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Environmental Protection
Agency

Office of Solid Waste
and Emergency Response
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CEPP

CATASTROPHIC FAILURE OF STORAGE TANKS

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. Under CERCLA, section 104(e) and Clean Air Act (CAA), EPA has authority to conduct chemical accident investigations. Additionally, in January 1995, the Administration asked the Occupational Safety and Health Administration (OSHA) and EPA to jointly undertake investigations to determine the root cause(s) of chemical accidents and to issue public reports containing recommendations to prevent similar accidents. EPA has created a chemical accident investigation team to work jointly with OSHA in these efforts. Prior to the release of a full report, EPA intends to publish *Alerts* as promptly as possible to increase awareness of possible hazards. *Alerts* may also be issued when EPA becomes aware of a significant hazard. It is important that facilities, SERCs, LEPCs, emergency responders and others review this information and take appropriate steps to minimize risk.

CHEMICAL SAFETY
ALERT

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PROBLEM

Catastrophic failures of aboveground, atmospheric storage tanks can occur when flammable vapors in the tank explode and break either the shell-to-bottom or side seam. These failures have caused the tanks to rip open and, in some cases, hurled the tanks through the air. A properly designed and maintained storage tank will break along the shell-to-top seam. Then, the fire would more likely be limited to the damaged tank and the contents would not be spilled. This alert describes the types of tanks that may be prone to catastrophic failure and maintenance practices that can help prevent the accidents.

RECENT ACCIDENTS

Several accidents have occurred within the last few years in which storage tanks have failed catastrophically when the flammable vapors inside an atmospheric tank exploded. The tank was either propelled upward from its base (shell-to-bottom seam failed) or split along the side seam. As a result, workers were killed or injured and the contents were released into the environment.

Three specific incidents demonstrate the potential dangers posed to workers, the public, and the environment when these storage tanks fail catastrophically. In these incidents, the shell-to-bottom seam failed after an explosion and the tank was propelled upward. All occurred in older, atmospheric steel storage tanks. Often workers were performing tank maintenance or other activities that introduced an ignition source. The vapors were ignited either inside the tank or outside and then flashed back into the tank.

In a 1995 incident, during a welding operation on the outside of a tank, the combustible vapor inside two large, 30-ft. diameter by 30-ft. high, storage tanks exploded and propelled the tanks upward — one landing more than 50 feet away. The flammable liquid inside was instantly released and ignited, resulting in a massive fire that caused five deaths and serious injuries.

In a 1992 incident, while workers were welding the outside of a tank empty of liquid, the residual vapor in the storage tank exploded and propelled the tank upward and into an adjacent river. Three workers were killed and one was injured.

In a 1994 incident, during a grinding operation on a tank holding petroleum-

based sludge, the tank was propelled upward, injuring 17 workers and spilling its contents over a containment berm into a nearby river.

Hazard Awareness

Tank design and inspection/maintenance practices are factors directly related to catastrophic tank failure.

Tank design

Historically, accidents where the shell-to-bottom seam fails are more common among older storage tanks. Steel storage tanks built before 1950 generally do not conform to current industry standards for explosion and fire venting. Atmospheric tanks used for storage of flammable and combustible liquids should be designed to fail along the shell-to-roof seam when an explosion occurs in the tank. This prevents the tank from propelling upward or splitting along the side. Several organizations have developed standards and specifications for storage tank design. Published standards relevant to this design feature include API-650,"Welded Steel Tanks for Oil Storage" issued by the American Petroleum Institute (API). Additional codes and standards, published by API and other organizations, address tank design, construction, venting, and safe welding and are listed at the end of this alert.

Poor inspection, maintenance, and repair practices

Tanks that are poorly maintained, rarely inspected, or repaired without attention to design, risk catastrophic failure in the event of a vapor explosion. Either weakening of the shell-to-bottom seam through corrosion or strengthening the shell-to-roof seam relative to the shell-to-bottom seam will increase the vulnerability of the tank to failure along the shell-to-bottom seam. The practice of placing gravel and spill absorbants around the base of the tank, may increase the likelihood of bottom corrosion. Given years of this practice, the bottom of some tanks, especially older ones, may be below ground level, thereby trapping moisture along the tank bottom. This can weaken the bottom and the shell-to-bottom seam. Alternatively, changes to the roof seam such as modifications to or replacement of the roof, or attachments to the roof, could make the roof-to-shell seam stronger relative to the shell-to-bottom seam.

Other hazards that can contribute to a tank explosion and possible consequences are:

Combustible vapors

Generation of combustible vapors is a hazard not only for the storage of pure flammable liquids but also for the storage of any sludge or mixture where a combustible component is present or can be produced by reaction. Sludge (slop tanks) and mixture (e.g., oil/water) tanks may be particularly vulnerable because they are sometimes open to the air; explosive atmospheres may form inside and outside the tank. Facilities may not always recognize this hazard. In addition, even tanks appearing to be empty may pose a hazard if they still contain combustible vapors.

In the cited cases, the potential for combustible vapors was not clearly recognized and materials were stored in tanks that were not equipped with flame arresters to prevent external fire from reaching the vapor space inside the tank or with vapor control devices to limit vapor emissions from the tank.

Ignition sources

When combustible vapors escape from their containment and mix with air in the presence of an ignition source, combustion may occur. To minimize this hazard, all possible ignition sources must be isolated from potential combustible vapors, e.g., welding equipment or other maintenance equipment that can spark or arc, sources of static electricity, lightning, "hot work" in adjacent areas, and any electrical equipment in the vicinity of tanks that does not conform to National Fire Protection Association (NFPA)-70, "National Electric Code."

Proximity to workers and environment

The danger posed by these tanks is often increased when the location of the tank does not conform with current minimum spacing requirements. Sections 2-3.2 to 2-3.3 of NFPA-30 discuss minimum spacing. For mitigating consequences to workers, the environment, and other tanks, proper secondary containment (diking) should be considered for containment.

Hazard Identification

Facilities should evaluate their storage tanks for potential to catastrophically fail and identify factors that could cause storage tank explosion. Some of the factors to look for include, but are not limited to, the following:

- Atmospheric storage tanks that do not meet API-650 or other applicable code(s) and contain flammable liquids or liquids that may produce combustible vapor.
- Tanks with corrosion around the base and/or steel tanks whose base is in direct contact with ground and exposed to moisture.
- Tanks or associated structures (e.g., pipes) with weakened or defective welds.
- Tanks used to store mixtures containing water and flammables where the water phase is at the tank bottom and may contribute to internal bottom corrosion.
- Tanks containing combustible vapor and not equipped with flame arrestors or vapor control devices to limit emissions.
- Possible ignition sources near tanks containing combustible vapor.

Process Safety Areas for Hazard Reduction

Storage tanks should comply with all regulations, industry codes and standards, including inspection and maintenance requirements to keep tanks in proper condition. Facilities with storage tanks that can contain flammable vapors should review their equipment and operations. Areas to review should include, but not be limited to, the following:

1) Design of atmospheric storage tanks

API and other organizations have standards and codes that address recommended practices for tank design and construction. It is imperative to evaluate whether the liquids or certain components of liquid mixtures may generate combustible vapors. Design measures include fire protection, flame arrestors, emergency venting (such as part of the API-650), prevention of flash back (for tanks containing flammable liquids), and proper berming or diking.

2) Inspection and maintenance of storage tanks

API-653 has tank inspection guidelines and procedures for periodic inspections and testing, especially for older tanks. These procedures call for written documentation of inspections by API Certified Tank Inspectors. Measures to review include procedures for pressure testing, welding inspections, and checks for corrosion or metal fatigue. API-650 specifies welding procedures and welding qualifications as well as joint inspection (e.g., radiograph and magnetic particle examination). Programs for tank inspection and maintenance should be developed in accordance with these standards.

3) Hot-work safety

Both the Occupational Safety and Health Administration's (OSHA) regulations concerning

hot work and NFPA's standards on welding should be reviewed for compliance. Hazard reduction measures include proper hot-work procedures such as obtaining a hot work permit, having a fire watch and fire extinguishing equipment present, and proper testing of atmosphere for explosivity; covering and sealing all drains, vents, manways, and open flanges; sealing all sewers (to prevent gas or vapor migration); and training workers and providing them with appropriate protective equipment.

4) Ignition source reduction

Both OSHA regulations and NFPA standards should be reviewed for compliance. Hazard reduction measures may include: having all electrical equipment in a hazardous environment conform with the requirements of the National Electric Code (NFPA-70), grounding tanks to dissipate static charge, using only "non-spark producing" tools and equipment in flammable atmospheres, and taking care to not create sufficient heat or sparks to cause ignition of flammable vapors.

Information Resources for Hazard Reduction

The above information is for general guidance only. References with information about the hazards of catastrophic failures and methods of minimizing them are listed below. Regulations potentially applicable to storage tanks and codes and standards that may be relevant are included.

For more information consult the following:

Statutes and Regulations

Section 112(r) of the Clean Air Act focuses on prevention of chemical accidents. It imposes on facilities with regulated substances or other extremely hazardous substances a general duty to prevent and mitigate accidental releases. Accident prevention activities include identifying hazards and operating a safe facility.

EPA's Risk Management Program (RMP) Rule [40 CFR 68] is intended to prevent and mitigate accidental releases of listed toxic and flammable substances. Requirements under the RMP rule include development of a hazard assessment, a prevention program, and an emergency response program.

EPA has tank inspection regulations under the Spill Prevention Countermeasure and Control Plan and Oil Pollution Control Act of 1990 [40 CFR119].

The Occupational Safety and Health Administration (OSHA) has the Process Safety Management Standard [29 CFR 1910.119], which includes regulations on tank inspection, fire prevention, and conduct during hot-work; regulations concerning the storage of flammable and combustible liquids [29 CFR 1910.106]; regulations concerning fire protection and prevention during welding, brazing, and cutting [29 CFR 1910.252] and regulations covering the duties and responsibilities of a fire watch [29 CFR Part 126].

Occupational Safety and Health Administration
Phone: (202) 219-8151 - Public Information
Web site: http://www.osha.gov

Codes and Standards

The American Petroleum Institute (API) has tank standards and guidelines on safe welding.

American Petroleum Institute
1220 L St NW
Washington DC 20005
Phone: (202) 682-8000
Web site: http://www.api.org

Relevant API standards include:
API Standard 620 — Design and Construction of Large, Welded, Low-Pressure Storage Tanks, ninth edition, February 1996 (includes Addendum 1, December 1996).

[API Standard 650 comes from] Welded Steel Tanks for Oil Storage, ninth edition, May 1993 (includes Addendum 1, December 1994; Addendum 2, December 1995; and Addendum 3, December 1996).

API Recommended Practice (RP) 651 — Cathodic Protection of Aboveground Petroleum Storage Tanks, first edition, April 1991.

API RP 652 — Lining of Aboveground Petroleum Storage Tank Bottoms, first edition, April 1991.

API Standard 653 — Tank Inspection, Repair, Alteration, and Reconstruction, second edition, December 1995 (includes Addendum 1, December 1996).

API Standard 2000 — Venting Atmospheric and Low-Pressure Storage Tanks: Nonrefrigerated and Refrigerated, fourth edition, September 1992.

API RP 2003 — Protection Against Ignitions Arising Out of Static, Lightning, and Stray Current, fifth edition, December 1991.

API PUBL 2210 — Flame Arrestors for Vents of Tanks Storing Petroleum Products, second edition, 1982.

API RP 2350 — Overfill Protection for Petroleum Storage Tanks, first edition, March 1987.

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The American National Standards Institute (ANSI) has the B-31.3 Refinery Piping Code and other standards and codes.

American National Standards Institute
655 15th St NW
Washington DC 20005
Phone: (202) 639-4090 or
11 West 42nd St
New York, NY 10036
Phone: (212) 642-4900
Web site: http://www.ansi.org

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The American Society of Mechanical Engineers (ASME) has the Pressure Vessel Code and other codes relevant to tanks and storage vessels.

American Society of Mechanical Engineers
1828 L St NW, Suite 906
Washington DC 20036
Phone: 1 (800) 843-2863 or (202) 785-3756
Publications and membership 1 (800) 843-2763
Codes and standards (212) 705-8500
Accreditation and certification programs (212) 705-8581
Web site: http://www.asme.org

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The American Society of Nondestructive Testing (ASNT) certifies welding and non-destructive examination (NDE) and non-destructive testing (NDT) inspectors.

American Society of Nondestructive Testing
P.O. Box 28518
1711 Arlingate Lane
Columbus, OH 43228
Phone: 1 (800) 222-2768 or (614) 274-6003
Web site: http://www.asnt.org

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The American Welding Society (AWS) certifies welding inspectors with the designation AWS QC-1 (Quality Control) Welding Inspector and has guidelines on safe welding.

American Welding Society
550 NW LeJeune Rd
Miami, FL 33126
Phone: 1 (800) 443-9353 or (305) 443-9353
Web site: http://www.amweld.org

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The National Fire Protection Association (NFPA) has lightning and flammable/combustible liquid codes.

National Fire Protection Association
1 Batterymarch Park
P.O. Box 9101
Quincy, MA 02269-9101
Phone: (617) 770-3000
Customer Service: 1 (800) 344-3555
Web site: http://www.nfpa.org

Relevant NFPA codes include:
NFPA 30 — Flammable and Combustible Liquid Code, 1996 edition.
NFPA 51 — Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes, 1992.

NFPA 51B — Fire Prevention in Use of Cutting and Welding Processes, 1994.
NFPA 70 — National Electric Code, 1996.
NFPA 77 — Static Electricity, 1993.
NFPA 780 — Lightning Protection Code, 1995.

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Underwriters Laboratories Inc. (UL) has standards for product safety.

Underwriters Laboratories Inc.
333 Pfingsten Rd
Northbrook, IL 60062
Phone: (847) 272-8800
Web site: http://www.ul.com

Relevant UL standards include:
UL-142 — Standard for Steel Aboveground Tanks for Flammable and Combustible Liquids, 1993.

FOR MORE INFORMATION...

CONTACT THE 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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http://www.epa.gov/swercepp/