



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).

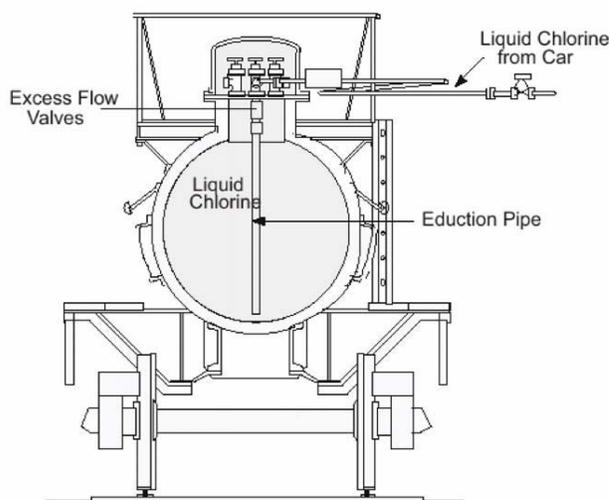


Figure 1. EFV in Chlorine Railcar Liquid Outlet Line

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.

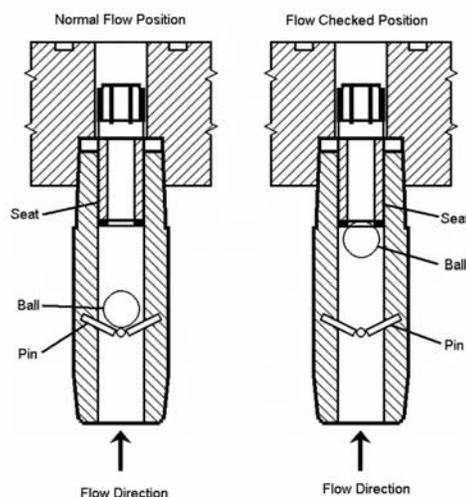


Figure 2. EFV for Chlorine Service

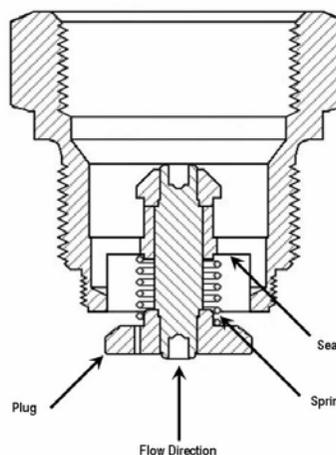


Figure 3. EFV for Ammonia or LPG Services

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),

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| <p>Herrig Brothers Feather Creek Farm,
Albert City, Iowa, April 9, 1998.”</p> <ul style="list-style-type: none">• 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 | <p>No. 2002-01-SA, “Chlorine Transfer Hose Failure”</p> <ul style="list-style-type: none">• U.S. Chemical Safety and Hazard Investigation Board: Safety Bulletin No. 2005-06-I-LA, “Emergency Shutdown Systems for Chlorine Transfer” |
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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

