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# Failures of Excess Flow Valves in Hazardous Materials Service

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.

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## Problem

*Undue reliance may be placed on excess flow valves (EFVs) as the sole, or primary, protection to control accidental chemical releases from tanks and piping.*

Excess flow valves (EFVs) are protective devices intended to prevent the uncontrolled release of hazardous materials from transport and storage vessels. 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.

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 recent 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, and stationary tankage. 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

*Failure to understand the limitations of EFVs has been a contributing factor in a number of significant incidents where flow restrictions prevented EFV closure.*

**8/2002 in Missouri** - Forty-eight thousand pounds of chlorine were released when an out-of-specification chlorine transfer hose ruptured during railroad tank car unloading operations. The release continued unabated for nearly 3 hours until HAZMAT personnel closed the tank car valves. Sixty-three people from the surrounding community sought medical evaluation due to respiratory distress. The community was advised to shelter-in-place for 4 hours, and traffic on the nearby interstate was halted for 1½ hours. A subsequent U.S. Chemical Safety and Hazard Investigation Board (CSB) investigation determined that the flow from the ruptured hose may have been too low for the EFV to close. Also, the emergency shut-off system at the facility did not work as intended.

**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. 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 EFV 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 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 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.

**9/1996 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 Department of Transportation (DOT) Research and Special Programs Administration 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.

A common theme in these accidents is that flow restrictions prevented the flow through an EFV from exceeding the shut-off flow rate. A literature review revealed a number of additional incidents where the rates of discharge from releases were insufficient to close the EFVs.

## 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. 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).

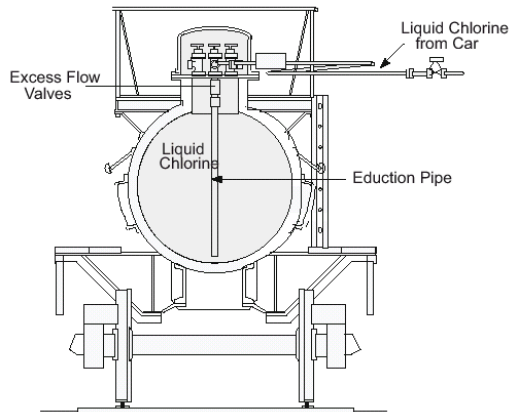


Figure 1. EFV in Chlorine Railcar Liquid Outlet Line

EFVs are used with a variety of hazardous chemicals, of which chlorine, liquefied petroleum gases (LPG), and anhydrous ammonia are among the most common. Consequently, these three chemicals are used as examples in this *Hazard Alert*. Guidance for the application of EFVs with regard to these three 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 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.

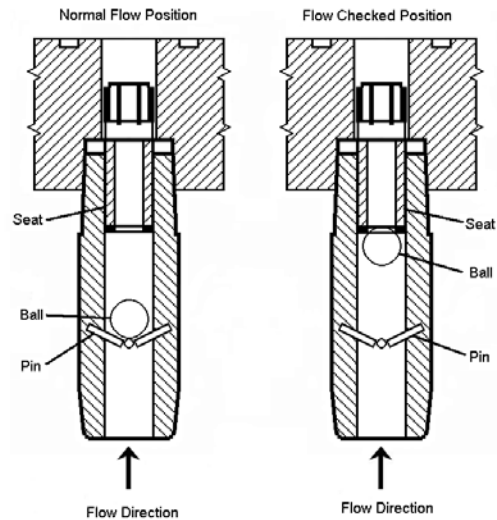


Figure 2. EFV For Chlorine Service

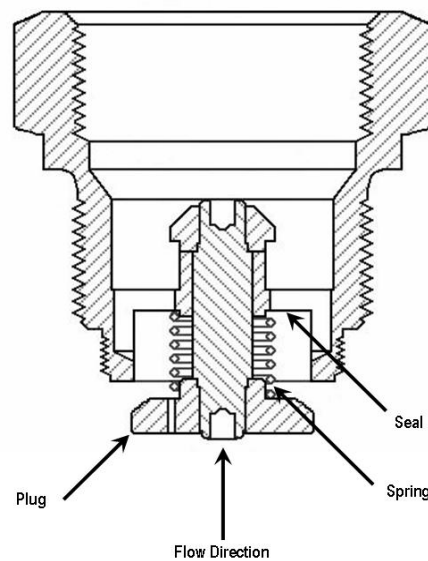


Figure 3. EFV For Ammonia or LPG Service

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 more common 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 EFVs 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 from likely release points, such as flexible hoses in unloading systems to determine if the flow resistance in the intervening piping 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 when the 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.

### *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 (ITPM) 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.
- Controls to manage system changes that might otherwise compromise the function of the EFV.

### *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 release, 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 would be more prone to a release than a system containing more robust rigid piping.
- 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 of the 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 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.

The technologies, systems, and practices cited above are meant only to be illustrative, 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 ("hands-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; 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 releases 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. Appropriate revisions should be made to Risk Management Program elements such as operating procedures, training, and emergency response plans.

## 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 (b)(1) - General Duty
- EPA's Risk Management Program (RMP) 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

- U.S. Chemical Safety and Hazard Investigation Board: Report No. 98-007-I-IA, "Propane Tank Explosion" and Safety Advisory No. 2002-01-SA, "Chlorine Transfer Hose Failure"
- 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"

## For More Information:

Contact EPA's Emergency Planning and  
Community Right-to-Know Hotline  
(800) 424-9346 or (703) 412-9810  
TDD (800) 553-7672

Monday-Friday, 9 AM to 6 PM, Eastern Time

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Visit the Emergency Prevention, Preparedness and  
Response website:

<http://www.epa.gov/emergencies>

### NOTICE:

The statements in this document are intended solely as guidance. This document does not substitute for or change any applicable statutory provisions or regulations, nor is it a regulation itself. The guidance it provides may not be appropriate for every situation.