United States
Environmental Protection
Agency

Office of Solid Waste
and Emergency Response
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EPA

CEPPO

RUPTURE HAZARD OF PRESSURE VESSELS

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

Improperly operated or maintained pressure vessels can fail catastrophically, kill and injure workers and others, and cause extensive damage even if the contents are benign.

ACCIDENTS

In a 1996 accident, three workers were killed and a number of others were injured when a high-pressure vessel containing air and water ruptured.

The vessel that ruptured was originally designed with a working pressure of 1740 pounds per square inch (psi), but was operating between 2000-3000 psi. After a number of years of service, the vessel developed a pin-hole leak. The leak was repaired but not in adherence with recognized codes. About a month later, the vessel failed catastrophically at the weld area. The vessel ripped apart and rocketed through the roof. Major pieces of shrapnel weighed from 1000 to 5000 pounds. Some pieces were thrown a half mile away. Fortunately, people on a nearby highway and a nearby commuter railway narrowly missed injury. Damage to the plant was extensive and a portion of the state was without phone and electrical services for many hours.

HAZARD AWARENESS

This accident demonstrates the potential danger of pressure vessels if they are not properly designed, constructed, operated, inspected, tested, or repaired. The higher the operating pressure and the larger the vessel, the more energy will be released in a rupture and the worse the consequences. It should be emphasized that the danger exists even if the vessel contents are not flammable, reactive, or explosive. In the case above, a vessel containing only water and air ruptured and released great energy. Had the contents of the vessel been flammable and/or toxic, the consequences would probably have been magnified.

Factors in Pressure Vessel Failure

The following conditions and factors have played major roles in pressure vessel accidents:

- Operation above the maximum allowable working and test pressures.

- Improper sizing or pressure setting of relief devices.
- Improper operation of relief devices due to faulty maintenance and failure to test regularly.
- Failure of the vessel due to fatigue from repeated pressurization, general thinning from corrosion or erosion, localized corrosion, stress corrosion cracking, embrittlement, holes and leaks.
- Failure to inspect frequently enough.
- Improper repair of a leak or other defect involving welding and annealing that embrittles and further weakens the vessel. Hazards posed by a vessel can be worse if repair welds are made without shutting down and de-inventorying the vessel. If a pressure vessel is repaired without removing the water, the quench effect of the water can embrittle the steel.
- Overpressuring and failure of the vessel due to exothermic reaction or polymerization.
- Vessel exposure to fire.

Pressure Vessel Laws

Requirements for pressure vessels vary widely from state to state. Many states have a boiler law, but others do not. Even for those states that have a boiler law, typical practices (e.g., inspector requirements) for pressure vessels may vary. State boiler laws that require general adherence to American Society of Mechanical Engineers (ASME) codes or National Board Inspection Code (NBIC) usually require the following for each pressure vessel:

- Registering with the state boiler and pressure vessel department.
- Designing and constructing in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code (ASME Code), "Rules for Construction of Pressure Vessels" Division 1, which covers vessels operating between 15 psi and 3000 psi.
- Marking the ASME Code on the vessel with specified information that includes the manufacturer, the serial number, the year built, and the maximum allowable working pressure for a specific temperature, and any special suitability such as for low temperature and poisonous gases or liquids.
- Having the vessel approved for installation with the submission of drawings, specifications, welding details and calculations, and having an authorized inspector be satisfied with the welding and witness the testing.
- Operating at pressures below the maximum allowable working pressure with pressure relieving devices set according to the ASME Code; testing at regular intervals.
- Periodically inspecting for corrosion and defects, and testing according to the NBIC "A Manual for Boiler and Pressure Vessel Inspectors" or API 510, "Pressure Vessel Inspection Code," for vessels in the petrochemical industry.
- Repairing or altering only according to a plan approved by an authorized inspector and conducted by test-qualified welders. The inspector must be satisfied that the repairs are performed according to NBIC or API 510 and specify any necessary nondestructive and pressure testing. Increasing the maximum allowable working pressure or temperature is considered an alteration whether or not physical work is done.

Authorized NBIC inspectors must be employees of an authorized inspection agency such as (1) a state boiler and pressure vessel department, (2) an insurance company licensed to provide boiler and pressure vessel insurance, or (3) an owner-user who maintains a regularly established

inspection department, whose organization and procedures meet National Board rules. API authorized inspectors may also serve under contract to an owner-user who maintains an established inspection department. Inspectors must qualify by written examination and NBIC inspectors must hold a valid National Board Commission.

In states with no pressure vessel law, good safety practices require that similar precautions be followed in the design, construction, welding, testing, marking, operation, inspection, and repair of any pressure vessel. The ASME Code should be used for the design, construction, initial testing, and operation of pressure vessels. The NBIC or API 510 should be used for maintenance and inspection and subsequent testing. Boiler and machinery insurance companies, some pressure vessel suppliers, or jurisdiction-licensed independent contractors can provide authorized inspectors.

Evaluating Potential Explosion Hazard

Facilities, particularly those without formal pressure vessel inspection programs, should survey their vessels, review pertinent history and data to identify hazards, and prevent vessel rupture or catastrophic failure. Among the questions to be asked and answered are the following:

- Does the vessel operate above 15 psi, and was it designed, fabricated, and constructed according to the ASME Code or other applicable code? Is the vessel code labeled or stamped? Is the operating pressure and size of the vessel known?
- Is the vessel maintained, inspected, and repaired according to the NBIC and/or API 510?
- Are the ratings and settings of the relieving devices appropriate? Are the devices tested regularly and how recently?
- Is the vessel inspected periodically? What are the criteria for inspection frequency? When was it last inspected externally? When was it last inspected internally? Did the inspection disclose general thinning of walls due to corrosion, localized corrosion, stress corrosion cracking, embrittlement, holes, leaks, or any other defects that required follow up? Were they followed up?
- Has the vessel been repaired? Were the plan of repair, welding techniques and safety tests approved by a certified or authorized inspector? Was the welding done by a qualified welder? Were the welding performance qualification tests approved by an inspector? Was the vessel tested after the repair was completed?
- Was the vessel down rated and were the necessary changes in operating conditions and relief device settings made?
- Are exothermic reactions carried out in the vessel? Does the vessel have an emergency relief system to handle runaway reactions?

Process Safety Areas for Hazard Reduction

Pressure vessels must comply with all regulations, industry codes, and standards to keep vessels in safe condition to handle design pressures and temperatures. Areas to review could include, but are not limited to, the following:

Design

At a minimum, pressure vessels should be designed in accordance with the ASME Code for material contents of varying characteristics. Facilities should address any added concerns about the temperature and characteristics of vessel contents (e.g., toxic, corrosive, reactive, or flammable contents). When the vessel contents are changed from those the vessel was designed for, a risk analysis should be conducted to determine if it is still safe for the new materials.

Certification of Vessels

In states with a pressure vessel law, all pressure vessels must be certified by the relevant state authority, such as a Chief Boiler and Pressure Vessel Inspector, as meeting requirements of the ASME Code. When a pressure vessel cannot be constructed to comply fully with the ASME Code, however, the NBIC provides a procedure by which the pressure vessel may get state approval without bearing the ASME symbol. This procedure includes submittal of drawings, calculations, welding procedures, service conditions, welding qualification and performance tests, and professional engineering certifications. This should be done before any construction begins.

When a facility finds an unmarked vessel or is about to bring one into a state, similar information plus the repair history should be submitted to the state pressure vessel authority for review and approval before use begins or continues.

On the other hand, when a pressure vessel is located in a state without a pressure vessel law, is not marked with the ASME symbol, and there are doubts about the safety of the vessel, the information listed above should be submitted to a pressure vessel consulting engineer and authorized inspector for a safety review.

Inspection

The NBIC and API 510 require that vessels be periodically inspected externally and internally. External inspections are made more frequently and involve visual and nondestructive examination. An internal inspection is more difficult to perform because it usually requires a confined space entry and the vessel must be taken out of service, cleaned, and prepared. General or localized thinning of the internal walls due to corrosion or erosion is a potential problem and must be monitored, with records kept of the rate of thinning. When the vessel is reaching the end of its useful life, the period between inspections is shortened so that the vessel may be taken out of service before it can become dangerous. An internal test may also reveal stress corrosion, cracking, pitting, embrittlement, and other defects that could weaken the vessel. In addition to the vessel itself, the relieving devices must also be tested. When practical, this can be done in place for vessels containing non-hazardous substances, but for vessels containing hazardous substances without special controls (e.g., scrubbers), safety relief valves must be taken off to ascertain whether their settings are correct. How this can be done safely and conveniently should be considered.

Maintenance

In addition to maintenance requirements, the NBIC and API 510 include specific preheating and postheating requirements. Large temperature differences between the outside and inside surfaces of the vessel - during repair or other welding - must be avoided to minimize embrittling or stressing the metal. Nondestructive examinations may include radiographic, ultrasonic, liquid penetrant, magnetic particle, eddy current, visual checks, and leak testing.

Operation of Vessels

Operators should consider process start-up and shutdown conditions, possible process upsets, and any other unusual conditions that might cause overpressure problems. The ASME Code includes recommended pressure differentials between safety valve set pressures and maximum allowable working pressure, as well as the pressure differential settings of the relieving devices when there are multiple devices.

Information Resources for Hazard Reduction

The above listed information is generalized guidance only. Some references that contain information about the hazards of pressure vessel ruptures and methods of minimizing these hazards are listed below. Regulations potentially applicable to pressure vessels, and codes and standards that may be relevant, are also listed below.

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.

The Occupational Safety and Health Administration (OSHA) has the Process Safety Management Standard, which includes regulations on tank inspection and conduct during hot-work.

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

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Codes and Standards

The American National Standards Institute (ANSI) has vessel inspection standards and codes, including the NBIC. The purpose of the NBIC is to maintain the integrity and safety of boilers and pressure vessels after they have been placed in service by providing rules and guidelines for inspection after installation, repair, alteration, and rerating.

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

Relevant ANSI standards include:
ANSI/NB 23 — National Board Inspection Code, 1995 (see also API-510).

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The American Petroleum Institute (API) has vessel standards, guidelines, and recommended practices.

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

Relevant API standards include:
ANSI/API-510 — Pressure Vessel Inspection Code-Maintenance Inspection, Rating, Repair, and Alteration, seventh edition, 1992 (covers vessels in the petroleum and chemical process industries; see also ANSI/NB 23).

Supplement 2 to ANSI/API-510 — Pressure Vessel Inspection Code-Maintenance Inspection, Rating, Repair, and Alteration, December 1994 (contains revisions to Sections 1, 2, 3, 4, 5, and Appendices B and D).

ANSI/API Recommended Practice 572 — Inspection of Pressure Vessels, first edition, January 1992.

API Standard 653 — Tank Inspection, Repair, Alteration, and Reconstruction, second edition, December 1995.

ANSI/API-920 — Prevention of Brittle Fracture of Pressure Vessels, first edition, March 1990.

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The American Society of Mechanical Engineers (ASME) has the Boiler and Pressure Vessel Code that establishes rules of safety governing the design, fabrication, and inspection during construction of boilers and pressure 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 nondestructive examination (NDE) and nondestructive 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 Board of Boiler and Pressure Vessel Inspectors promotes greater safety to life and property through uniformity in the construction, installation, repair, maintenance, and inspection of boilers and pressures. A list of Chief Boiler and Pressure Vessel Inspectors is available on the internet or through the Board.

National Board of Boiler and Pressure Vessel Inspectors
1055 Cruppe Avenue
Columbus, OH 43229
Phone: (614) 888-8320
Web site: http://www.nationalboard.org

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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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Visit the CEPPO Home Page on the World Wide Web at:

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