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TWO UNITED STATES GOVERNMENT AGENCIES ISSUE REPORTS ENCOURAGING SMART HOSE TECHNOLOGY

Two United States Government Agencies the United States Environmental Protection Agency and the United States Chemical Safety Board have issued reports identifying the Smart-Hose technology as a solution to the ongoing problems of over reliance on excess flow valves.

The US-EPA report concluded "c**commercially available hoses with a self closing device at each end that will shut off flow entering the hose from either direction may be considered as an additional measure of protection. Such devices will protect against hose failure…."**

The US-CSB report asserts "some chlorine railcar transfer systems lack effective detection and emergency shutdown devices, leaving the public vulnerable to potential large-scale toxic releases. Chlorine railcars are equipped with an internal excess flow valve (EFV) that is designed to stop the flow of chlorine if an external valve breaks off while the railcar is in transit. However, these EFVs are not designed to stop leaks during railcar unloading, and the failure of a transfer hose may not activate the EFV and the toxic chlorine will continue to escape. Companies **should install emergency shutdown systems that can quickly stop the flow of chlorine if a hose ruptures during the unloading operation**, the bulletin said. **The shutdown system must be capable of stopping a chlorine release from both the railcar and the equipment at the facility receiving the chlorine**"

"We are pleased to have our technology referenced in these Safety Bulletins" said Tom Steinbach, Director of Business Development for Smart Hose. "We believe that all hoses used in hazardous applications where damage to the environment, risk to personnel and surrounding communities and excessive liability abound, should have a passive capability to shut off the flow of product in the case of hose separation. This is but another step towards reaching this vision. Our customers are always trying to improve safety which is why they use Smart Hose, we believe it is our responsibility to ensure that this additional commitment is recognized by the regulatory agencies and that our customers are rewarded for their safer facilities and environments."

Smart-Hose™ Technologies develops new safety applications for fluid transfer systems and assembles a patented hose assembly for fluid transfer systems. Smart-Hose Technologies has offices in the United States, China, Sweden, Columbia and India.

For additional information contact Andrea Guevara Vice President, Smart-Hose Technologies 215-730-9000.

United States
Environmental Protection
Agency

Office of Solid Waste
and Emergency Response
(5104A)

EPA 550-F-0-7001
Revised June 2007
www.epa.gov/OEM

CHEMICAL SAFETY *Alert*

Emergency Isolation for Hazardous Material Fluid Transfer Systems – Applications and Limitations of Excess Flow Valves

The Environmental Protection Agency (EPA) is issuing this *Alert* as part of its ongoing effort to protect human health and the environment by preventing chemical accidents. We are striving to learn the causes and contributing factors associated with chemical accidents and to prevent their recurrence. Major chemical accidents cannot be prevented solely through regulatory requirements. Rather, understanding the fundamental root causes, widely disseminating the lessons learned, and integrating these lessons learned into safe operations are also required. EPA publishes *Alerts* to increase awareness of possible hazards. It is important that facilities, State Emergency Response Commissions (SERCs), Local Emergency Planning Committees (LEPCs), emergency responders, and others review this information and consider whether additional action is needed to address the hazards.

Problem

While excess flow valves (EFV) are in extensive service and have prevented numerous pipe or hose breaks from becoming much more serious incidents, experience has shown that in some cases the EFV did not perform as intended, usually because of misapplication. Also, undue reliance must not be placed on EFVs as the sole or primary protection to control accidental chemical releases from tanks or piping.

Excess flow valves are protective devices intended to prevent the uncontrolled release of hazardous materials from road, rail and marine transport vessels, stationary storage vessels and distribution networks. EFVs are designed to close when the flow rate through them exceeds the expected range of normal operation, for example due to a downstream leak or valving error that provides an unintended release path to the atmosphere. EFVs are intended to bring the release under control until the leaking element (e.g. hose or pipe) can be blocked in and positively isolated for corrective action.

Industry incident experience, however, has shown that under certain circumstances, EFVs can fail to provide the protection anticipated of them. In fact, a number of significant releases of hazardous materials have occurred from systems ‘protected’ by EFVs. One event investigated by the National Transportation Safety Board (NTSB) resulted in the deaths of three plant employees and the evacuation of 2,000 nearby residents. Concerned that undue reliance might be placed upon EFVs, the NTSB recommended in its investigation report that EPA:

> “Notify all facilities that are required to submit risk management plans to the Environmental

> Protection Agency that tank car excess flow valves cannot be relied upon to stop leaks that occur during tank car loading and unloading operations and that those companies that have included reliance on such valves in their risk management plans should instead identify and implement other measures that will stop the uncontrolled release of product in the event of a transfer line failure during tank car loading or unloading."

EPA shares the NTSB's concerns and additionally recognizes that the use of EFVs extends beyond tank cars and includes loading and unloading operations associated with tank trucks, marine barges, stationary tankage and piping distribution networks. This *Hazard Alert* is intended to provide an understanding of (1) how EFVs function, (2) circumstances that can lead to their failure to function as intended, (3) important design and operational factors for enhancing the reliability of EFVs, and (4) alternate means available for stopping uncontrolled releases.

Facilities should be aware of, and give proper regard to, industry best practice guidance and regulatory requirements for the use of EFVs.

When they are properly designed, installed, and maintained, EFVs play an important role in comprehensive accidental release prevention systems. It is not EPA's intent to dissuade the regulated community from the use of EFVs but, rather, to provide precautionary guidance regarding their use as a sole means of protection.

Accidents

Provision should be included for blocking in (isolating) hazardous material transfer lines in addition to the protection provided by EFVs. As in the following incidents, failure to understand the limitations of EFVs has been a contributing factor in a number of significant incidents where flow restriction prevented EFV closure.

8/2002 in Missouri – A chlorine railcar transfer hose ruptured, releasing 48,000 pounds of chlorine. Hundreds of residents were evacuated or sheltered-in-place, and sixty-three local residents sought medical evaluation; three were admitted to the hospital. The chlorine also damaged tree leaves and vegetation around the facility. The CSB determined that an excess flow valve internal to the chlorine railcar did not close, contributing to the severity of the event. As a result of such chlorine releases, the CSB has issued a recommendation to the Department of Transportation (DOT) to expand the scope of DOT regulatory coverage to include chlorine railcar unloading operations and ensure the regulations specifically require remotely operated emergency isolation devices that will quickly isolate a leak in any of the flexible hoses (or piping components) used to unload a chlorine railcar.

7/2001 in Michigan – A methyl mercaptan release occurred when a pipe attached to a fitting on the unloading line of a railroad tank car fractured and separated. Fire damage to cargo transfer hoses on an adjacent tank car also resulted in the release of chlorine gas. Neither of the two EFVs closed to control the release. Three plant employees were killed in the resulting explosion and several employees were injured. Approximately 2,000 local residents were evacuated from their homes for 10 hours. Failure of the EFVs to close contributed to the severity of the incident. The NTSB determined that the facility placed undue reliance on the tank car EFV to close in the event of a leak from the transfer line.

4/1998 in Iowa – A propane release occurred when a vehicle struck and severed unprotected, aboveground liquid and vapor lines serving an 18,000-gallon propane storage tank. The lines fed vaporizers, which fueled heaters located in barns and other farm structures. The liquid line, which was sharply reduced in pipe diameter, was completely severed where it connected to a manual shut-off valve directly beneath the tank. The release ignited and the tank subsequently exploded, killing two fire fighters and injuring seven other emergency personnel. A subsequent CSB investigation determined that the flow capacity of the liquid outlet piping system downstream of the EFV was insufficient to allow the EFV to close.

9/1999 in North Carolina – More than 35,000 gallons of propane were released when the discharge hose on an LPG transport truck separated from its hose coupling at the delivery end of the hose, and none of the safety systems on either the truck or the receipt tank worked as intended to stop the release. The DOT determined that emergency systems such as EFVs do not always function properly when a pump is used to unload the protected vessel. If a release occurs downstream of the pump and the EFV activation point is greater than the pump capacity, the pump will function as a regulator limiting the flow to below that required to close the EFV.

Two common themes in these accidents are that flow restrictions prevented the flow through an EFV from exceeding the shut-off flow rate, and emergency isolation block valves were not activated. A literature review revealed a number of additional incidents where the rates of discharge from releases were insufficient to close the EFVs.

The literature also shows, cases such as the one below, where an EFV was not installed but would have been beneficial:

7/1998 in Virginia – A natural gas release occurred in the underground feed line serving a newly constructed residence in which the occupants had moved-in just hours before. The leaking gas entered the basement where it found an ignition source and exploded killing one of the new owners and injuring the other parent and their two children. The investigation report concluded that the release was attributed to the plastic feed line being damaged by heat from a faulty splicing in a buried electrical service cable located close to the natural gas line. The natural gas feeder line was not equipped with an excess flow valve. Among the findings it was concluded that "Had an excess flow valve been installed in the gas line to the residence, the valve would have closed after the hole in the pipeline developed, and the explosion likely would not have occurred."

Understanding the Hazard

Proper use of EFVs requires an understanding of their capabilities and their limitations.

The National Fire Protection Association (NFPA) defines an EFV as a "valve designed to close when the liquid or vapor passing through it exceeds a prescribed flow rate" (NFPA 58). EFVs are most commonly used on the liquid and vapor connections of transport containers (e.g., rail cars and tank trucks) and on some stationary tankage. EFVs are often installed inside of the vessel so that protection is provided even if the piping external to the vessel is damaged. EFVs are also very commonly used in natural gas distribution lines serving end-users such as residential and commercial consumers. Figure 1 shows an EFV installed in the liquid unloading line on a chlorine railcar. In-line EFVs can also be installed in external piping systems (e.g., to protect individual distribution lines).

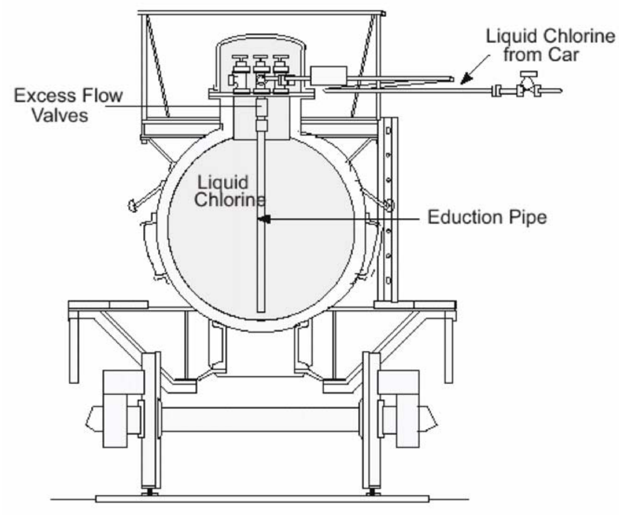

Figure 1. EFV in Chlorine Railcar Liquid Outlet Line

EFVs are used with a variety of hazardous chemicals, of which chlorine, liquefied petroleum gases (LPG), natural gas and anhydrous ammonia are among the most common. Consequently, these four chemicals are used as examples in this *Hazard Alert*. Guidance for the application of EFVs with regard to these four chemicals is issued, respectively, by the Chlorine Institute (CI), NFPA, and the Compressed Gas Association (CGA). Regulatory requirements for the usage of EFVs are imposed by various state and federal agencies, including the Occupational Safety and Health Administration (OSHA) and the DOT.

Figures 2 and 3 illustrate two common designs for EFVs. The valve in Figure 2, designed for use on a chlorine rail car or tank truck, contains a ball that is driven upwards against a seat to stop the flow when it exceeds the shut-off rate. The design of this type of EFV requires that it be mounted in the vertical orientation shown in the figure. The valve shown in Figure 3 is used in LPG and anhydrous ammonia service. A spring normally holds the plug in the open position shown. When the flow through the valve is high enough, the plug is forced against the seat, stopping the flow. This design permits the valve to be installed in any orientation. It should be noted that EFVs permit flow in both directions, but only stop flow in one direction. Consequently, flow direction must be correctly considered in the installation of the EFV. In both figures, the protected flow direction would be upwards through the valves.

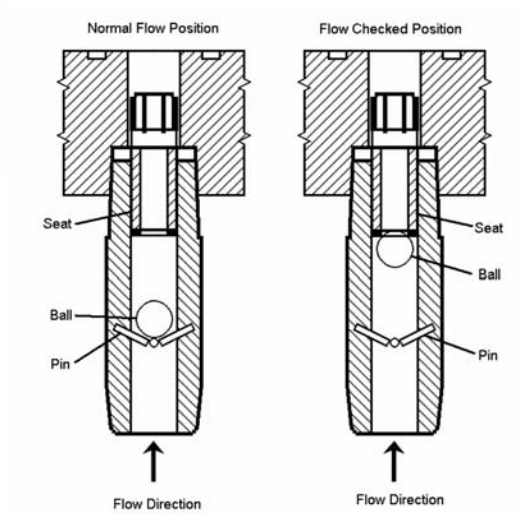

Figure 2. EFV for Chlorine Service

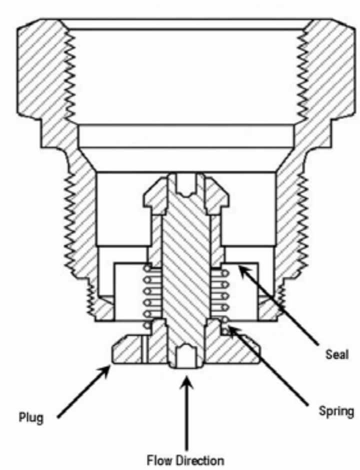

Figure 3. EFV for Ammonia or LPG Services

The potential for flow restrictions preventing the closure of the EFV is well recognized by organizations issuing good practice guidance for the use of EFVs. For example, the CI cautions that the EFV is principally a protection against an event that damages the manual valve on the transport container during transit and not a protection against damage to connected loading or unloading system piping. The CI notes that the EFV "may close if a catastrophic leak involving a broken connection occurs but it is not designed to act as an emergency shut-off device during transfer." CI guidance does not specify the use of EFVs on stationary tankage, but recognizes that some users choose to use EFVs in such a manner. CI pamphlets addressing EFVs are identified in the Information Resources section, below.

The installation of EFVs in stationary tankage is commonly used with LPG and anhydrous ammonia. NFPA, in its *Liquefied Petroleum Gas Code*, specifies that, where EFVs are required, the "connections, or line, leading to or from any individual opening shall have greater flow capacity than the rated flow of the excess-flow valve protecting the opening." CGA, in its *Safety Requirements for the Storage and Handling of Anhydrous Ammonia*, specifies that "piping, including valves and fittings in the same flow path as the excess flow valve, shall have a greater capacity than the rated flow of the excess flow valve."

The National Propane Gas Association (NPGA) notes a number of conditions which could result in the failure of an EFV to close:

- Piping system restrictions such as pipe length, branches, reduction in pipe size, and partially closed shut-off valve, could limit the flow rate through the EFV.

- The size of break or damage downstream of the EFV is not large enough to allow a flow sufficient to close the valve.

- The system pressure upstream of the EFV is not high enough to produce a closing flow rate.

- Foreign matter such as welding slag or a build up of process contaminants lodged in the EFV can prevent its closing.

- The piping break or damage occurs upstream of an in-line EFV.

- The flow through the EFV is in the wrong direction.

- The EFV has been damaged, or is otherwise not operable.

Recognizing the limitations inherent in the design and application of EFVs, NPGA, CI, NFPA, and CGA all recommend or require the use of some secondary means of preventing uncontrolled releases in certain high risk situations.

Controlling the Hazard

Careful analysis is required in order to determine how much reliance can be placed upon EFV's ability to bring the rate of release under control, and to identify any necessary and appropriate supplemental controls for accidental releases.

System Design and Installation

System design and installation issues must be considered in evaluating the degree of reliance to be placed on an EFV. Considerations should include:

- For the EFV to close, the failure in the downstream piping must result in enough flow to exceed the EFV activation point. Analyze credible, catastrophic failures at likely release points, such as flexible hoses in unloading systems, to determine if the flow resistance in the piping both upstream and downstream of the EFV might prevent the EFV from closing.

- The characteristics of the hazardous material have to be considered. Release rate calculations must address the effect on flow rate of two-phase flow that will result upstream of the release point when liquefied compressed gases flash to vapor as system pressure is released.

- The pressure in the vessel must be adequate to produce the flow necessary to seat the EFV. Consider the effects of low vapor pressure liquids and minimum credible winter temperatures.

- The type of EFV specified must be appropriate to the intended service, and any necessary constraints on the physical orientation of the valve must be identified.

- The system must be installed in strict accordance to design specifications.

- The flow capacity of the EFV must be great enough to avoid nuisance flow stoppages caused by normal variations in process flow rates, but not so high as to negate its protective function.

- A piping system network with smaller branch lines coming off the main line will need separate EFVs to control releases in these branch lines.

- A release that is not large enough to activate the EFV can still be large enough to lead to serious consequences and thus require alternative control capability.

Operation and Maintenance Practices

Like any safety device, an EFV must be properly maintained and operated in order for it to provide its intended protective function. There should be:

- An appropriate inspection, testing (including verification of flow rate necessary to activate the EFV), and preventive maintenance program for the EFV based upon past experience, the characteristics of the process stream, and standard EFV maintenance guidelines (*e.g.*, CI Pamphlet 042, which may provide guidance to facilities handling other chemicals).

- Operating procedures and training to address the operation of the EFV and all supplemental controls.

- Controls to manage system changes that might otherwise compromise the function of the EFV. (Management of Change)

Determining the Need for Additional Protection

Facilities, absent any applicable industry guidance or regulatory requirements, should take a risk-based approach in evaluating the need to supplement EFVs in controlling accidental releases. Considerations, addressing both the consequences and the likelihood of a catastrophic release, would include:

- The hazardous nature of the chemical involved, such as toxicity, flammability, and hazard to the environment.

- The size of potential releases, depending on the potential for significant back-flow to the point of release, size of inventory, and flow rates involved.

- The likelihood of a release, depending on frequency of loading and unloading operations and type of equipment used. A system containing flexible hoses or articulated (swivel-joint) piping may be more prone to a release than a system containing more robust rigid piping.

- Local conditions such as the possibility of flooding, mud or rock slides, wash-outs, sink holes and subsidence or other earth movement situations warrant particular attention for stationary systems.

- The severity of a credible release on surrounding populations, workers, facilities, and the environment.

Alternative/Additional Means for Controlling Releases

Industry guidance and regulatory requirements increasingly recognize the prudence of providing alternative means of stopping accidental releases in certain situations, either in place of or in addition to EFVs. Examples of approaches used in industry include:

- Remotely isolating leaking transfer systems, with particular emphasis on flexible hoses, by bolting fail-safe (air-to-open) actuated valves on the discharge side of railcar manual valves.

- Shut-off protection by quick closing valves that can be controlled from locations that would be accessible even in the event of a release.

- Emergency shutoff valves equipped for remote manual closure and automatic shutoff using thermal (fire) actuation or chemical detection. The valve may be internal to the tank, in lieu of an EFV, or it may be installed external to the tank as close as practical to the tank outlet, provided there is an internal EFV. Emergency shut-off systems should be thoroughly tested on a regular schedule to ensure that they will operate as intended when needed.

- Commercially available hoses with a self closing device at each end that will shut off flow entering the hose from either direction if the hose is pulled apart or sheared may be considered as an additional measure of protection. Such devices will protect against hose failure, but not against leaks that occur upstream or down-stream of the hose.

The technologies, systems, and practices cited above are meant only to be illustrative; they do not constitute a definitive list of options, and are not meant to establish 'requirements' for any particular application. Additional details are provided in the references at the end of this *Alert*. References to regulatory requirements and industry best practices are not intended as interpretations and users should consult the referenced documents to determine applicability to their own particular circumstances.

If it is determined that manual ("hand-on") intervention is the most appropriate approach to responding to releases, a critical analysis should be made of issues such as: the number and location of isolation valves relative to likely points of release; the properties of the released chemical and the correspondingly required personal protective equipment (PPE); personnel staffing, location and response times; and the adequacy of training provided to personnel responding to a release.

What Needs To Be Done

EPA urges users of EFVs to evaluate their applications to verify the operability of in-place controls and to determine whether additional controls are warranted to minimize the risk of release of hazardous materials. Industry experience indicates that sole reliance on EFVs to control accidental releases may not always be sufficient and needs to be substantiated by a thorough engineering and risk evaluation. In most cases where supplemental controls were available and clearly identified, they were successfully applied. Where this has not been the case, appropriate revisions should be made to Risk Management Program elements such as operating procedures, training, and emergency response plans.

Conclusion

Millions of EFVs are in service and each year many properly-sized and correctly installed EFVs operate as intended to greatly mitigate the consequences of hazardous material releases. Incident investigations show that when the EFV was in place but did not function as intended, it was usually because either the valve was not correctly sized and flow-rated or line restrictions or low inlet pressure prevented sufficient flow needed for valve closure. Mechanical malfunction of the EFV is very rarely shown to be a contributing factor. Release rates that are less than the EFV activation rate represent a very serious situation. Natural gas or city gas leaks downstream of the regulator or meter fall into this category. Alternate or additional means of release prevention/mitigation should be installed for high-risk situations and situations where EFV's may not be effective.

Information Resources

References with information about the use of EFVs and other methods for controlling hazardous releases are listed below. Regulations potentially applicable to EFVs and codes and standards that may be relevant are also included.

Statutes and Regulations

- Clean Air Act Section 112(r)(1) – General Duty
- EPA's Risk Management Program Rule [40 CFR 68]
- OSHA Process Safety Management Standard [29 CFR 1910.119]
- OSHA Standards: 29 CFR 1910.110, *Storage And Handling Of Liquefied Petroleum Gases;* 29 CFR 1910.111, *Storage and Handling of Anhydrous Ammonia*; and 29 CFR 1926.153, *Liquefied Petroleum Gas* (LP-Gas)
- DOT regulations [49 CFR 171-180]

Codes and Standards

- The Chlorine Institute, Inc.: Pamphlet 001, *Chlorine Manual*; Pamphlet 042, *Maintenance Instructions for Chlorine Institute Standard Excess Flow Valves*; Pamphlet 049, *Recommended Practice for Handling Bulk Highway Transports*; Pamphlet 057, *Emergency Shut-Off Systems for Bulk Transfer of Chlorine*; Pamphlet 066, *Recommended Practice for Handling Chlorine Tank Cars*

- The Compressed Gas Association, Inc.: ANSI K61.1 (CGA G-2.1), *American National Standard Safety Requirements for the Storage and Handling of Anhydrous Ammonia*

- The National Fire Protection Association, Inc.: NFPA 58, *Liquefied Petroleum Gas Code*

- Freeman, R. A., and D.A. Shaw, "Sizing Excess Flow Valves," *Plant/Operations Progress*, Vol. 7, No. 3, July 1988

- UK Health and Safety Executive: "Emergency Isolation," http://www.hse.gov.uk/hid/land/comah/level3/5c7177c.htm

Accident Histories

- National Transportation Safety Board, Hazardous Materials Accident Report NTSB/HZM-02/01, "Hazardous Materials Release From Railroad Tank Car With Subsequent Fire at Riverview, Michigan, July 14, 2001"

- National Transportation Safety Board, Pipeline Accident Report, NTSB/PAR-01/01, "Natural Gas Explosion and Fire in South Riding, Virginia July 7, 1998"

- U.S. Chemical Safety and Hazard Investigation Board, Investigation Report No. 98-0071-1-1A, "Propane Tank Explosion (2 Deaths, 7 Injuries),

Herrig Brothers Feather Creek Farm, Albert City, Iowa, April 9, 1998."

- U.S. Chemical Safety and Hazard Investigation Board: Investigation Report No. 2002-04-I-MO, "Chlorine Release (66 Sought Medical Evaluation), DPC Enterprises, L.P., Festus, Missouri, August 14, 2002."
- U.S. Chemical Safety and Hazard Investigation Board: Safety Advisory No. 2002-01-SA, "Chlorine Transfer Hose Failure"
- U.S. Chemical Safety and Hazard Investigation Board: Safety Bulletin No. 2005-06-I-LA, "Emergency Shutdown Systems for Chlorine Transfer"

For More Information:

Call the Superfund, TRI, EPCRA, Risk Management Program, and Oil Information Center

(800) 424-9346 or (703) 412-9810

TDD (800) 553-7672 or (703) 412-3323

Safety Bulletin

U.S. Chemical Safety and Hazard Investigation Board

No. 2005-06-I-LA| June 2007

Emergency Shutdown Systems for Chlorine Transfer

Summary

The U.S. Chemical Safety and Hazard Investigation Board (CSB) issues this Safety Bulletin to emphasize the importance of installing, testing, and maintaining chlorine detection and emergency shutdown devices on chlorine railcar transfer systems.

This bulletin compares two chlorine releases investigated by the CSB. In both, a railcar unloading hose failed and chlorine was released. In the first incident, an emergency shutdown system malfunctioned, resulting in a release of 48,000 pounds of chlorine and a significant community impact. In the second, the emergency shutdown system worked to minimize the release, and the community was not impacted.

Figure 1. August 14, 2002, chlorine release at DPC Enterprises in Festus, Missouri

Uncontrolled Release Event

In 2002, the CSB investigated a chlorine release at DPC Enterprises (DPC) in Festus, Missouri, that resulted when a chlorine railcar transfer hose ruptured. The CSB determined that although the supplier's manufacturing records and identification tag indicated that the metal braid on the failed hose was made of Hastelloy C, as specified by DPC, it was actually made of stainless steel. Neither the manufacturer nor DPC confirmed that the hose was constructed of the proper material before it was put into chlorine service. Chlorine rapidly degraded the braid and the hose ruptured[1] (CSB, 2003).

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[1] The braided metal hose was Teflon-lined.

DPC had an emergency shutdown system to stop chlorine releases from the railcar, which included remotely activated emergency shutdown valves installed at each end of the chlorine transfer hose. These valves were supposed to close automatically when detectors identified chlorine in the area or if operators pushed an emergency shutdown button. However, on the day of the incident, even though the chlorine detectors detected the release and the operators pushed the shutdown button, the valves remained open.[2, 3] Furthermore, the excess flow valve (internal to the railcar) did not close.

Consequently, 48,000 pounds of chlorine was released into the neighboring community, resulting in hundreds of residents being evacuated or sheltered-in-place. Sixty-three local residents sought medical evaluation; three were admitted to the hospital. The chlorine caused tree leaves and vegetation around the facility to turn brown.

The CSB recommended that DPC develop a quality assurance system for chlorine hoses, and implement procedures and practices to ensure that the emergency shutdown system operates reliably. The CSB also recommended that the hose fabricator implement a materials' verification procedure to improve quality and ensure that hastelloy chlorine hoses are readily identifiable.

Controlled Release Event

On August 11, 2005, a chlorine transfer hose ruptured at Honeywell International's (Honeywell) Baton Rouge chemical plant.[4] Chlorine began to escape from the railcar. A newly installed chlorine detector alerted control room operators of the release; a shift supervisor who was outside saw the escaping chlorine and sounded the evacuation alarm. A control room operator stopped the release by remotely closing the emergency shutdown valves on the chlorine transfer hose. The release lasted less than one minute.

Although contractors working in the area heard the alarm and evacuated, some inhaled chlorine and were taken to the hospital where they were treated and released. All returned to work the next day. Immediately after the release, Honeywell tested for chlorine at the facility property line and found none.

In contrast to the 2002 incident at DPC, the rapid and successful activation of the emergency shutdown system at Honeywell prevented a major release and off-site impact.

The August 2005 incident at Honeywell demonstrated that properly maintained chlorine detection and emergency shutdown systems are critical for protecting workers, adjacent communities, and the environment.

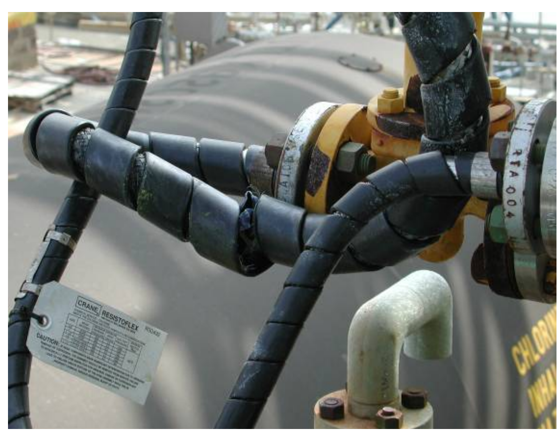

Figure 2. Honeywell ruptured chlorine transfer hose

Since 1994, the CSB and the Chlorine Institute have recorded at least five hose failures that resulted in chlorine releases. Additionally, one hose manufacturer reported that 6 of 2,781

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[2] The CSB determined that the valves were not adequately maintained or tested by DPC to ensure they would operate when needed.

[3] Employees pressed the remote emergency shutdown button to close the isolation valves every day during the transfer system shutdown. However, DPC did not require employees to verify that the valves actually closed.

[4] Microscopic examination of the hose revealed that corrosion of the wire hose braid at the failure site had reduced the diameter and pitted the failed wires. The CSB investigated the operating and environmental conditions the hose was subject to prior to the failure, but did not identify a likely cause of the corrosion.

chlorine hoses had been returned for failure analysis between January 2000 and September 2006. This data indicates that chlorine hoses are susceptible to failure, and that emergency shutdown systems are needed to prevent human exposure to chlorine that is released during a hose failure.

Chlorine Background

Chlorine Properties

Molecular Formula – Cl_2
Boiling Point – 29.2 °F
Vapor Pressure – 53.5 psi at 32 °F

Chlorine is highly toxic and corrosive. It irritates the mucous membranes of the nose, throat, and lungs, and exposure to relatively low concentrations can be fatal. The National Institute for Occupational Safety and Health (NIOSH) and OSHA have determined that 10 ppm is immediately dangerous to life and health (IDLH). Table 1 summarizes the health effects of acute chlorine inhalation.

Chlorine is used for water and wastewater disinfection, and to manufacture products such as household bleach, pesticides, medicines, plastic piping, silicon chips, and automotive parts. Facilities that use chlorine are located throughout the country, sometimes close to residential communities. Many of these facilities receive chlorine in railcars; according to the Surface Transportation Board Carload Waybill Sample almost 3 million tons of chlorine was shipped by railcar in 2005 in the United States (Surface Transportation Board, 2005).

Table 1: Health effects of short term chlorine inhalation

Concentration (parts per million)	Health Effects
1-3	Mild mucous membrane irritation, tolerable up to one hour
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.

Chlorine Railcar Unloading Systems

The most basic chlorine railcar unloading system consists of hoses and manual valves. Pressurized nitrogen or dry air is fed to the railcar through one hose to force liquid chlorine through a second hose. The railcars themselves are equipped with an internal excess flow valve (EFV) designed to close if the rate of chlorine flow becomes excessive (7,000 to 32,000 pounds per hour depending on the design parameters for the specific application). For instance, excessive flow might occur if the manual valve breaks off during an accident in transit.[5, 6]

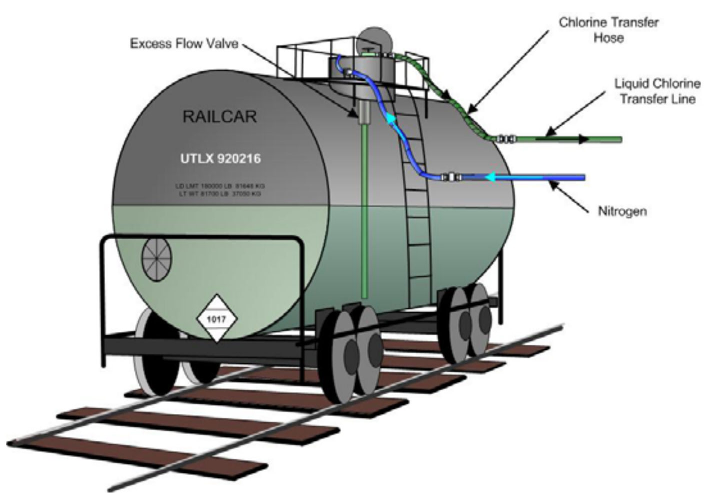

Figure 3. Basic unloading system

[5] DOT Hazardous Materials Regulations (49 CFR 173.314 (k)) require that chlorine railcars be equipped with excess flow valves (HMR, 2006).

[6] The Chlorine Institute Pamphlet 66, "Recommended Practices for Handling Chlorine Tank Cars," contains recommendations for excess flow valve design.

With this basic system, the EFV is the only physical safeguard to prevent a large chlorine release into the atmosphere if an unloading hose ruptures. However, the design of EFVs requires a compromise: they must be designed to allow a reasonable flow such as what may occur during routine unloading, but close if the flow becomes very large. Hence, an EFV is unlikely to stop a small to moderate leak from a ruptured hose. The Federal Railroad Administration (FRA) warns that when unloading equipment is attached to a railcar, product flow "will not be sufficient to activate the EFV" (FRA, 2003).

Numerous incidents have demonstrated that EFVs should not be relied upon solely to stop a hazardous material release during unloading.[7] As an example, the National Transportation Safety Board (NTSB) investigated a July 2001 methyl mercaptan release from a railcar at ATOFINA Chemicals, Inc. (ATOFINA), and found that reliance on the excess flow valve to stop a leak contributed to the size of the release. The release started when "a pipe attached to a fitting on the unloading line of a railroad tank car fractured and separated" (NTSB, 2002). The methyl mercaptan, which is both toxic and flammable, ignited, causing a large fire. Three ATOFINA employees were killed, and several other employees and local residents were injured.

In response to an NTSB recommendation, the U.S. Environmental Protection Agency (EPA) issued a Chemical Safety Hazard Alert titled "Failures of Excess Flow Valves in Hazardous Materials Service" (EPA, 2004). The Hazard Alert describes four significant incidents where excess flow valves failed to stop hazardous material releases. The Hazard Alert noted that the National Propane Gas Association, Chlorine Institute, National Fire Protection Agency, and Compressed Gas Association either "recommend or require" that additional protections be used to supplement EFVs (EPA, 2004).

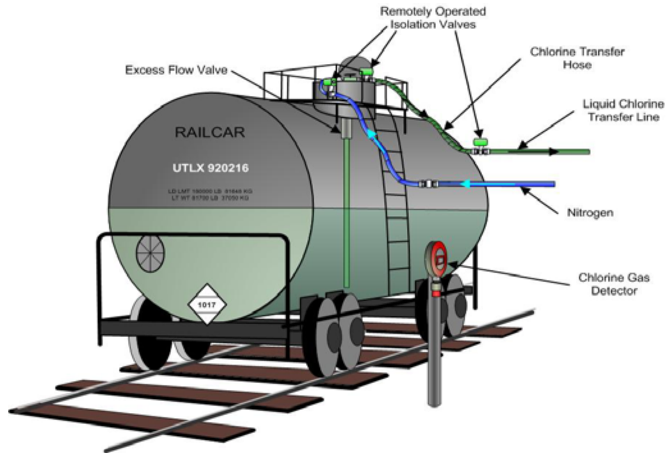

Figure 4. Chlorine railcar unloading system with an emergency shutdown system

Despite these warnings, the CSB investigators found that approximately 30 percent of the bulk chlorine users contacted during this investigation continue to rely only on excess flow valves to stop chlorine flow in the event of a transfer hose rupture.[8]

At a minimum, chlorine railcar unloading systems (Figure 4) should include the following components:

- Automatic shutdown valves, which are capable of isolating the unloading system within 8-10 seconds, located on the nitrogen or dry air hose-to-railcar connection, and at both ends of the chlorine transfer hose.
- Emergency shutoff switches, to activate the shutdown valves, installed in at least two easily accessible remote locations.
- Leak detection equipment that either automatically activates the shutdown valves or alerts personnel to manually activate them. This equipment may include atmospheric monitoring systems, video monitoring, loading line pressure monitoring, or railcar derailer position sensors.

[7] Excess flow valves will not close if the flow rate through them is less than the design rate, or if some foreign material prevents the ball from seating.

[8] The CSB investigators contacted approximately 30 bulk chlorine users.

Furthermore, these systems should be designed to be highly reliable[9] to ensure that they will function when required. The emergency shutdown system should be regularly tested and maintained.[10] Chlorine transfer and emergency shutdown procedures should be in writing and employees should be trained on them.

OSHA and EPA Regulations

The OSHA Process Safety Management (PSM) standard (29 CFR 1910.119) and the EPA Risk Management Program (40 CFR 68) require that facilities handling significant amounts of chlorine (more than 1,500 pounds for PSM and more than 2,500 pounds for the Risk Management Program) implement comprehensive management systems to prevent or minimize the consequences of a release (OSHA, 2006),(EPA, 2006).

These regulations require:

- "[T]hat equipment complies with recognized and generally accepted good engineering practices" [29 CFR 1910.119(d)(3)(ii); 40 CFR 68.65 (d)(2)];
- A comprehensive process hazards analysis that addresses "[e]ngineering and administrative controls applicable to the hazards…" [§ 1910.119(e)(3)(ii); §68.67(c)(7)]; and that
- Equipment "inspections and tests shall be performed…" [§ 1910.119(j)(4)(i); §68.73(d)(1)].

Because these are performance-based regulations, neither have specific requirements for chlorine railcar unloading systems.

[9] For more information about safety integrity levels for critical components, see International Electrotechnical Commission (IEC), 2004. 61511, "Functional Safety Instrumented Systems for the Process Industry Sector."

[10] For detailed information, see The Chlorine Institute, Inc., 2003. "Emergency Shut-off System for Bulk Transfer of Chlorine," Pamphlet 57, 4th ed., October 2003.

DOT Regulations

The Department of Transportation (DOT) Hazardous Materials Regulations (HMR; 49 CFR 171 through 180) govern transportation of hazardous materials by rail, aircraft, vessel, and motor vehicle tank truck (DOT, 2006). The HMR requires emergency shutdown equipment for motor vehicle tank truck chlorine transfer systems but not for railcar chlorine transfer systems.

On October 30, 2003, the DOT issued a final rule clarifying the scope of the HMR, which defines transportation as "the movement of property and loading, unloading, or storage incidental to the movement." The final rule explained that transportation, and therefore DOT regulatory authority, ends when the consignee takes possession of the material (DOT, 2003).

When hazardous materials are delivered to a facility by tank truck, the carrier usually unloads the material for the consignee, who then takes possession after unloading. When hazardous materials are delivered by railcar, the consignee commonly takes possession when the railcar is placed onsite; the material is later unloaded by the consignee. As a result of this distinction, the HMR covers tank truck unloading but not railcar unloading.

The NTSB identified this as a regulatory gap in its investigation of the 2002 ATOFINA incident and recommended that the DOT develop safety requirements that include "emergency shutdown measures" for railcar unloading (NTSB, 2002).[11] However, the DOT did not implement the recommendation; the NTSB classified the DOT response "Open-Unacceptable Response," and asked the DOT to reconsider.[12]

[11] During the 2001 ATOFINA investigation, the NTSB interviewed nine companies that handled hazardous materials and found that six relied solely on excess flow valves to stop leaks (NTSB, 2002).

[12] As of the writing of this bulletin, the NTSB recommendation to DOT remains classified as "Open-Unacceptable Response."

The Chlorine Institute Recommendations

The Chlorine Institute, Inc. is a trade association that represents companies that manufacture, distribute, and use chlorine. The Chlorine Institute members produce 98 percent of chlorine manufactured in the United States and Canada (Chlorine Institute, 2007). The Chlorine Institute develops and publishes technical and safety pamphlets with recommendations for handling and distributing chlorine, which include requirements for railcar unloading. Its members agree to adhere to these recommendations and to a signed safety and security commitment.

The Chlorine Institute requires its members to also ensure that their customers:

- Are adhering to The Chlorine Institute safety recommendations,
- Have a risk management program in place, and
- Are in compliance with the "Chlorine Customers Generic Safety and Security Checklist" in The Chlorine Institute Pamphlet 85, "Recommendations for Prevention of Personal Injuries for Chlorine Production and Use Facilities" (Chlorine Institute, 2005).[13]

Pamphlet 85 specifically requires "a remotely operated or automatically actuated emergency shutoff valve system in place which can safely isolate both ends of transfer hoses/flexible piping."

Lessons Learned

- Excess flow valves should not be relied upon as the sole means to stop chlorine releases during railcar unloading.
- Effective emergency shutdown systems are critical in preventing major chlorine releases.
    - Emergency shutdown systems should be designed in accordance with industry best practices, such as those published by The Chlorine Institute.
    - Procedures for using emergency shutdown systems should be in writing, and personnel should be trained on their use.
    - Emergency shutdown systems should be maintained and tested periodically to verify their operability.

[13] Bulk chlorine customers (those that receive chlorine by railcars, barges, or tank trucks) must comply by December 31, 2007. Packaged chlorine customers (those who receive chlorine in 2,000 pound containers or cylinders) must comply by December 31, 2008.

Recommendations

US Department of Transportation

2005-06-I-LA-R1

Expand the scope of DOT regulatory coverage to include chlorine railcar unloading operations. Ensure the regulations specifically require remotely operated emergency isolation devices that will quickly isolate a leak in any of the flexible hoses (or piping components) used to unload a chlorine railcar. The shutdown system must be capable of stopping a chlorine release from both the railcar and the facility chlorine receiving equipment. Require the emergency isolation system be periodically maintained and operationally tested to ensure it will function in the event of an unloading system chlorine leak.

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