak as possible, the PHA team did not recommend integration of the chlorine railcar emergency shutdown procedure into the G-143a emergency shutdown procedures.

3. **Incidents of chlorine odors in the control room were not formally investigated to determine how chlorine entered the positive pressure control room.**

On previous occasions, Honeywell employees noticed chlorine odors in the positive pressure control room. Although actions were taken to eliminate the source of the odors, no formal investigation was conducted to determine how chlorine entered the control room.

2.7 Recommendations[27]

Honeywell Baton Rouge Facility

1. Revise inspection and testing procedures to include effective methods for detecting and preventing leaks in coolers that use chlorine. These procedures should include the use of appropriate NDT methods. (2003-13-I-LA-R1)

2. Analyze layers of protection installed to prevent possible consequences of failure of heat exchangers that use chlorine, and implement corrective actions as appropriate. Examples of additional measures include installing monitors on the coolant stream to detect the presence of chlorine, and determining the feasibility of operating the coolant stream at a pressure high enough to prevent the entry of chlorine in the event of a leak. (2003-13-I-LA-R2)

3. To address ongoing issues regarding layers of protection and leaks in heat exchangers, revise procedures for performing process hazard analyses for equipment that contains hazardous materials such as chlorine to, at a minimum:

   - Require an evaluation of the effects of leaks in heat exchangers.
     (2003-13-I-LA-R3)

   - Consider the layers of protection necessary to prevent a catastrophic incident and require recommendations to be implemented when existing protection is inadequate.
     (2003-13-I-LA-R4)

[27] Section 6.0 lists all recommendations from the CSB investigations of the July 20, July 29, and August 13 incidents.

4. Revise the incident investigation procedure to ensure that odors inside positive pressure control rooms are investigated, the causes identified, and the appropriate corrective actions implemented. Address causes of the releases as well as entry of the material into the building. (2003-13-I-LA-R5)

5. Survey units that handle chlorine and evaluate the effectiveness of shutdown systems for detecting and preventing the release of chlorine. At a minimum, ensure that shutdown systems and procedures are integrated to stop all potential sources of chlorine. (2003-13-I-LA-R6)

6. Conduct training to emphasize that MOC evaluations must consider whether emergency shutdown procedures need to be changed when there are changes in material inventory. (2003-13-I-LA-R7)

Honeywell International, Inc.

Develop and implement corporate standards to ensure positive pressure control rooms, including the HVAC systems, are designed and maintained to prevent the short-term entry of hazardous materials. Implement corporate standard changes at the Baton Rouge facility and other Honeywell facilities as appropriate. (2003-13-I-LA-R14)

American Society of Heating, Refrigeration, and Air Conditioning Engineers (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 materials. (2003-13-I-LA-R22)

Baton Rouge Fire Department

Evaluate and update as necessary community notification procedures to include timely notification of residents in the event of a chemical release. Conduct periodic refresher training with staff on the requirements in the procedures. (2003-13-I-LA-R23)

East Baton Rouge Parish Office of Homeland Security and Emergency Preparedness (OHSEP)

Conduct an awareness campaign to educate residents on the proper response during a chemical release. Include instructions on the way residents (including those outside the affected area) can obtain information during an emergency. (2003-13-I-LA-R24)

American Society for Nondestructive Testing (ASNT)

Communicate the findings and recommendations from the July 20 incident to your membership. Emphasize the need to evaluate test methods for appropriateness in the given equipment. (2003-13-I-LA-R28)

3.0 July 29 Contaminated Antimony Pentachloride Exposure

During the July 20 chlorine release, all units at the Baton Rouge plant were shut down. Chlorine had corroded the process control system, which needed to be replaced. Work at the facility during the days that followed consisted mainly of maintenance, shipping activities, and the return of process equipment to a safe, normal state.

On July 29, an operator working in the ton-cylinder area of the plant was preparing empty 1-ton refrigerant cylinders for offsite testing. During this procedure, he removed a plug from a 1-ton cylinder he likely believed to be empty. The cylinder was actually full, and its contents were released. The operator was engulfed in a cloud later determined to be contaminated[28] antimony pentachloride; he died the following day, July 30.

3.0 Background

3.1.1 Antimony Pentachloride Use

Honeywell uses "fresh" or virgin antimony pentachloride in the refrigerant manufacturing process as a catalyst to promote the desired reaction between hydrogen fluoride, chlorohydrocarbon,[29] and chlorine in the process reactor. The antimony pentachloride becomes contaminated by residual material from the reaction, and becomes "spent." Honeywell periodically collects the spent antimony pentachloride into

[28] The materials involved in this incident were a mixture of antimony pentachloride and unknown materials, including a high vapor pressure component.

[29] A chlorohydrocarbon is a carbon and hydrogen-containing compound with chlorine substituted for some hydrogen in the molecule.

1-ton cylinders and ships it to Chemical and Metal Industries (C&MI), a vendor located in Colorado. C&MI regenerates the spent antimony pentachloride and returns fresh antimony pentachloride to Honeywell.

Precautions for Honeywell Baton Rouge's fleet of antimony pentachloride 1-ton cylinders include:

- Each of the nearly 200 cylinders is logged in a database that records serial number, weight, and cylinder location.
- The cylinders are color-coded to distinguish them from refrigerant cylinders—antimony pentachloride cylinders are painted silver-gray.
- Only Omni[30] operations personnel handle the cylinders after they are taken off a truck by receiving department personnel.
- The cylinders are equipped with fusible plugs.[31] These plugs are designed to melt and relieve internal pressure in the event the cylinder is exposed to external fire.

C&MI regenerates antimony pentachloride for fluorocarbon producers worldwide.

C&MI follows these basic steps upon receipt of spent cylinders:

- Cylinders are weighed and matched to their shipping papers.
- Cylinder contents are sampled and analyzed to verify that the material meets C&MI specifications for spent antimony pentachloride.

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[30] The Baton Rouge plant operates several processes that manufacture refrigerants. Several of these processes combine to form what Honeywell calls the Omni unit.

[31] Refrigerant cylinders are equipped with pressure relief devices instead of fusible plugs.

- Material that does not meet C&MI specifications is rejected and returned. C&MI has no formal procedures for handling rejected material; the return shipment is discussed with the customer, including proper shipment labeling for the material.

- Material that meets specifications is regenerated and loaded back into the 1-ton cylinders to be returned to the customer.

3.1.2 Honeywell El Segundo Facility

Honeywell operated a refrigerant production facility in El Segundo, California, until spring 2004. Prior to 1992, Honeywell El Segundo produced refrigerants similar to those produced in Baton Rouge; antimony pentachloride was used as a catalyst in the process. In the early 1990s, the El Segundo facility was modified to make hydrochloroflourocarbons using a process that did not require antimony pentachloride catalyst. The catalyst was removed from reactors and placed in 1-ton cylinders. CSB could not determine the final disposition of these cylinders.

In 1997, Honeywell shut down all but one operating process at the California facility, though the plant continued to serve as a collection point for empty refrigerant cylinders. Eventually, all cylinders remaining onsite were removed. Refrigerant cylinders were shipped directly to Honeywell Baton Rouge. Antimony pentachloride cylinders were presumed empty and shipped to C&MI for cleaning and then to Honeywell Baton Rouge. The last operating process at El Segundo was shut down in 2002.

3.1.3 Antimony Pentachloride

Antimony pentachloride is commonly used as a catalyst for organic chemical reactions, as a chlorinating agent, and by the pharmaceutical industry. It is a colorless-to-reddish-yellow liquid with a pungent odor, and it is highly toxic. It also reacts violently with water or moisture to form highly corrosive hydrochloric acid and has a low vapor pressure at ambient conditions.

Antimony pentachloride is very harmful to humans, as noted by these reactions:

- Eye contact causes redness, pain, and burns with possible loss of vision.
- Ingestion burns the mouth, esophagus, and stomach and may damage the liver and kidneys.
- Inhalation may damage the liver and kidneys or nervous system.

3.1.4 Refrigerant Cylinder Operation

The Honeywell Baton Rouge site produces Genetron refrigerants packaged for sale in reusable 1-ton cylinders. Customers return the empty cylinders to Honeywell, and truckloads of cylinders arrive almost daily. On any given day, there may be 500 to 600 1-ton cylinders at the facility.

When a new shipment arrives, a Honeywell receiving department employee separates any cylinders that might belong to other refrigerant manufacturers, isolating them in a controlled area until they can be sent to the rightful owner.

Operators from the ton-cylinder area then take the Honeywell cylinders for sorting into two categories—"in test" and "out of test." Those categories are based on the fact that the 1-ton cylinders are pressure tested every 5 years in accordance with DOT regulations and stamped with the test date.[32] "In test" 1-ton cylinders are those whose test date has not expired, and they can be reused immediately. They are stripped of labels and sent to the staging area. "Out of test" 1-ton cylinders are those with expired test dates. They are placed in a storage area until operators can prepare them for testing at offsite facilities.

This preparation is normally done once a week. The process follows these basic steps:

- Cylinders are placed on a rack, which holds 10, 1-ton cylinders (Figure 12).

[32] DOT (49CFR173.34) requires that all cylinders used to hold compressed gases be pressured tested every 5 years to determine if they are fit for service.

Figure 12. 1-ton refrigerant cylinder prep rack.

- Hoses are connected to valves on the ends of the cylinders, which are opened to empty residual material to a vent pipe permitted by LADEQ.[33] The setup can be seen in Figure 13 (section 3.2).
- Cylinders are flushed with nitrogen to remove residual refrigerant.
- Cylinders are verified empty and depressurized using a common pressure gauge on the vent line.
- All plugs and valves on the cylinder are removed and replaced with plastic plugs.
- Upon completion of this process, the cylinders are ready to be sent offsite for testing.

3.2 Incident Description

On the morning of July 29, 2003, a ton-cylinder operator began to prepare “out of test” 1-ton refrigerant cylinders for offsite testing. At approximately 1:30 pm that afternoon, employees saw a large cloud in the ton-cylinder area, and one employee sounded the plant alarm. Employees then saw the ton-cylinder operator emerge from the cloud. They assisted him into an emergency shower for decontamination, and

[33] Honeywell written procedures specify that G-22 (also known as R-22), a specific Genetron refrigerant produced at the Baton Rouge facility, should not be vented at this stack.

he was subsequently transported to East Baton Rouge General Hospital. The operator died from his exposure at 9:45 am the next morning.

Ten 1-ton cylinders labeled “refrigerant gas” were found on the ton-cylinder rack. Nine of the 10 cylinders were connected to the vent system and properly drained/cleared of residual refrigerant. The 10th cylinder—which had serial number 83-3410 (and was painted white and green as opposed to the standard gray for antimony pentachloride)—was not hooked up to the vent system (Figure 13); and a plug at the five o’clock position had been removed from the end of the cylinder.

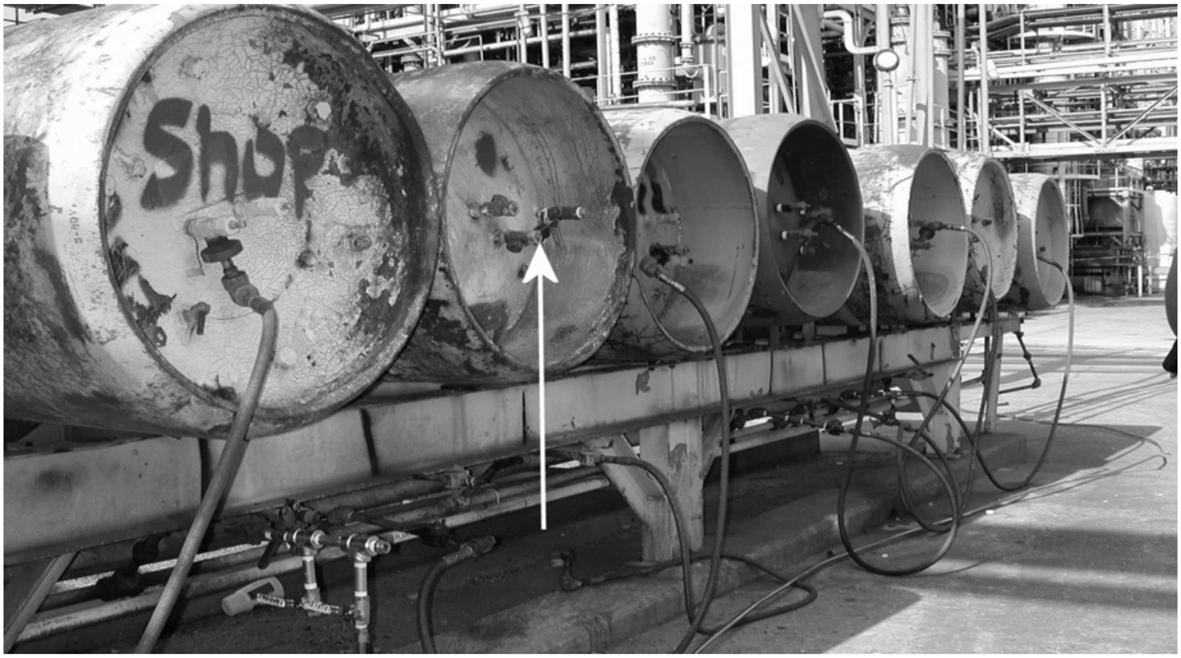

Figure 13. Incident cylinder (83-3410), which is not connected to vent system.

This cylinder was identified by a "Chlorodifluoromethane R-22" stencil (Figure 14). Further examination of cylinder 83-3410 revealed that the valves would not open due to buildup of corrosion products.

Figure 14. Stencil on cylinder 83-3410.

Witnesses stated that just before they saw the cloud, they observed the ton-cylinder operator approaching the rack from the rear, carrying an impact wrench. Presumably, he removed a plug from cylinder 83-3410 and was sprayed with its contents.

Honeywell employees interviewed by CSB stated that they immediately recognized the odor of antimony pentachloride. The cloud filled the area around the cylinder rack and was visible from offsite. Neighbors directly to the southeast of the facility noticed a strong odor. Shortly after seeing the cloud, plant personnel activated the nearby water deluge towers to knock it down. Plant employees were evacuated, and the plant emergency response team, dressed in appropriate personal protective equipment (PPE), entered the area to plug the cylinder.

Table 4 shows the timeline for the July 29 incident.

Table 4

July 29 Incident Timeline

Time	Activity
Morning	Operator assigned to prepare 1-ton cylinders for testing.
7:00 am–noon	Operator picks up 10 1-ton cylinders from “out of test” pile, presumably containing only empty refrigerant gas cylinders, and places them on rack; operator begins to prepare cylinders.
noon–1:30 pm	Operator sent to assist others loading a truck.
1:30 pm	Operator resumes preparation of 1-ton cylinders.
	Contractors notice operator with impact wrench walking toward cylinder rack.
	Cloud visible around cylinders; plant alarm activated.
1:35 pm	Injured worker removed from area; plant emergency response team makes initial entry into incident area.
1:57 pm	All clear sounded at plant.
2:00 pm	Injured worker transported to hospital.

3.3 Reconstructive Analysis

3.3.1 Cylinder Contents Analysis

The Louisiana State Police and EPA sampled cylinder 83-3410. The sample was then split for analysis by both EPA and Honeywell.

EPA analyzed the sample for antimony and chlorides, and confirmed that the material was predominantly antimony pentachloride. Honeywell's laboratory test concluded that the material was contaminated antimony pentachloride.

The cylinder contents were under considerable pressure at the time of the incident. Based on interviews with technical personnel at C&MI, CSB learned that such pressure buildup is not typical for spent antimony pentachloride cylinders. This suggests that the material in cylinder 83-3410 may have been different from the typical spent antimony pentachloride received at C&MI.

In the refrigerant process, hydrogen fluoride and a chlorohydrocarbon react in the presence of the antimony pentachloride catalyst. CSB was informed that C&MI normally advises customers to ensure the HF reaction is complete prior to loading the contaminated antimony pentachloride.[34] C&MI also reported to CSB that contaminated antimony pentachloride containing chlorohydrocarbon and hydrogen fluoride can continue to react at a very slow rate to form refrigerant, which would build pressure in the cylinder.[35]

Because only residue of the material in cylinder 83-3410 was analyzed, CSB could not conclusively determine if the material was similar to the spent antimony pentachloride typically shipped to C&MI. Therefore, it is possible that a failure to fully react hydrogen fluoride before loading the cylinder resulted in a difference between its contents and the spent antimony pentachloride normally received at C&MI.

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[34] C&MI informed CSB that it provides its customers with a checklist to ensure that the refrigerant reaction is complete prior to loading antimony pentachloride cylinders.

[35] The amount of fluorine found in the cylinder sample was higher than the C&MI normal specification.

Based on evidence described above, witness statements, and the victim's injuries,[36] CSB determined that cylinder 83-3410 likely contained antimony pentachloride contaminated with other unknown substances.

3.3.2 1-Ton Cylinder Mislabeling

CSB examined shipping records and determined that cylinder 83-3410 was shipped from the Honeywell El Segundo facility to C&MI. From C&MI, it was returned to Honeywell's Baton Rouge facility. Table 5 shows the tracking data.

Table 5

Cylinder 83-3410 Shipment Tracking

Shipment Date	Shipped From	Shipped To	Cylinder Labeling
October 23, 1998	Honeywell El Segundo	C&MI Denver	"ANTIMONY PENTACHLORIDE RESIDUE"
December 10, 1998	C&MI Denver	Honeywell Baton Rouge	"R22, CHLORODIFLUOROMETHANE"

The CSB investigation revealed the following sequence of events (Figure 15):

- ***October 23, 1998***: Eleven 1-ton cylinders, including 83-3410, labeled as antimony pentachloride residue[37] are shipped from Honeywell (which was AlliedSignal at the time) El Segundo to C&MI.
  - Upon arrival at C&MI, the cylinders are weighed and sampled per normal C&MI practice.

[36] The victim's injuries, as recorded in the medical examiners report, were consistent with antimony pentachloride exposure.

[37] Residue is the small amount of material remaining after a cylinder has been emptied.

   - Four cylinders, including 83-3410, are found to contain significant amounts of material rather than just residue.

   - The contents of cylinder 83-3410 are weighed at 3,228 pounds (net weight).

- ***October 27, 1998***: C&MI log sheets show that cylinder 83-3410 is sampled and the sample taken to the laboratory for analysis. The sample contains "a tar-like solid with only a small amount of liquid."

   - Based on those witnesses interviewed by CSB and their recollection of general practice, C&MI would have contacted Honeywell to inquire about disposition of the four cylinders that do not exhibit the expected characteristics of spent antimony pentachloride residue. The CSB was unable to find records or direct witness recollection of this call or information that was exchanged during this call. Subsequently, C&MI relabels the cylinder 83-3410 as refrigerant. (Four cylinders of refrigerant had been sent mistakenly to C&MI from El Segundo in the 2 years prior to this incident.)

- ***December 10, 1998***: C&MI ships the four cylinders that were part of the Oct. 27, 1998 shipment, labeled as refrigerant (including 83-3410), to Honeywell Baton Rouge—along with eight full cylinders of regenerated antimony pentachloride.

Following the July 29, 2003, incident, two of the three other cylinders shipped with 83-3410 in December 1998 were analyzed by Honeywell and confirmed to contain refrigerant. The third cylinder had already been emptied.

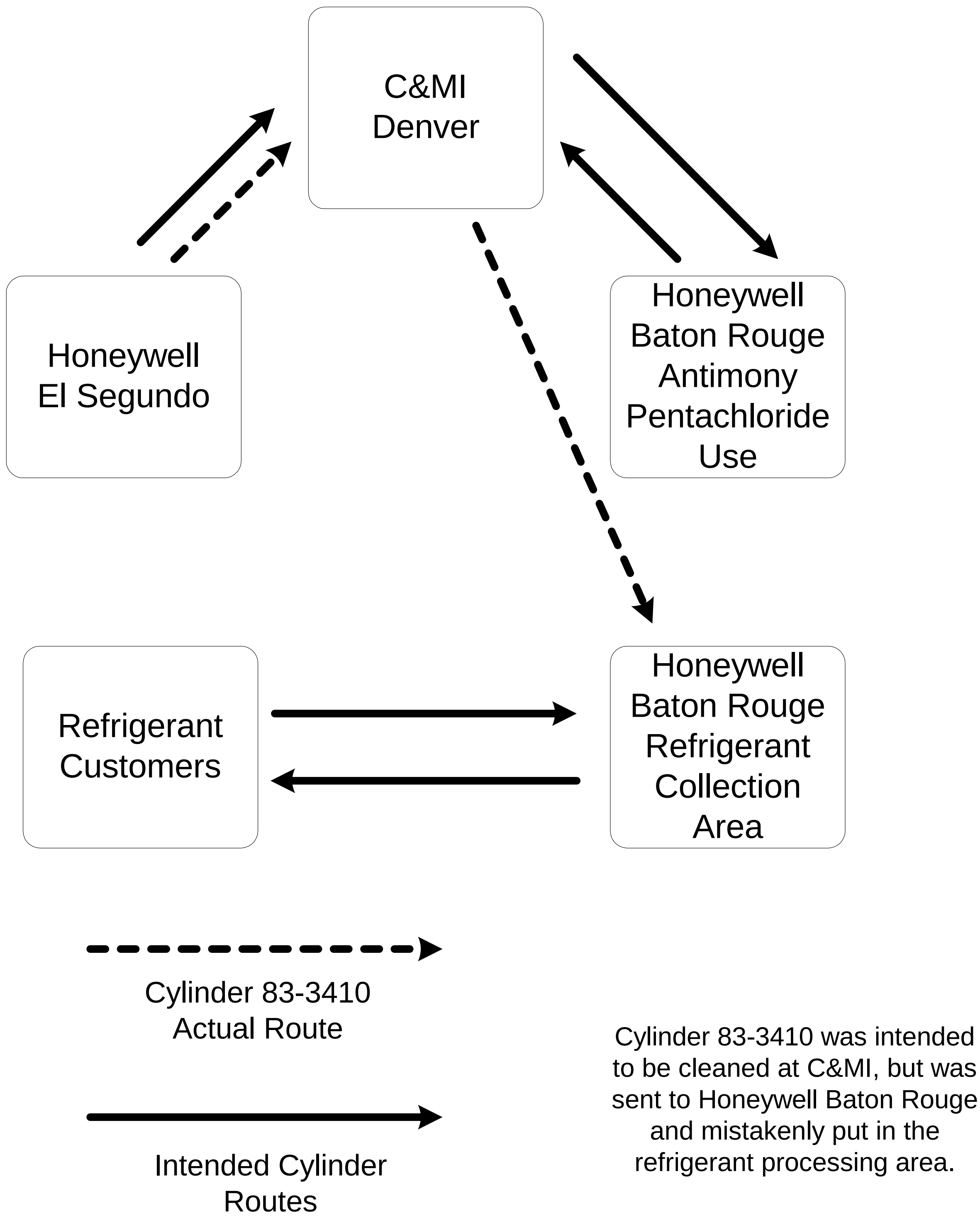

Figure 15. Intended and actual routes.

3.4 Incident Analysis

3.4.1 Refrigerants vs. Contaminated Antimony Pentachloride

To understand the relative importance of mislabeling and work practices in this incident, CSB examined the differences between the hazards of antimony pentachloride and refrigerants.

CSB reviewed material safety data sheets (MSDSs) for R-22 and antimony pentachloride and spoke with industry personnel familiar with refrigerant properties. CSB concluded that if the cylinder had actually contained R-22 refrigerant instead of contaminated antimony pentachloride, the consequences likely would have been less severe.

If the operator had attempted to open the plug on a cylinder full of R-22 refrigerant, it might have come out forcibly due to pressure in the cylinder. The refrigerant might have escaped and turned into a gas when exposed to normal ambient conditions. However, exposure to R-22, while it can cause frostbite, likely would not have caused fatal injuries.

3.4.2 Hazard Analysis

No hazard analysis was conducted for the refrigerant ton-cylinder area.[38] A simple hazard analysis, such as a job safety analysis (National Safety Council, 1988),[39] could have been used to identify the major hazards of this job. Relevant questions might have included:

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[38] A PPE assessment was done.

[39] A job safety analysis is a procedure used to review job methods and uncover hazards that: (1) may have been overlooked in the layout of the plant or building, and in the design of the machinery, equipment, tools, workstations, and processes; (2) may have developed after production started; or (3) resulted in changes in work procedures or personnel.

- What other materials are stored onsite in 1-ton cylinders?
- What consequences would result from inadvertently bringing other materials to the refrigerant ton-cylinder area?
- What consequences would result from emptying a full cylinder at the ton-cylinder area?
- What consequences would result from removing a plug from a cylinder before that cylinder is emptied and purged?

If Honeywell had conducted a job safety or hazard analysis, the company could have identified the hazards associated with the questions above and developed specific safeguards to be included in standard operating procedures and operator training.

3.4.3 Standard Operating Procedures

Honeywell Baton Rouge had written procedures for sorting 1-ton refrigerant cylinders according to test date and for preparing "out of test" cylinders for offsite testing. These procedures did not provide personnel with information to aid in identifying nonroutine situations. Nor did they list the consequences of common deviations. Additionally, CSB found that normal practice in the receiving and 1-ton-cylinder areas did not always follow the written procedures that did exist.

Although the facility sometimes received full or partially full refrigerant cylinders, the majority of the cylinders were empty. Facility procedures were based on handling those empty cylinders. For example, personnel were not required to verify cylinder weight.

There was no guidance for identifying abnormal cylinders—in this case a cylinder marked "refrigerant cylinder" arriving from a facility that handles only antimony pentachloride. Additionally, no one noted that antimony pentachloride is heavier than refrigerant; the weight of cylinder 83-3410—recorded on the shipping papers—exceeded the weight of a full refrigerant cylinder.

Honeywell's operating procedures for preparing 1-ton cylinders for testing contain a safety caveat in the "General Information" section that says: "If any abnormal conditions occur (for whatever reason), take the necessary steps to protect yourself and others, the environment, and the equipment (in that order), and then notify your supervisor." Although this is an appropriate warning, it is general in nature and does not give examples of common deviations.

The operating procedures also do not indicate what steps to take if the valves on a cylinder are inoperable, as was the case in this incident. Likewise, they do not caution against removing plugs from a cylinder that has not been verified as empty of material and pressure.

Written procedures require that refrigerant R-22 be recovered in a designated area and not released to the vent pipe. Although cylinder 83-3410 was labeled R-22, it was taken to the ton-cylinder area where its contents would have been released to the vent pipe. CSB found this to be common practice at the facility; the initial separation of arriving refrigerant cylinders was based only on test dates.

In conclusion, shipping papers for arriving cylinders were not reviewed for weights. Written procedures did not explain likely abnormal or nonroutine situations, detail specifically how to handle these situations, or list consequences of common deviations. In addition, normal practice in the receiving and ton-cylinder operations area did not directly follow written procedures.

3.4.4 Experience/Training

The operator involved in this incident started work at the Honeywell Baton Rouge facility in June 1999. From training records, CSB determined he received close to 200 hours of formal classroom instruction, including written testing to verify that he understood the material.

The operator started training for the ton-cylinder operator job on June 28, 2003. During the first week of training, he worked with an already qualified operator,[40] watching and assisting in routine activities of the job. During the second week, he performed the job under the qualified operator's supervision and by the end of that week, he was qualified to work on his own. During those 2 weeks, the two operators did not encounter or discuss cylinders with inoperable valves.

Because the operator working on the day of the incident had not worked with antimony pentachloride cylinders, he likely did not know the difference between these cylinders and refrigerant cylinders. Other operators interviewed by CSB stated they might have noticed certain differences between cylinder 83-3410 and typical refrigerant cylinders. For example, refrigerant cylinders are fitted with at least one pressure relief valve, while antimony pentachloride cylinders, including cylinder 83-3410, are fitted only with fusible plugs.

Neither the operator's training nor the standard operating procedures provided the ton-cylinder operator with specific guidelines for recognizing a nonroutine situation such as the one that occurred on July 29.

3.5 Regulatory Analysis

3.5.1 U.S. Department of Transportation

DOT regulates hazardous materials shipping, including both antimony pentachloride and refrigerant R-22. DOT's regulations (49 CFR) require shippers to properly classify and describe materials. These classifications and descriptions are important because they provide information necessary for safe handling. Though DOT regulation is designed to protect those who encounter materials during shipping; personnel at final receiving locations rely upon the same labels for identification and handling information.

[40] The area supervisor qualifies operators. The supervisor also selects the qualified operator that assists in training new operators.

The DOT hazardous materials regulations allow unidentified material to be shipped for testing. In current DOT regulations, this material must be labeled to reflect its testing status, and the sample cannot weigh more than 5.5 pounds. In 1998, when this cylinder (83-3410) was shipped, DOT regulations did not explicitly require special labeling or restrict sample weight. Still, a letter of interpretation from DOT clearly states that its shipping provision was intended for shipping sample size quantities to laboratories for identification purposes only (USDOT 1995).

C&MI's informal practice for handling material that does not meet specifications was to return the material to the customer. Where the material received in a cylinder was not consistent with labeling, C&MI informed CSB that its general practice would have been to discuss proper reclassification and return the shipment.

CSB's investigation was unable to uncover any documentation or direct witness recollection concerning knowledge of the cylinder involved in this incident or any call or knowledge of information exchanged between C&MI and Honeywell. For a reason not directly uncovered by CSB, cylinder 83-3410 was relabeled "R-22 chlorodifluoromethane" and shipped to Honeywell Baton Rouge. The relabeling occurred despite the fact that the weight of the cylinder exceeded that of a full refrigerant cylinder, and despite abnormalities, such as the tar-like substance present in the sample.[41]

Companies such as C&MI assume certain regulatory responsibilities as DOT shippers when they label and ship material—even when returning material identified by the customer. If C&MI had formal procedures for handling nonconforming materials that included a review of material properties, it may have realized that more information was needed before relabeling cylinder 83-3410.

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[41] C&MI does not handle refrigerants and would not be familiar with how much a refrigerant cylinder should weigh.

3.5.2 Occupational Safety and Health Administration

The OSHA PSM Standard did not cover the refrigerant ton-cylinder area. The standard does not list either the refrigerants or antimony pentachloride.

OSHA expanded its inspection of the July 20 chlorine release to include areas involved in the July 29 contaminated antimony pentachloride incident. OSHA then issued a citation for violation of the Hazard Communication Standard (29 CFR 1910.1200), citing Honeywell for failure to provide adequate training on procedures, including work practices, to protect employees from exposure to hazardous chemicals.

3.6 Key Findings

1. Cylinder 83-3410 was shipped from Honeywell in El Segundo, California, to C&MI in Denver, Colorado as an empty antimony pentachloride cylinder, though its contents actually weighed 3,228 pounds (with the weight of the cylinder, gross weight was 4,328 pounds).
2. Cylinder 83-3410 was rejected by C&MI. It was labeled and shipped to Baton Rouge, Louisiana, as R-22, refrigerant gas, without positive identification of the contents.
3. Paperwork for shipping cylinder 83-3410 (marked as R-22) to Baton Rouge showed the cylinder's actual gross weight as 4,328 pounds. However, the gross weight of a full R-22 cylinder would be only approximately 3,000 pounds.
4. Cylinders arriving at Honeywell Baton Rouge were not weighed, and the weight on the shipping document was not checked.
5. Cylinder 83-3410—though full of material—was placed in the empty refrigerant cylinder storage area at the Honeywell Baton Rouge facility.
6. Honeywell procedures specified that R-22 cylinders should not be sent to the vent pipe at the ton-cylinder recovery area.
7. No hazard analysis[42] was completed to identify potential hazards in the ton-cylinder area.

[42] A PPE assessment was completed for the area.

3.7 Root Causes

3.7.1 Root Causes

1. **Honeywell had no program to identify and address potential hazards in the ton-cylinder area.**

   No hazard analysis was completed to identify potential hazards in the ton-cylinder area. Procedures and training did not adequately prepare the ton-cylinder operator so that he could recognize the hazards of the operation. Specifically, neither procedures nor training identified the consequences of:

   - Removing a plug from the rear of the cylinder without prior venting.
   - Placement of 1-ton cylinders containing material other than specified refrigerants.
   - Attempting to vent a full cylinder.

2. **Honeywell and C&MI have no systematic processes for positively verifying the contents of cylinders rejected by C&MI.**

   Honeywell shipped 1-ton cylinders of antimony pentachloride to C&MI. Upon receipt, C&MI sampled the containers to verify contents. If sampling showed material other than antimony pentachloride, C&MI's general practice was to seek further instruction from Honeywell. On several occasions, C&MI returned cylinders to Honeywell labeled as refrigerant without positive identification of the material. The cylinder involved in the July 29 incident was labeled and shipped as refrigerant even though there was no positive verification of its contents.

3. **The Honeywell systems for segregating and storing 1-ton cylinders did not include procedures for identifying and handling abnormal cylinders.**

   Cylinder 83-3410—a mislabeled cylinder containing contaminated antimony pentachloride catalyst—was placed in an area of the Baton Rouge plant reserved for empty refrigerant cylinders. Honeywell systems and procedures for receiving ton cylinders were not adequate to prevent this from happening. There were no procedures to identify filled or abnormal cylinders.

4. **Day-to-day operator practices and operator training did not conform to the standard operating procedures for handling R-22 cylinders.**

Cylinder 83-3410 was labeled as “R-22 chlorodifluoromethane.” Honeywell procedures specified that R-22 cylinders should not be sent to the vent pipe at the ton-cylinder area. However, through employee interviews, CSB determined that operators did not follow this procedure. If work practices in this area had followed written procedures, cylinder 83-3410 would not have been brought to the ton-cylinder area.

3.8 Recommendations[43]

Honeywell Baton Rouge Facility

1. Conduct a hazard analysis (such as a job safety analysis) in the ton-cylinder area, incorporate appropriate findings into unit operating procedures, and train personnel accordingly. (2003-13-I-LA-R8)

2. Revise plant procedures on receiving cylinders to require that weights be recorded on incoming materials and suspicious materials be isolated so that cylinders containing hazardous material are handled appropriately. (2003-13-I-LA-R9)

Honeywell International, Inc.

Develop and implement procedures for positively identifying material rejected by contractors such as C&MI so that hazardous materials are handled appropriately. (2003-13-I-LA-R15)

Chemical and Metal Industries (C&MI)

Develop formal procedures for disposition of nonconforming materials received from customers. Ensure that procedures include positive identification prior to shipment. (2003-13-I-LA-R27)

[43] Section 6.0 lists all recommendations from the CSB investigations of the July 20, July 29, and August 13 incidents.

4.0 August 13 HF Release

Following the July 20 and 29 incidents at the Baton Rouge facility, the president of the Honeywell Specialty Materials group ordered a review of all facility operations prior to restarting operations. While Honeywell was investigating the two incidents and reviewing overall plant safety systems, plant activities were limited to maintenance and inspection.

During the July 20 chlorine release, the plant's G-22 unit was rapidly shut down using emergency procedures. Some equipment, such as an HF vaporizer, was left in an abnormal shutdown state (i.e., it contained liquid hydrogen fluoride). For the next few weeks, operations personnel started returning equipment to normal conditions. On August 12, operators began using a venturi stick[44] to remove liquid hydrogen fluoride from a vaporizer in the G-22 process. This activity resulted in an HF release on August 13 that injured one employee and exposed one operator.

4.1 Background

4.1.1 Hydrogen Fluoride

Hydrogen fluoride—a colorless liquid that boils at 67 degrees Fahrenheit[45]—is very hazardous to humans. Among its health effects are the following:

- Skin contact can result in serious burns, tissue destruction, and death. HF burns are typically very painful and slow to heal.
- Large HF burns may cause a depletion of calcium in the body and other toxic effects, which may be fatal (Honeywell's MSDS).

[44] A venturi stick uses the same principle of operation (eduction) as the spray application of fertilizer, which utilizes a garden hose and an attached bottle containing fertilizer.

[45] Pure 100 percent hydrogen fluoride does not contain water. When water is added, hydrogen fluoride becomes hydrofluoric acid, with concentration expressed as a percent of hydrogen fluoride present.

- Delayed reactions may not be apparent for hours after the initial exposure and may be as serious as fatal pulmonary edema (flooding of the lungs with fluid).

OSHA has established a permissible exposure limit of 3 ppm averaged over an 8-hour work shift. The National Institute for Occupational Safety and Health (NIOSH) has set 30 ppm as the level that hydrogen fluoride is immediately dangerous to life and health.

4.1.2 Hydrogen Fluoride Use

Hydrogen fluoride has numerous uses including:

- Manufacturing pesticides, plastics, refrigerants, and high-octane fuels.
- Etching and polishing glass.
- Cleaning stone and marble.

At the Honeywell Baton Rouge facility, hydrogen fluoride is used to manufacture G-22[46] refrigerant. Liquid hydrogen fluoride is fed from one of two storage vessels and heated to a gaseous state in a vaporizer. In a connected reactor system, the gaseous hydrogen fluoride reacts with chloroform in the presence of antimony pentachloride catalyst to form G-22 refrigerant.

Under normal procedures, the vaporizer is emptied of liquid prior to initiating a shutdown, and only gaseous hydrogen fluoride remains inside. If it is necessary to open the vaporizer for maintenance, an evacuation system is used to remove the remaining HF gas. However, the evacuation system is not designed to remove liquid hydrogen fluoride.

[46] G-22 is Chlorodifluoromethane. Numbering of refrigerants (e.g., 22) is defined in ASHRAE 34-2004, Designation and Safety Classification of Refrigerants.

A new system for emptying vaporizers full of liquid hydrogen fluoride was installed in May 2003. This system was used for the first time following the July 20 shutdown. However, it did not function properly, and its operation was stopped prior to the August 13 incident.

4.1.3 Venturi Stick Operation

Because the new liquid HF draining system could not be used, a venturi stick procedure was used to evacuate the liquid from the G-22 vaporizer. The plant had a general written procedure for using venturi sticks to evacuate various liquids—but no specific procedure for removing liquid hydrogen fluoride from process equipment.

A venturi stick uses the same principle of operation as the spray application of fertilizer with a garden hose and attachment. In the Honeywell procedure, water flowing through a 1-inch pipe (venturi stick) creates a slight vacuum in attached tubing (Figure 16). The liquid (in this case, hydrogen fluoride) being

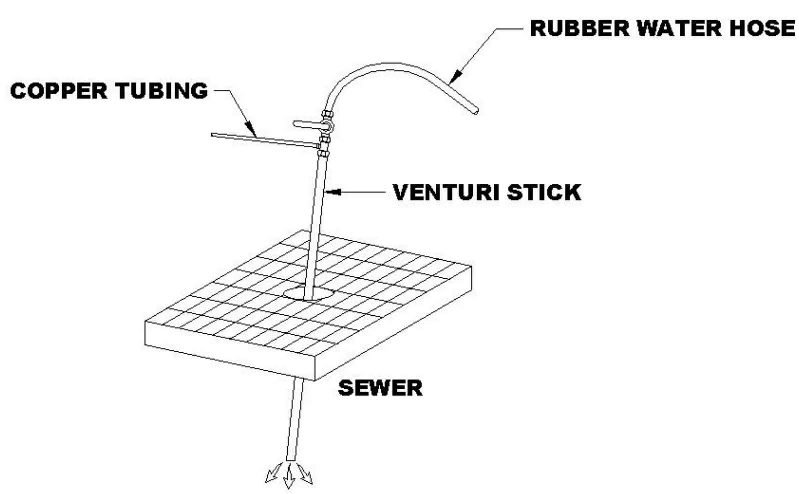

Figure 16. Venturi stick.

evacuated mixes with water and is discharged to the plant sewer. The plant also uses nitrogen to help push the liquid hydrogen fluoride out; however, the procedure does not specify how to secure the venturi stick or to select the appropriate nitrogen pressure to apply to the system.

4.2 Incident Description

On August 12, the operations department set up a venturi stick to empty the G-22 HF vaporizer. Personnel fed plant nitrogen—with a 200-pound-per-square-inch gage (psig) supply pressure—to the equipment upstream of the vaporizer. They attached a venturi stick with copper tubing to the vaporizer, inserted it into the plant sewer, and attached a water hose to the end of the stick to draw the liquid hydrogen fluoride to the sewer (Figure 17). The venturi stick was tied off with a rope.

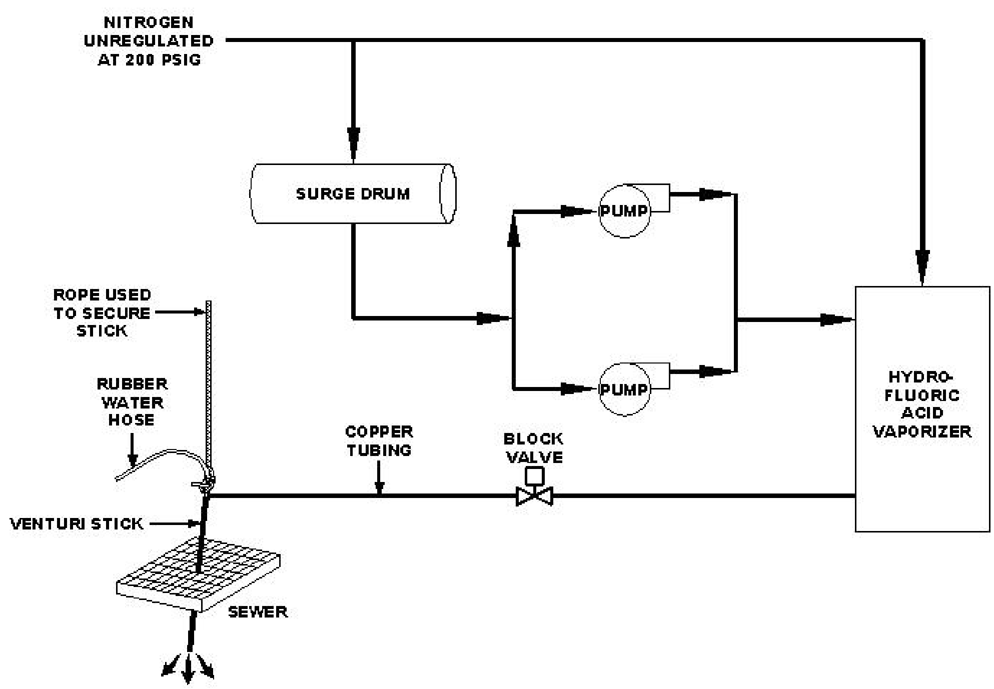

Figure 17. Simplified diagram of the setup to remove liquid hydrogen fluoride utilizing a venturi stick.

Once the system was in place, operations personnel began to empty the liquid hydrogen fluoride from the vaporizer. This draining operation continued into the next day, August 13. At approximately 9 am on that day, an operator monitoring the venturi process checked on its progress. The operator suspected a problem with nitrogen flow to the vaporizer, and opened and closed some valves to create a surge in the system and clear any blockage. Flow to the sewer rapidly increased, causing the venturi stick to lift out of the sewer—which created a cloud that likely contained hydrogen fluoride.

The operator instructed a nearby contractor to leave the area and then stopped the flow to the sewer by closing a valve at the vaporizer. Noticing a red mark on his arm, he immediately got under a nearby safety shower and remained there until assistance arrived.

A maintenance supervisor walking through the area aided the operator in moving to first aid. After a brief period, the maintenance supervisor experienced a coughing spell and suggested to the facility nurse that he may have been exposed to HF vapors.

Baton Rouge Emergency Medical Services transported the operator and maintenance supervisor to the hospital. The operator was treated and released; the maintenance supervisor was held in the hospital overnight for observation and released the next day.

4.3 Incident Analysis

4.3.1 Nonroutine Job Planning

Following the July 20 incident, Honeywell was faced with a nonroutine situation in the G-22 unit. The vaporizer was full of liquid hydrogen fluoride and needed to be emptied. The new system for removing liquid hydrogen fluoride from a vaporizer was used for the first time. When the system did not function properly, Honeywell decided to use a venturi stick procedure. However, the plant had only a generic venturi stick procedure and not one specifically for draining liquid hydrogen fluoride. Consequently, Honeywell personnel reviewed the generic venturi stick procedure, and added specific references for hydrogen fluoride prior to starting the work. Those references only addressed PPE and sewer monitoring when draining hydrogen fluoride. They did not contain specific instructions for setting up the venturi stick in a manner that would ensure that hazards are identified and controlled.

Abnormal or nonroutine operations fall outside normal operating procedures (CCPS, 1995). Such operations should be identified as nonroutine, and specific job planning and procedures should be developed to address them. Honeywell did not identify draining hydrogen fluoride from the vaporizer with a venturi stick as nonroutine. Operations personnel should have treated emptying the vaporizer with a venturi stick as a nonroutine job and planned appropriately. Such planning likely would have addressed proper PPE, specific procedures that needed to be followed, review of the system setup, and identification of possible deviations and their consequences.

4.3.2 Hazard Analysis

Although Honeywell conducted a HAZOP study on the G-22 process, it did not consider the consequences of an emergency shutdown. Furthermore, a hazard analysis conducted on the new HF draining system did not thoroughly consider possible deviations.

The normal procedure for shutting down the G-22 process was to empty the liquid hydrogen fluoride in the vaporizer into the reactor, leaving the vaporizer empty of liquid. During the July 20 chlorine release, the plant was shut down rapidly, so liquid was left in the vaporizer—a situation that was not identified in the hazard analysis.

Honeywell stated that when the new liquid HF draining system was used for the first time, the system did not function properly. The problems encountered with the new system were not specifically considered in Honeywell's hazard analysis. If deviations from expected conditions had been evaluated at that time, Honeywell might have identified solutions for some of the problems encountered in using the liquid HF draining system.

4.3.3 HF Handling Practices and Guidelines

CSB researched associated industry standards and guidance. Both the HFIPI and API publish guidelines for HF use.

4.3.3.1 API Recommended Practices

API standards are written for the petroleum industry. Recommended Practice 751, Safe Operation of Hydrofluoric Acid Alkylation Units (API, 1999), is specific to petroleum refineries rather than addressing general HF use. The API standard focuses on management systems, operating procedures, worker protection, materials of construction, maintenance, inventory control, transportation, and mitigation for safe handling of hydrogen fluoride in refinery operations.

4.3.3.2 HFIPI Guidelines

HFIPI, a subsidiary of ACC, is an association of HF producers and users. Its stated objectives are to develop industry handling guidelines, to share experiences, and to coordinate a semiannual safety seminar (www.hfipi.com). HFIPI guidelines are grouped into four areas—materials of construction, transportation, storage, and PPE. Honeywell is a member of HFIPI.

The HFIPI PPE Guidelines for Anhydrous Hydrogen Fluoride and Hydrofluoric Acid list recommended PPE for various jobs involving potential HF exposure. For work such as opening equipment before establishing that all hydrogen fluoride is emptied[47] (analogous to the situation at Honeywell), the standard recommends Level B PPE, which typically includes:

- Positive pressure, full-face-piece, self-contained breathing apparatus (SCBA) or positive pressure supplied-air respirator with NIOSH-approved escape SCBA.

- Hooded HF-resistant clothing, such as overalls and long-sleeved jacket, coveralls, or one- or two-piece splash suit.

[47] CSB interprets this requirement to be applicable to draining equipment in any open system.

- HF-resistant inner gloves.
- HF-resistant outer gloves.
- HF-resistant boots with steel toe and shank.

The operator injured on August 13 was not wearing the HFIPI-recommended PPE (Section 4.3.4).

There are no HFIPI guidelines on general handling practices for hydrogen fluoride, such as draining equipment and maintenance preparation.

4.3.3.3 Industry Best Practices

Through interviews and document requests, CSB determined that Honeywell has no current corporate guidelines for handling hydrogen fluoride.[48] AlliedSignal developed a manual of HF best practices in 1994. Although these practices may have been incorporated into various plant operating procedures at that time, Honeywell has not updated or maintained the best practices manual. CSB visited a Honeywell facility that manufactures hydrogen fluoride and confirmed that HF practices are not standardized throughout the company.

[48] Honeywell does have corporate guidelines for HF medical treatment and materials of construction.

During the investigation, CSB met with another HF manufacturer to discuss best practices. This company has a comprehensive HF safety program and corporate standards that prohibit draining hydrogen fluoride to an open system. It also had a formal system for job planning for nonroutine operations.

Based on review of HF standards and guidance, CSB concluded that HF users could benefit from additional guidance on handling practices, particularly in establishing best practices for draining equipment.

4.3.4 Use of PPE

Exposure to hydrogen fluoride may have severe consequences. Although PPE is generally considered the final layer of defense, such equipment can minimize consequences of exposure to hazardous chemicals, including hydrogen fluoride. The type of PPE chosen should reflect potential exposure at the specific time and location of task performance.

The Baton Rouge facility's PPE matrix lists the following PPE for working with hydrogen fluoride:

- Hardhat
- Safety glasses with side shields
- Rubber steel-toe boots
- Acid suit—jacket, pants, cuffs, and gloves
- Air-supplied acid hood or full-face respirator

The matrix does not specify conditions under which these PPE requirements can be lowered. PPE levels were often downgraded when operators no longer anticipated potential contact with hydrogen fluoride. If the PPE Matrix had specified equipment more in line with HFIPI guidelines, the operator may have been less likely to downgrade the PPE level.

CSB interviews revealed that, at the time of the August 13 release, the operator was wearing a hardhat, safety glasses, work boots, and gloves. The possibility of exposure was present in this case because hydrogen fluoride was being drained through the venturi stick to an open sewer. If the operator had been wearing the level of PPE required by either the Honeywell PPE matrix or HFIPI guidelines, it is unlikely he would have been exposed.

Engineering controls minimize the chances of exposure. Administrative controls, such as PPE, minimize the consequences of exposure. If Honeywell had a functional permanent system for removing liquid hydrogen fluoride from the vaporizer, the risk of employee exposure would have been substantially lower, and there would have been less reliance on PPE—the final layer of protection.

4.4 Regulatory Analysis

Both the OSHA PSM Standard and the EPA RMP regulation list hydrogen fluoride as a covered chemical. Consequently, both standards cover the G-22 process. These standards require management systems that will prevent accidental releases, as described in Section 2.4. RMP also requires Honeywell to identify release scenarios for hydrogen fluoride, and these were included in the RMP plan Honeywell submitted to EPA.

Following the August 13 incident, OSHA issued a citation for violation of the safe work practices element contained in the operating procedures section of the PSM Standard.

4.5 Key Findings

1. A permanent system for removing liquid hydrogen fluoride from equipment after shutdown had recently been installed at the Baton Rouge facility. The system did not function properly, and an alternate method was used on August 12.

2. There were no formal procedures for identifying and planning nonroutine activities.

3. The G-22 PHA did not consider the consequences of leaving hydrogen fluoride in the vaporizer following an emergency shutdown.

4. HFIPI has construction, transportation, storage, and PPE guidelines for HF materials. Honeywell is a member of HFIPI.

5. There are no HFIPI guidelines on draining equipment and maintenance operations for hydrogen fluoride.

6. The operator exposed on August 13 was not wearing the PPE required by the plant matrix or recommended by HFIPI.

7. Honeywell has no current corporate guidelines for handling hydrogen fluoride.[49]

8. PPE levels were routinely downgraded by plant personnel after setting up a job.

4.6 Root and Contributing Causes

4.6.1 Root Causes

Honeywell had no procedures for identifying and planning for nonroutine job situations.

The procedure used to evacuate liquid hydrogen fluoride from the vaporizer was a general plant procedure for using a venturi stick. Given the highly hazardous nature of hydrogen fluoride, more specific procedures and job planning were necessary to ensure the operation was safe. A formal job evaluation might have considered:

- Appropriateness of using 200-psig nitrogen.

- Adequate means for securing the venturi stick.

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[49] Honeywell has corporate guidelines for HF medical treatment and materials of construction, but not for handling—which includes activities such as transferring.

- PPE requirements prior to emptying the vessel of hydrogen fluoride.

4.6.2 Contributing Cause

Beyond the initial job setup, it was not plant practice to wear standard HF PPE.

Honeywell Baton Rouge had a matrix that specified PPE requirements for hydrogen fluoride. Plant practice was to downgrade PPE levels after job setup. HFIPI guidelines specify that prescribed levels of PPE should be worn as long as potential exposure to hydrogen fluoride exists. The required PPE would have protected the operator from burn injuries.

4.7 Recommendations[50]

Honeywell Baton Rouge Facility

Revise the personal protective equipment matrix to include requirements for specific activities, such as draining HF equipment. Refer to the HFIPI guidelines as appropriate. (2003-13-I-LA-R10)

Honeywell International, Inc.

Develop and implement corporate standards for safely handling hydrogen fluoride. (2003-13-I-LA-R16)

Hydrogen Fluoride Industry Practices Institute (HFIPI)

1. Conduct a survey of members to determine best industry practices for HF handling activities, such as draining equipment, use of open systems, and nonroutine work. Develop best practices guidance as appropriate and communicate it to your members. (2003-13-I-LA-R25)

2. Communicate the findings and recommendations from the August 13 incident to your membership. (2003-13-I-LA-R26)

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[50] Section 6.0 lists all recommendations from the CSB investigations of the July 20, July 29, and August 13 incidents.

5.0 Three Incidents in Four Weeks

5.1 Management Systems

The three incidents discussed in this investigation report occurred at the same plant, but in different operating units and with different chemicals. Together, they occurred within a 4-week period. Conditions created a clear link between the July 20 chlorine release and the August 13 HF release—the earlier incident resulted in an emergency shutdown that led to the nonroutine condition of a vaporizer full of HF liquid. The July 29 contaminated antimony pentachloride exposure is not as clearly linked to the other two incidents.

CSB found common causes among the three incidents. The root cause analysis revealed deficiencies in several management systems including:

- ***Hazard analysis***: The hazard analyses completed for the G-143a, G-113 R-1, and G-22 units were not thorough. The hazard analysis method as applied did not ensure a review of all equipment, procedures, and likely scenarios. The safeguards listed were generic and, in many cases, relied too heavily on administrative procedures. Additionally, no hazard review of the procedure for preparing 1-ton cylinders was done, and no potential hazards and safeguards were included in the written procedures or training.

- ***Nonroutine situations***: Nonroutine situations were not always recognized and reviewed to ensure that work could proceed safely. For example, on previous occasions employees noticed chlorine odors in the positive pressure control room but did not recognize this as a nonroutine situation requiring investigation. The ton-cylinder operator working on July 29 did not recognize that the inoperable valves created a nonroutine condition needing additional review. The plant-wide shutdown on July 20 and inability to use the new HF draining system created an abnormal situation with the HF vaporizer. Operators used a generic procedure designed for evacuating liquids using a venturi stick, without recognizing that the highly hazardous nature of hydrogen fluoride required a more specific and detailed review of procedures.

- ***Written operating procedures***: CSB identified that employees did not strictly follow written operating procedures. For example:

  - Written procedures in the ton-cylinder area specified that the contents of R-22 cylinders should not be released to the vent pipe, which was standard practice at the ton-cylinder area. CSB also found that R-22 cylinders were not segregated from others, and therefore, they were commonly sent to the ton-cylinder area and vented.

  - The Baton Rouge plant had a matrix that specified what PPE should be worn when handling certain chemicals, including hydrogen fluoride. The matrix did not specify conditions for downgrading PPE levels. However, CSB found accepted practice at the plant was to downgrade PPE levels in situations such as the one that caused the August 13 incident.

5.2 Recommendations[51]

Honeywell Baton Rouge Facility

Develop and implement a program for the identification and management of hazards in nonroutine situations. Ensure that this program covers the following:

- Situations where employees are unable to follow standard operating procedures, such as purging equipment. (2003-13-I-LA-R11)

- Circumstances where there is no specific formal procedure for handling a highly hazardous chemical. (2003-13-I-LA-R12)

- Operations following an emergency shutdown. (2003-13-I-LA-R13)

Honeywell International, Inc.

1. In light of the findings of this investigation report, conduct a comprehensive audit of fluorine-based manufacturing facilities in your Specialty Materials group facilities. Ensure that the audit addresses:

    - Thoroughness of hazard analysis and adequacy of safeguards. (2003-13-I-LA-R17)
    - Recognition and management of nonroutine situations. (2003-13-I-LA-R18)
    - Adherence to standard operating procedures. (2003-13-I-LA-R19)

    Implement the recommendations from the audit and communicate the findings to the work force. (2003-13-I-LA-R20)

2. Communicate the findings and recommendations of this report to your employees at fluorine-based manufacturing facilities in your Specialty Materials group. (2003-13-I-LA-R21)

[51] Section 6.0 lists all recommendations from the CSB investigations of the July 20, July 29, and August 13 incidents.

6.0 Complete List of Recommendations

CSB developed recommendations based on the findings and conclusions of the CSB investigations following the July 20, July 29, and August 13 incidents. CSB makes its recommendations to parties that can effect change to prevent future incidents. Those parties typically include the facility where an incident has occurred; the parent company of that facility; trade organizations responsible for developing good practice guidelines; and organizations that have the ability to broadly communicate lessons learned, such as trade associations and labor unions. Recommendations are also made to entities responsible for regulations and oversight.

Honeywell Baton Rouge Facility

1. Revise inspection and testing procedures to include effective methods for detecting and preventing leaks in coolers that use chlorine. These procedures should include the use of appropriate NDT methods. (2003-13-I-LA-R1)

2. Analyze layers of protection installed to prevent possible consequences of failure of heat exchangers that use chlorine, and implement corrective actions as appropriate. Examples of additional measures include installing monitors on the coolant stream to detect the presence of chlorine, and determining the feasibility of operating the coolant stream at a pressure high enough to prevent the entry of chlorine in the event of a leak. (2003-13-I-LA-R2)

3. To address ongoing issues regarding layers of protection and leaks in heat exchangers, revise procedures for performing process hazard analyses for equipment that contains hazardous materials such as chlorine to, at a minimum:

    - Require an evaluation of the effects of leaks in heat exchangers. (2003-13-I-LA-R3)

- Consider the layers of protection necessary to prevent a catastrophic incident and require recommendations to be implemented when existing protection is inadequate. (2003-13-I-LA-R4)

4. Revise the incident investigation procedure to ensure that odors inside positive pressure control rooms are investigated, the causes identified, and the appropriate corrective actions implemented. Address causes of the releases as well as entry of the material into the building. (2003-13-I-LA-R5)

5. Survey units that handle chlorine, and evaluate the effectiveness of shutdown systems for detecting and preventing the release of chlorine. At a minimum, ensure that shutdown systems and procedures are integrated to stop all potential sources of chlorine. (2003-13-I-LA-R6)

6. Conduct training to emphasize that MOC evaluations must consider whether emergency shutdown procedures need to be changed when there are changes in material inventory. (2003-13-I-LA-R7)

7. Conduct a hazard analysis (such as a job safety analysis) in the ton-cylinder area, incorporate appropriate findings into unit operating procedures, and train personnel accordingly. (2003-13-I-LA-R8)

8. Revise plant procedures on receiving cylinders to require that weights be recorded on incoming materials and suspicious materials be isolated so that hazardous materials are handled appropriately. (2003-13-I-LA-R9)

9. Revise the personal protective equipment matrix to include requirements for specific activities, such as draining HF equipment. Refer to the HFIPI guidelines as appropriate. (2003-13-I-LA-R10)

10. Develop and implement a program for the identification and management of hazards in nonroutine situations. Ensure that this program covers the following:

    - Situations where employees are unable to follow standard operating procedures, such as properly purging equipment. (2003-13-I-LA-R11)

- Circumstances where there is no specific formal procedure for handling a highly hazardous chemical. (2003-13-I-LA-R12)

- Operations following an emergency shutdown. (2003-13-I-LA-R13)

Honeywell International, Inc.

1. Develop and implement corporate standards to ensure positive pressure control rooms, including the HVAC systems, are designed and maintained to prevent the short-term entry of hazardous materials. Implement corporate standard changes at the Baton Rouge facility, and other Honeywell facilities as appropriate. (2003-13-I-LA-R14)

2. Develop and implement procedures for positively identifying material rejected by contractors such as C&MI so that hazardous materials are handled appropriately. (2003-13-I-LA-R15)

3. Develop and implement corporate standards for safely handling hydrogen fluoride. (2003-13-I-LA-R16)

4. In light of the findings of this investigation report, conduct a comprehensive audit of fluorine-based manufacturing facilities in your Specialty Materials group facilities. Ensure that the audit addresses:

    - Thoroughness of hazard analysis and adequacy of safeguards. (2003-13-I-LA-R17)

    - Recognition and management of nonroutine situations. (2003-13-I-LA-R18)

    - Adherence to standard operating procedures. (2003-13-I-LA-R19)

    Implement the recommendations from the audit and communicate the findings to the work force. (2003-13-I-LA-R20)

5. Communicate the findings and recommendations of this report to your employees at fluorine-based manufacturing facilities in your Specialty Materials group. (2003-13-I-LA-R21)

American Society of Heating, Refrigeration, and Air Conditioning Engineers (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 materials. (2003-13-I-LA-R22)

Baton Rouge Fire Department

Evaluate and update as necessary community notification procedures to include timely notification of residents in the event of a chemical release. Conduct periodic refresher training with staff on the requirements in the procedures. (2003-13-I-LA-R23)

East Baton Rouge Parish Office of Homeland Security and Emergency Preparedness (OHSEP)

Conduct an awareness campaign to educate residents on the proper response during a chemical release. Include instructions on the way residents (including those outside the affected area) can obtain information during an emergency. (2003-13-I-LA-R24)

Hydrogen Fluoride Industry Practices Institute (HFIPI)

1. Conduct a survey of members to determine best industry practices for HF handling activities, such as draining equipment, use of open systems, and nonroutine work. Develop best practices guidance as appropriate and communicate it to your members. (2003-13-I-LA-R25)

2. Communicate the findings and recommendations from the August 13 incident to your membership. (2003-13-I-LA-R26)

Chemical and Metal Industries (C&MI)

Develop formal procedures for disposition of nonconforming materials received from customers. Ensure that procedures include positive identification prior to shipment. (2003-13-I-LA-R27)

6.1 Recommendations to Communicate the Findings from the Investigation

In an effort to widely distribute lessons learned from investigations, CSB recommends that organizations communicate relevant findings and recommendations to their memberships. CSB intends for those organizations to use multiple avenues to communicate, such as having presentations at conferences, placing summaries of reports and links to full CSB reports on their websites, developing and holding training sessions that highlight report findings, and summarizing relevant findings in newsletters or direct mailings to members. CSB encourages organizations to use all their existing methods of communication and explore new ways to more widely distribute these messages.

American Society for Nondestructive Testing (ASNT)

Communicate the findings and recommendations from the July 20 incident to your membership. Emphasize the need to evaluate test methods for appropriateness in the given equipment. (2003-13-I-LA-R28)

International Brotherhood of Teamsters Local #5

Work with Honeywell to communicate the findings and recommendations of this report to your members employed at the Honeywell Baton Rouge Facility. (2003-13-I-LA-R29)

By the

U.S. Chemical Safety and Hazard Investigation Board

Carolyn W. Merritt

Chair

Gary Lee Visscher

Member

March 2, 2005

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Appendix A: Corrosion Testing Laboratory, Inc., Report Investigation of Tube Failures in the E76HE Chlorine Cooler

The following excerpt details the Corrosion Testing Laboratory proposed scenario for failure of the tubes in the chlorine cooler. CSB makes no judgment on this scenario. Its inclusion in this report in no way implies endorsement by CSB.

> The evidence to date pointed to the following scenario that led to the failure of the tubes in the E76HE cooler:
>
> Tube 1-2 was damaged on the OD [outside diameter] when the inlet nozzle was replaced in September 2000; however, a hydrotest at that time did not indicate any leakage. This damage was caused by the arc welding process to enlarge the opening in the shell to permit the installation of the welded longneck forged flange drain. The damage resulted in significant wall loss of the tube.
>
> During the course of normal operation, deposits, including small additions of solids from the brine makeup, built up in the stagnant bottom area of the vertical cooler. These deposits were quite tenacious to the tube wall.
>
> After a matter of years, the natural corrosivity of the brine thinned the metal in the damaged area, resulting in a small through-wall hole in Tube 1-2, and permitted the escape of a relatively small amount of chlorine into the brine.
>
> Chlorine-induced chemical attack commenced, causing an enlargement of the initial through-wall penetration.
>
> Chlorine-induced erosion-chemical attack of the first baffle, and Tubes 3-1 and Tubes 4-1 ensued.
>
> The chemical attack of Tubes 3-1 and Tubes 4-1 resulted in relatively large holes and a significantly large leak of chlorine into the brine.

The chlorine chemically attacked the pump seals, and a chlorine release event occurred.

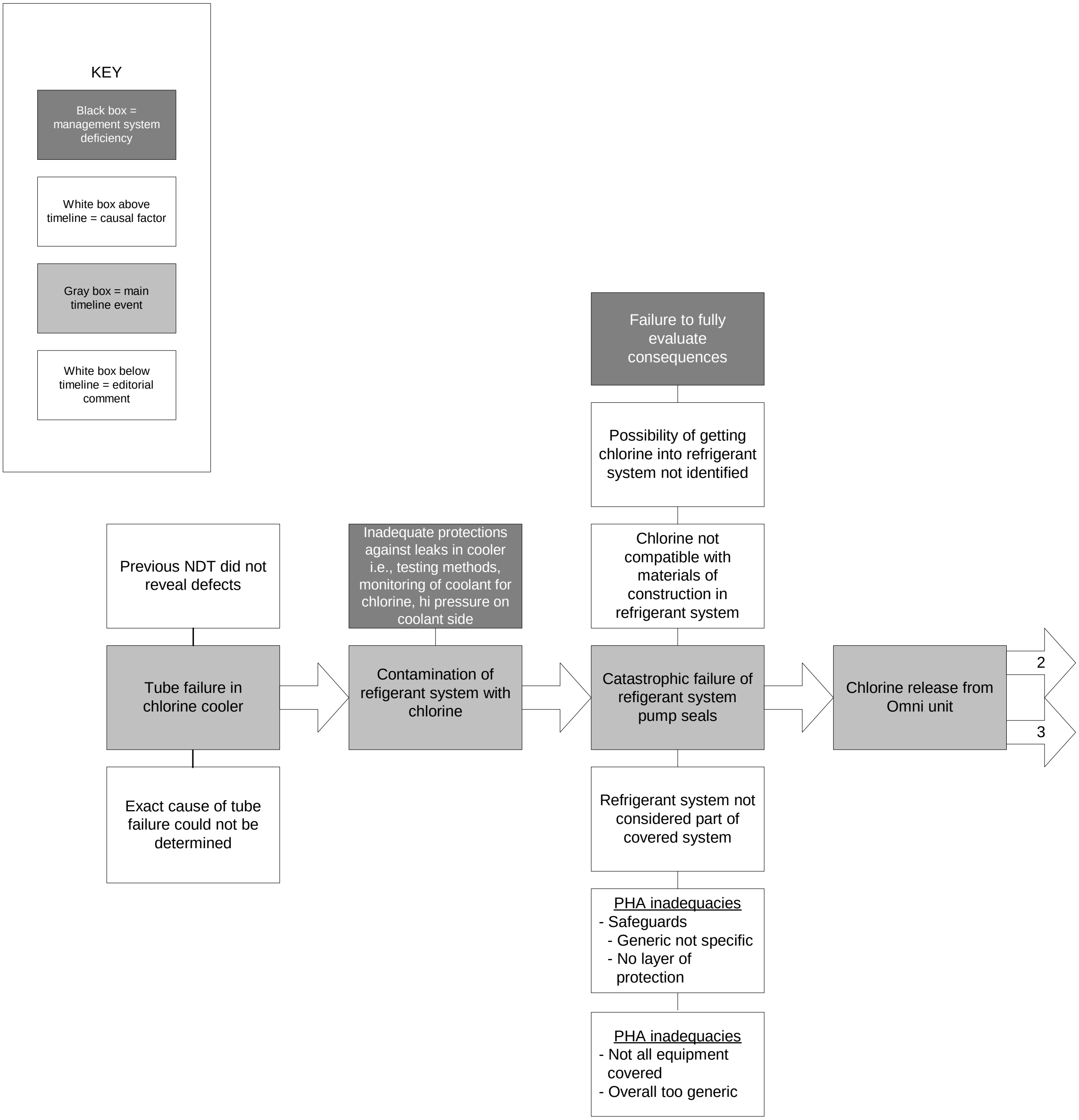
The system was taken off line, the cooler was removed from service, and the tubes cleaned.

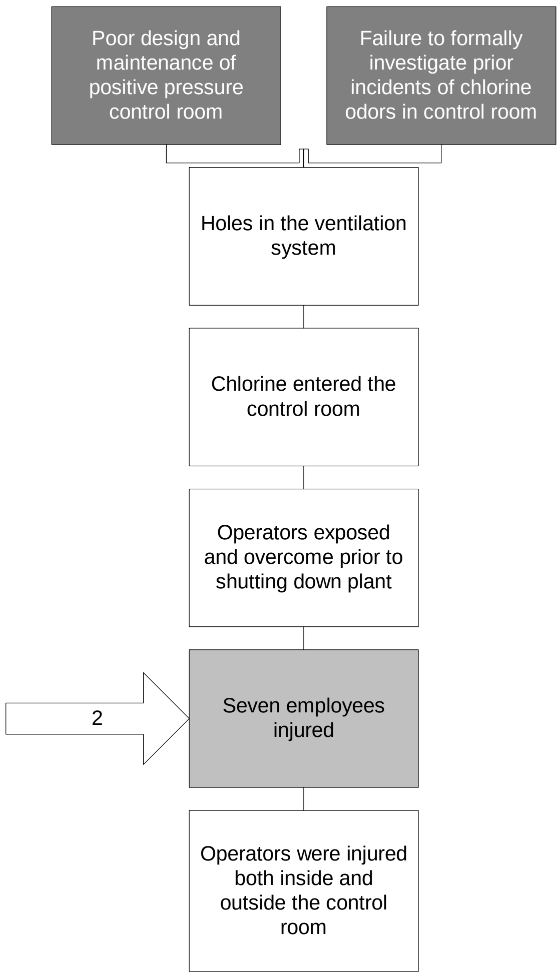
The full extent of the through-wall hole in Tube 1-2 was revealed when the solids were removed.

Appendix B: HFIPI-Recommended PPE for HF Exposure

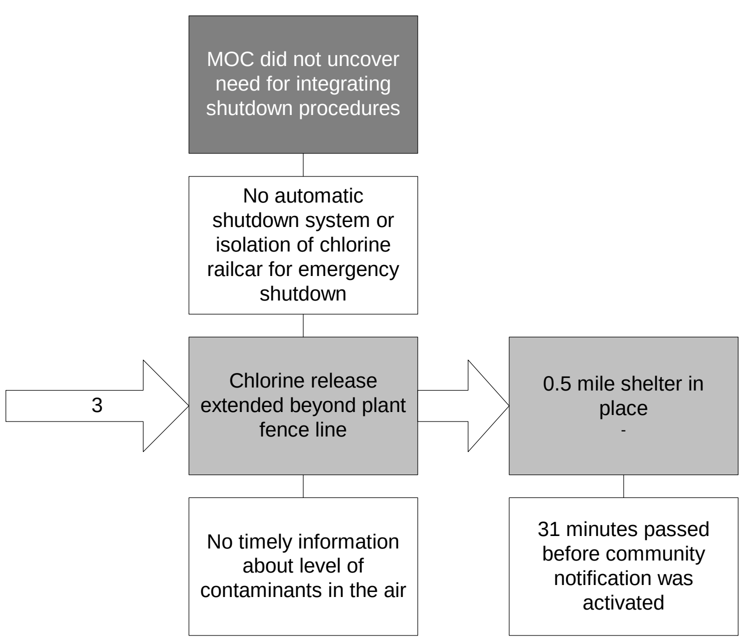
Level of Protection	Conditions for Use
Level A PPE Positive pressure, full-face-piece self-contained breathing apparatus (SCBA) or positive pressure supplied air respirator with NIOSH-approved escape SCBA Totally encapsulating, vapor-tight, chemical protective suit HF-resistant inner gloves HF-resistant outer gloves HF-resistant boots, with steel toe and shank	When HF vapor is expected or when there is a potential for liquid HF exposure; Level A PPE provides the greatest possible level of respiratory, skin, and eye protection
Level B PPE Positive pressure, full-face-piece SCBA or positive pressure supplied air respirator with NIOSH-approved escape SCBA Hooded HF-resistant clothing, such as overalls and long-sleeved jacket, coveralls, or one- or two-piece splash suit HF-resistant inner and outer gloves HF-resistant boots, with steel toe and shank	Specified when low-level HF vapor exposure is anticipated; Level B PPE provides the highest level of respiratory protection, but a lesser level of skin protection
Level C PPE Full-face NIOSH-approved air-purifying respirators or NIOSH-approved hood assembly respirators; NIOSH-approved half-masks may be used with chemical splash goggles in certain situations Hooded HF-resistant clothing, such as overalls, two-piece chemical splash suit, or disposable HF-resistant overalls HF-resistant inner gloves HF-resistant outer gloves HF-resistant boots, with steel toe and shank, or disposable HF-resistant outer covers Hardhat, face shield, and chemical splash goggles. NIOSH-approved escape mask, (if no other respiratory protection is required)	Specified when minimal HF exposure is expected or when the concentration of hydrogen fluoride is known and meets the criteria for use in air purifying respirators
Level D PPE Coveralls and gloves HF-resistant boots, with steel toe and shank, or disposable HF-resistant outer covers Hardhat and face shield Safety glasses with side shields or chemical splash goggles Available escape respirator	Specified when no physical contact with hydrogen fluoride is anticipated and only minimal HF protection is needed; Level D is typically the site-specific normal work clothing requirement

Appendix C: Logic Diagram for July 20 Incident


KEY
Black box = management system deficiency
White box above timeline = causal factor
Gray box = main timeline event
White box below timeline = editorial comment
Failure to fully evaluate consequences
Possibility of getting chlorine into refrigerant system not identified
Previous NDT did not reveal defects
Inadequate protections against leaks in cooler i.e., testing methods, monitoring of coolant for chlorine, hi pressure on coolant side
Chlorine not compatible with materials of construction in refrigerant system
Tube failure in chlorine cooler
Contamination of refigerant system with chlorine
Catastrophic failure of refigerant system pump seals
Chlorine release from Omni unit
2
3
Exact cause of tube failure could not be determined
Refrigerant system not considered part of covered system
PHA inadequacies
- Safeguards
- Generic not specific
- No layer of protection
PHA inadequacies
- Not all equipment covered
- Overall too generic

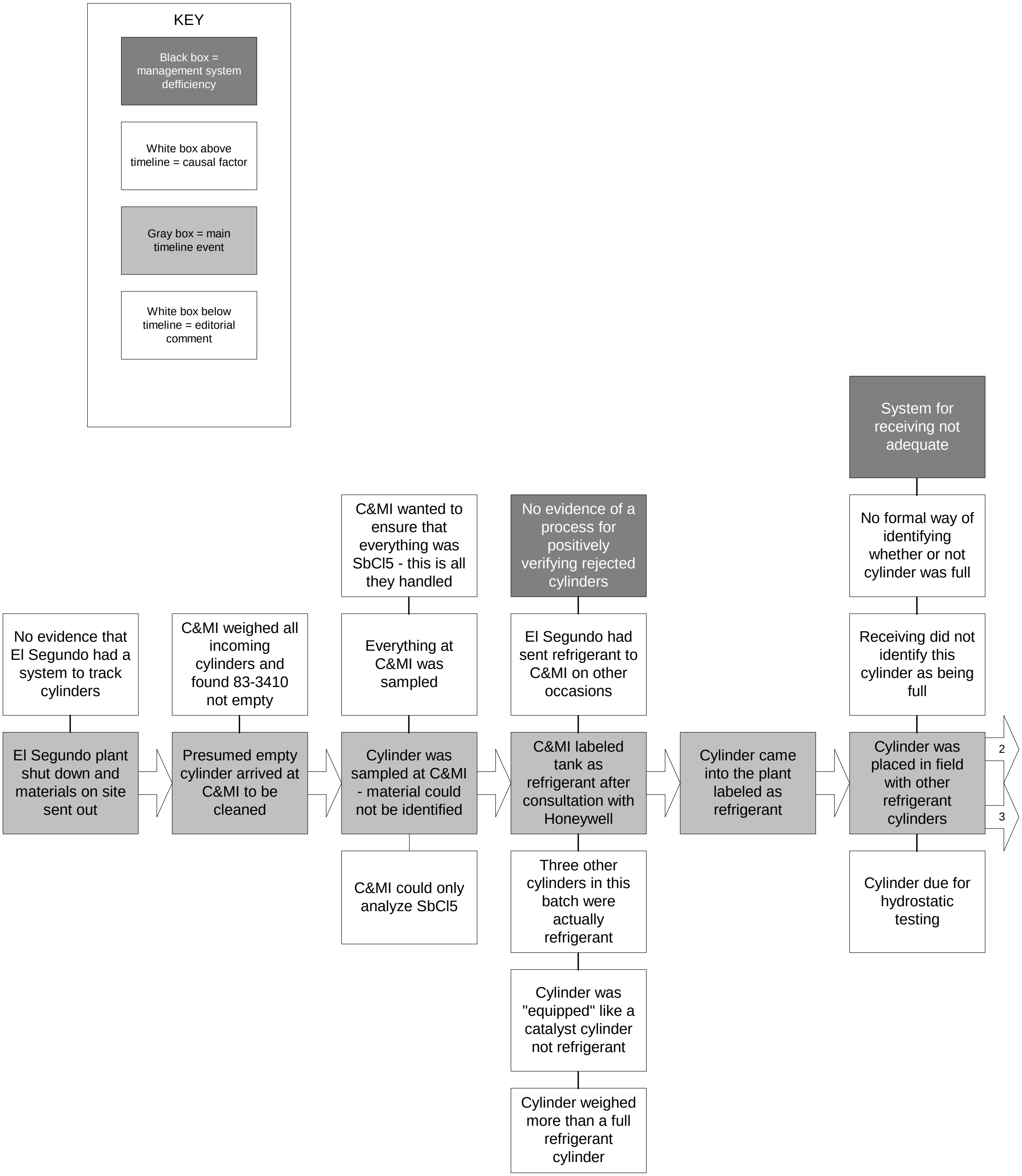


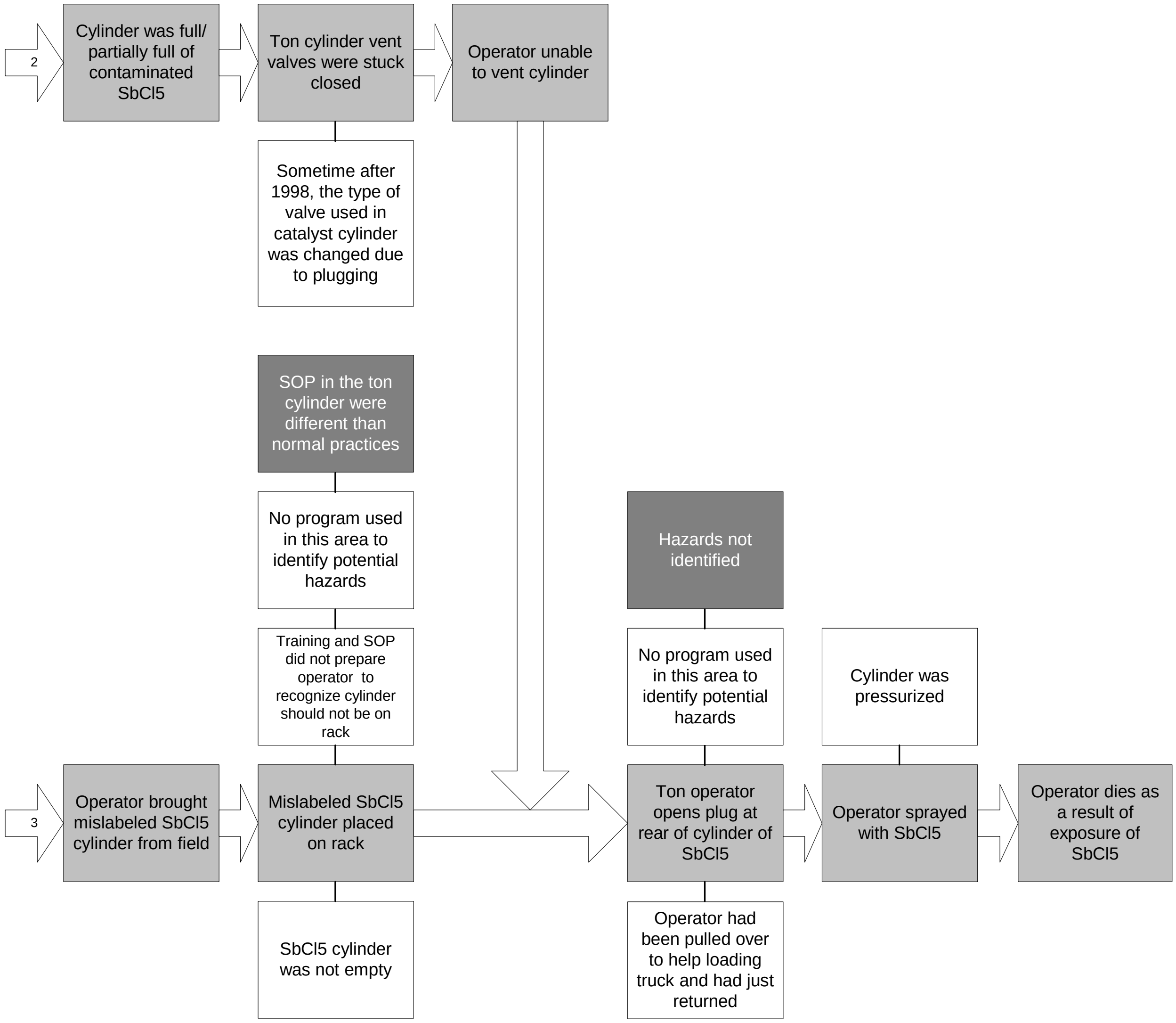
Poor design and maintenance of positive pressure control room
Failure to formally investigate prior incidents of chlorine odors in control room
Holes in the ventilation system
Chlorine entered the control room
Operators exposed and overcome prior to shutting down plant
2
Seven employees injured
Operators were injured both inside and outside the control room



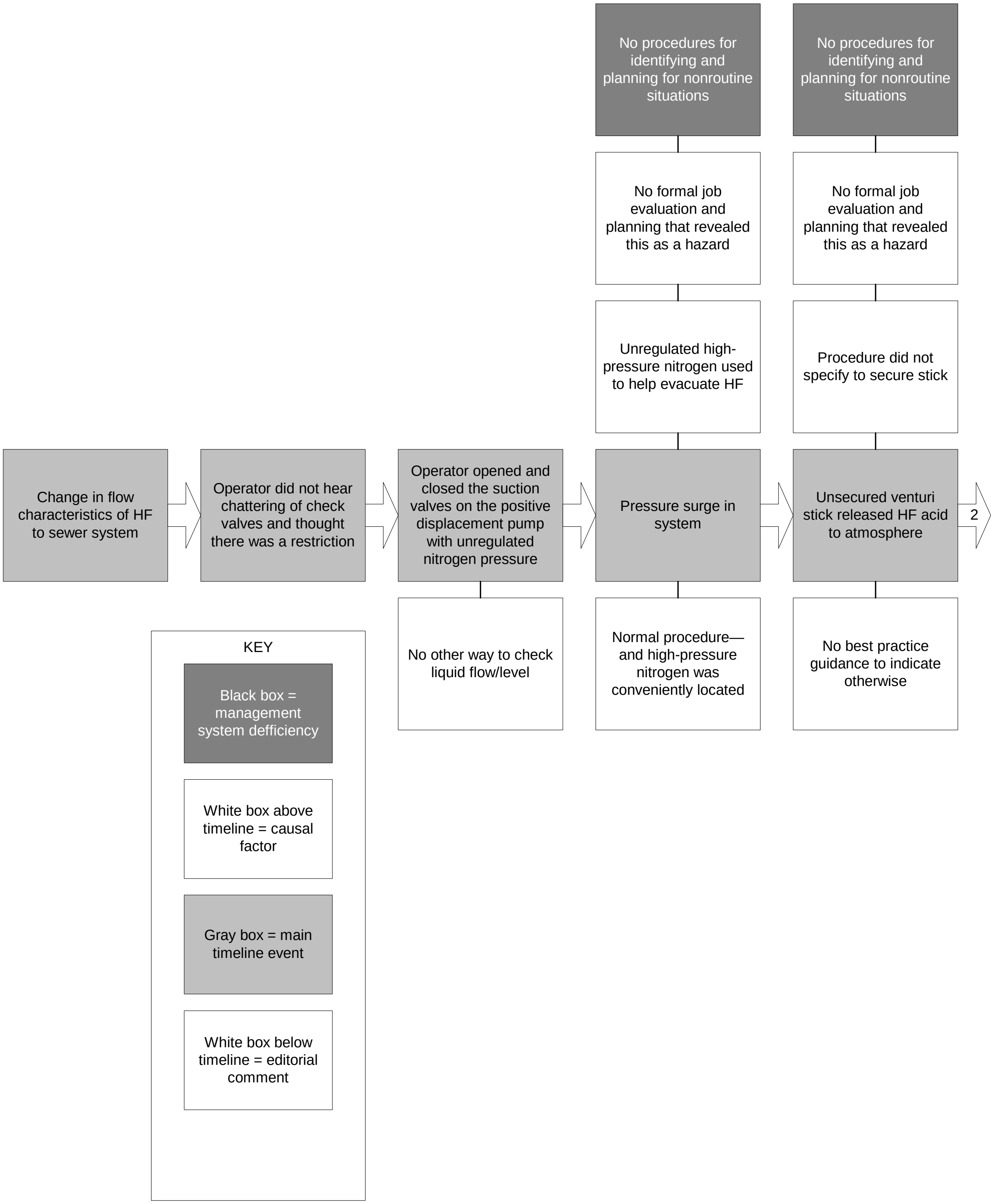
MOC did not uncover need for integrating shutdown procedures
No automatic shutdown system or isolation of chlorine railcar for emergency shutdown
3
Chlorine release extended beyond plant fence line
0.5 mile shelter in place
-
No timely information about level of contaminants in the air
31 minutes passed before community notification was activated

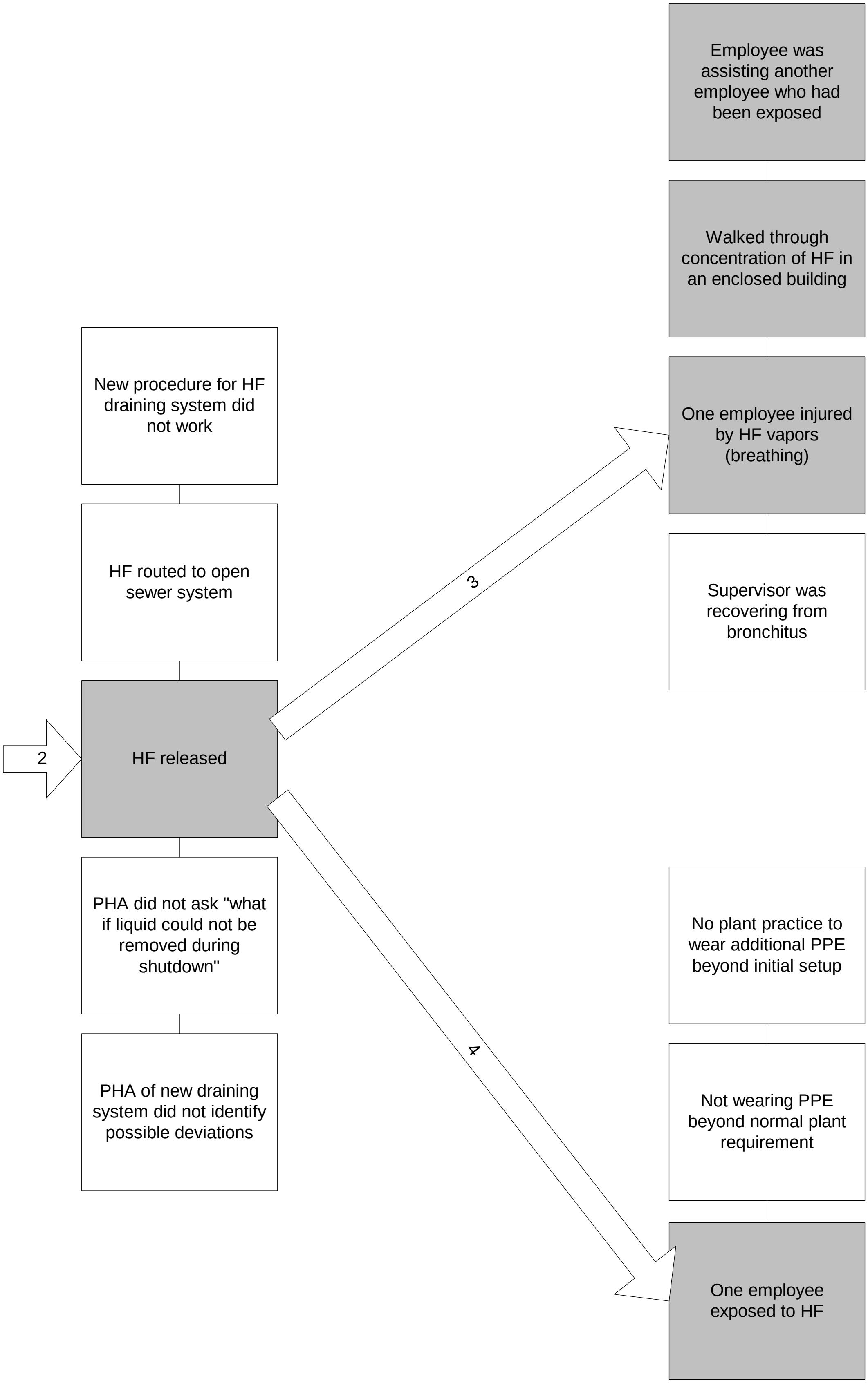
Appendix D: Logic Diagram for July 29 Incident




2
Cylinder was full/ partially full of contaminated SbCl5
Ton cylinder vent valves were stuck closed
Operator unable to vent cylinder
Sometime after 1998, the type of valve used in catalyst cylinder was changed due to plugging
SOP in the ton cylinder were different than normal practices
No program used in this area to identify potential hazards
Training and SOP did not prepare operator to recognize cylinder should not be on rack
Hazards not identified
No program used in this area to identify potential hazards
Cylinder was pressurized
3
Operator brought mislabeled SbCl5 cylinder from field
Mislabeled SbCl5 cylinder placed on rack
Ton operator opens plug at rear of cylinder of SbCl5
Operator sprayed with SbCl5
Operator dies as a result of exposure of SbCl5
SbCl5 cylinder was not empty
Operator had been pulled over to help loading truck and had just returned

Appendix E: Logic Diagram for August 13 Incident





Employee was assisting another employee who had been exposed
Walked through concentration of HF in an enclosed building
One employee injured by HF vapors (breathing)
Supervisor was recovering from bronchitus
New procedure for HF draining system did not work
HF routed to open sewer system
2
HF released
3
4
PHA did not ask "what if liquid could not be removed during shutdown"
PHA of new draining system did not identify possible deviations
No plant practice to wear additional PPE beyond initial setup
Not wearing PPE beyond normal plant requirement
One employee exposed to HF