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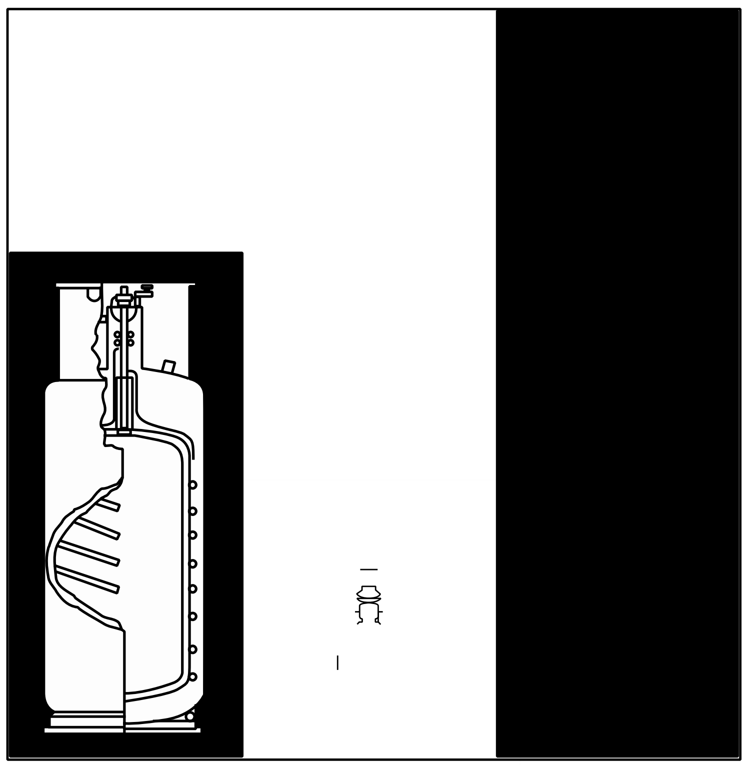
Pressure Safety Orientation

Live #769



July 2017

Los Alamos NATIONAL LABORATORY

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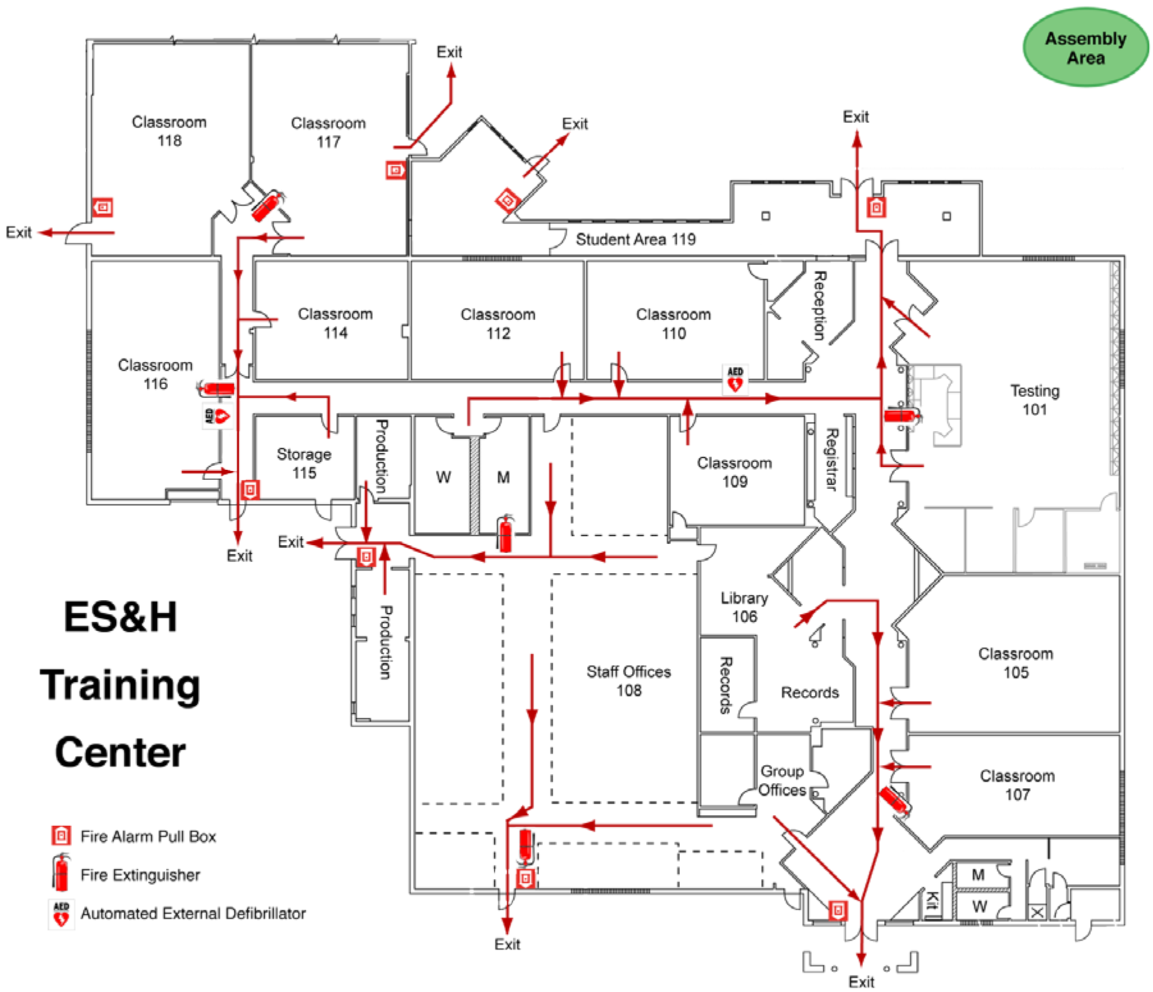

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COURSE 769
July 2017
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Contents

Introduction

Course Overview

Pressure Safety Orientation (course #769) introduces workers at Los Alamos National Laboratory (LANL) to the Laboratory Pressure Safety Program and to pressure-related hazards. This course also affords a hands-on exercise involving the assembly of a simple pressure system.

This course is required for all LANL personnel who work on or near pressure systems and are exposed to pressure-related hazards. These personnel include pressure-system engineers, designers, fabricators, installers, operators, inspectors, maintainers, and others who work with pressurized fluids and may be exposed to pressure-related hazards.

Course Objectives

When you have completed this course, you will be able to

- recognize the energy release hazards and potential accidents related to pressure systems,
- recognize hazards other than energy release hazards associated with the storage of fluids under pressure,
- identify the major components of the Laboratory Pressure Safety Program,
- recognize pressure-related accidents and lessons learned, and
- identify basic pressure system safety features.

Program Owner

The authors developed this course under the direction and technical oversight of the Occupational Safety and Health Division (OSH), the functional program owner for this training.

Target Audience

The LANL employees who work with or near pressurized systems and the supervisors of pressure system workers will benefit by taking this course, which has no prerequisites.

Course Limitations

This course does not address every type of hazard that may be associated with pressurized systems. It does not address site-specific pressurized hazards, nor does it eliminate the need for site-specific training.

Acronyms

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
CGA	Compressed Gas Association
CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
ESM	Engineering Safety Manual
HPI	Human Performance Improvement
IWD	integrated work document
LANL	Los Alamos National Laboratory
MAWP	maximum allowable working pressure
MOP	maximum operating pressure
NBIC	National Board Inspection Code
NFPA	National Fire Protection Association
NMED	New Mexico Environment Department
OSH	Occupational Safety and Health Division
OSHA	Occupational Safety and Health Administration
P	procedure
PPE	personal protective equipment
PSC	Pressure Safety Committee
psi	pounds per square inch
psig	pounds per square inch gauge
RFO	restricted flow orifice

Module 1: Laboratory Pressure Safety Program

Module Overview

The Laboratory instituted its Pressure Safety Program to help workers and others become more aware of pressure-related hazards and to control these hazards. This program is composed of required training, Laboratory documents in the form of procedures (Ps), and a pressure safety committee, as well as groups that provide support. This module describes the components of the Laboratory Pressure Safety Program.

Module Objectives

When you have completed this module, you will be able to

- recognize training requirements for pressure-system workers;
- recognize pressure-related codes, standards, regulations, and Laboratory requirements; and
- identify LANL pressure safety resources and supports.

Pressure Safety Training Requirements

LANL requires that only trained and qualified personnel design, install, test, inspect, maintain, and operate pressure systems at the Laboratory. If you work with pressure systems at LANL, you are required to take this course, *Pressure Safety Orientation*. Besides this course, the following related courses may be required by your line manager if they apply to your job:

- *Gas Cylinder Safety* (#9518),
- *Pressure Safety: Advanced* (#11459),
- *Cryogen Safety* (#8876), and
- *Flammable Gas Safety Self-Study* (#52827).

Pressure Safety Documents

Many hazardous operations require the use of clear integrated work documents (IWDs). IWDs help ensure that all safety precautions are taken. These precautions involve procedures, which in turn are based on a variety of national pressure-related codes, standards, and regulations.

Safety Codes, Standards, and Regulations

All pressure systems at LANL must comply with the following national codes and consensus standards:

- American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code* (Section VIII)*;
- American National Standards Institute (ANSI)/ASME *Pressure Piping Code* (B31.3)*;
- *National Board Inspection Code (NBIC).* National Board of Boiler and Pressure Vessel Inspectors.
- *National Fire Protection Association* (NFPA) *Codes and Standards*;
- Title 29, *Labor*, Code of Federal Regulations (CFR), Part 1910 (29 CFR 1910) Occupational Safety and Health Administration (OSHA)*;
- Title 49, *Transportation*, Code of Federal Regulations, Parts 106–180 (49 CFR 106–180) DOT;
- *Uniform Fire Code*;
- *Uniform Building Code*; and
- federal and state environmental regulations [Environmental Protection Agency [(EPA) and the New Mexico Environment Department (NMED)].

****Note:** According to Title 10, Worker Safety and Health Program, Part 851 (10 CFR 851) government contractors must comply with the above ASME codes or their equivalents and with OSHA.*

General References

- Matheson Gas Data Book (among others).
- Compressed Gas Association (CGA) handbook and pamphlets.

Laboratory Pressure Safety Program Documents

At LANL, procedures provide interpretation of national codes and standards. Those documents that apply to pressure systems include

- P101-14, *Chemical Management*;
- P101-34, *Pressure Safety;*
- P101-5, *Cryogenic Fluids or Cryogens*; and
- P342, *Engineering Standards Manual* (ESM), Chapter 17.

Pressure Safety Program Assistance

The following groups at LANL are part of the Pressure Safety Program and can help with many phases of pressurized work.

Pressure Safety Issue	Group	Phone Number
General hazards and controls	Industrial Safety and Hygiene Group of OSH Division	6-0295
Building/facility interface	Institutional Facilities and Central Services	7-4009
Operation, maintenance, and testing	Engineering Services-Design Engineering	7-4657
Fire-protection standards	Emergency Operations-Fire Protection	7-9045
Pressure-device calibration	Quality-Standards and Calibration Group	5-9981
Compressed gas procurement	Compressed Gas Facility (“Gas Plant”)	7-4406
Safety basis (risk analysis) for nuclear facilities	Safety Basis-Programs	5-1951
Respiratory protection	Respiratory Protection Program	5-8213
Institutional ES&H Training	Institutional Training Services	7-0059

This committee helps with many reviews and guidance in pressure-related areas.

Committee	Services
Pressure Safety Committee (PSC), also known as the Engineering Safety Manual Chapter 17 Technical Committee.	• Prescribes LANL-wide safeguards • Distributes pressure-related information • Reviews pressure safety program documents • Assists with hazard assessments and IWDs • Reviews and assists with designs • Reviews noncode designs • Performs walk-arounds of pressure systems • Advises and consults • Reviews operations, systems, vacuum vessels, and the safety of cryogenic Dewars • Maintains a Web page at http://int.lanl.gov/safety/industrial_hygiene_and_safety/pressure-safety-and-cryogens/index.shtml

Lessons Learned

The following lesson learned illustrates the kind of accident that can occur if precautions are not taken, even when working with vacuum systems.

From: DL-HS-HSRDSS 11/19/13 Annotated

Lesson ID: 2013-BNL-Burst Vacuum Port

Statement: During a vacuum chamber bleed-up operation at Brookhaven National Laboratory, an ultra-high vacuum (UHV) chamber was overpressurized and a glass viewport failed. From the damage observed, it appeared that a resultant projectile had sufficient momentum to cause injury had someone been in the path.

Discussion: The viewport failure resulted from the use of an unusual hardware configuration and procedure to vent the chamber. The researcher connected a compressed argon gas bottle to the chamber through a leak valve with no overpressure device in the transfer line. A regulator was fitted to the bottle. The regulator indicated approximately 800 psi on the bottle side and 30 psi on the delivery side. The chamber had no overpressure device. The glass viewport had been expected to fail at only 5 psi above atmospheric pressure. The standard practice of venting vacuum systems with low-pressure liquid nitrogen boil-off and the use of a transfer line fitted with an overpressure valve that releases at 0.5 to 1 psi above atmospheric pressure had been used several times just before this event but not in this instance. Vacuum system bleed-up operations must include overpressure protection on the gas transfer line.

The researcher had changed the procedure to allow for a slow venting of the chamber to protect a recently installed aluminum window, but did not recognize the risk introduced by that change. The researcher did not recognize the need for additional planning to manage any new risks introduced when changing the venting hardware configuration and procedure.

Notes . . .

Module 2: Pressure-Related Hazards and Accidents

Module Overview

This module describes how pressure systems can be the source of serious accidents. Some of these accidents result from the characteristics of the pressurized contents; others result from the effects of pressure on the system itself or its surroundings. To prevent such accidents, it is first necessary to recognize the major causes and types of accidents.

Module Objectives

When you have completed this module, you will be able to recognize

- hazards associated with pressurized fluids,
- the general causes of pressure-related accidents, and
- the consequences of neglecting safety while working with pressurized systems and containers.

Hazards Associated with Pressurized Fluids

Pressurized gases and liquids pose various hazards that can result in personal injury and property damage. Your familiarity with these hazards will help you control them. You may encounter any of the following general hazards when you work on or around pressure systems:

Mechanical failure—Gas cylinders at LANL are often filled to around 2100 pounds per square inch gauge (psig). Under such high pressure, and at a gas volume of $1^1/_2$ ft^3, damaged or mishandled cylinders can fracture violently and release very large amounts of energy, comparable to the energy of a 3000-lb car speeding at 90 miles per hour.

Just the dropping or overheating of a pressurized vessel can cause a fracture and a sudden release of its contents. Other concerns that could lead to airborne material include

- plastic piping,
- insecure fittings,
- regulator failure, and
- glass window port failure.

Whipping injuries—If not secured properly, broken fluid lines and hoses under pressure can cause severe whipping injuries, as well as property damage.

Injection hazards—Above 75 psig, pressurized fluid leaking from a small opening at high velocity can penetrate the skin and cause severe internal injury.

Oxygen-deficient atmosphere—When a compressed inert gas or any otherwise harmless gas escapes from its container, it may displace oxygen in the air to dangerous levels, putting workers at risk of asphyxiation. This situation can be especially hazardous in small, enclosed work areas such as trailers.

Reactivity hazards—Some gases are toxic, corrosive, or support combustion and require special handling. For example,

- fluorine, a toxin that is potentially fatal if inhaled, can also corrode many systems materials; and
- oxygen, although not flammable, will make flammable objects ignite more readily and burn much more intensely, as in the case of aluminum, which burns in the presence of pure oxygen. Grease and oil, which are already inflammable, become almost pyrophoric in the presence of high-pressure oxygen.

Pyrophoric – capable of igniting spontaneously

Cryogen hazards—A cryogenic system is one that is composed of substances, such as liquid nitrogen, that boil at extremely low temperatures. When used improperly or because of unforeseen problems, a cryogenic system can develop very high pressures. Thus, cryogenic systems must be equipped with pressure-relief devices to prevent dangerous levels of pressure buildup in all portions of the system where

- liquid cryogens are present,
- cryogen boil-off gases could be trapped (for example, in a pipe between two closed valves), or
- air could condense and become trapped.

Cryogenic materials are extremely cold and can cause injuries similar to burns. Cryogens can also expand greatly as they warm to room temperature, creating hazards related to energy release and oxygen deficiency. (The expansion factor in Los Alamos is ~1000.)

Causes of Pressure-Related Accidents

Pressure-related accidents often result from one of three general causes:

- failure to consider and control hazards,
- failure to identify hazards before and during the work process, or
- failure to follow safe work practices.

More specifically, pressure-related accidents usually stem from

- poor design in terms of
  - control and safety devices,
  - container dimensions and material strengths, or
  - material compatibility between the container and its contents;
- faulty component manufacture;
- faulty assembly and/or installation;
- poor maintenance;
- poor operating procedures, including failure to follow IWDs; or
- inadequate safeguards against damage (for example, lack of shields around delicate components).

Lessons Learned

Hit by Gas-Driven Spinning Pipe

An electric utility maintenance worker had installed a 610-millimeter-diameter pipe extension onto a non-condensable gas line. The extension was installed to prevent the sludge and brine that was in the line from blowing on the employee as he was draining it. He had installed the extension hand tight. When the employee tried to open the valve with his right foot, nothing happened. He put more pressure on the valve handle with his right foot, and the contents of the pipe, at 690 to 956 kilopascals (99 to 137 psi) of pressure, were released all at once. The pipe extension, which had a 90-degree elbow on its open end, started spinning around, tightening itself onto the pipe. The spinning extension hit the employee on his left foot. When he shifted his weight to his right foot, the spinning pipe also hit that foot and the employee fell to the ground. While he was on the ground, the still-spinning pipe hit his left forearm. The extension continued to spin until it tightened itself onto the gas line. The employee was hospitalized with four fractured toes on his left foot, fractures of the bones in the arch of his right foot, and a fractured right wrist.

- OSHA Accident Investigation Search 170203962

Too Few Screws

A 2-cu-ft chamber made of aluminum with 1/2-in.- thick walls and a 35 x10-sq-in. cover plate had been designed to use 36 screws to seal the plate to the chamber. Only 12 screws were used, partly because 18 screws had been misplaced over time and partly because 6 holes had been stripped, a somewhat strange rationale since there were 6 more threaded holes that could have been used by the 6 screws that were still available. In any case, the chamber was subjected to 25 psig of P-10 gas, which was enough to propel the lid through a window. Fortunately no injuries occurred. The force on the lid was at most 8750 lb, which subjected each threaded hole to about 730 lbs. The aluminum threads had stripped despite being well within a safety factor of 4 to handle the 730-lb force had the material been up to grade. But subsequent investigation revealed that the aluminum was defective and perhaps damaged by overtightened steel screws.

Causes

The direct cause was the defective material that failed, but the contributing causes were a) defective procedure, b) error in material selection, and c) no training provided. The root cause was inadequate supervision that should have insisted on the use of steel helical inserts instead of tapping directly into the aluminum.

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Corrective Actions

The equipment was removed from service. The group was informed at a group safety meeting of management and worker responsibilities when conducting hazardous operations. These responsibilities include adequate procedures to be provided for ensuring that the required training is taken and that “stop work” must be implemented if the operator thinks that any safety requirements have not been met.

Tube Trailer Explosion

In 1981, workers at LANL were about to fill hydrogen cylinders from a large, hydrogen-filled tube trailer. They used a manifold containing residual oxygen, which was also connected to a tube trailer of oxygen with only one valve separating these incompatible gases. The workers were attempting to purge oxygen from the manifold using low-pressure hydrogen when the mix ignited. The resultant fire destroyed the valve, allowing high-pressure oxygen to flow into the low-pressure hydrogen tube. The subsequent large mix of oxygen and hydrogen resulted in an extremely violent explosion.

Because the energy required to ignite hydrogen-oxygen mixtures is so low and can even be created by friction, rushing sand particles in the tubing sparked an explosion. Pieces of the tube flew as far as the Los Alamos landfill, approximately 700 yards away. Two workers were severely burned, and damage to equipment was extensive.

Causes

Investigators determined that the fittings for the hydrogen and oxygen delivery systems were similar, allowing the connection of incompatible gases to the same manifold. In addition, workers were not following procedures and did not understand the serious hazards of mixing hydrogen and oxygen.

Corrective Actions

As a result of the explosion,

- the gas facility’s management structure was changed;
- standard operating procedures were rewritten;
- worker training requirements were improved; and
- engineering changes were made, including changing the fittings and piping to make it impossible to mistakenly mix hydrogen and oxygen.

Low-Pressure/High-Volume Systems

The total force of even very low pressure on a large area can create a serious hazard. Failure to consider low-pressure/high-volume hazards can have serious consequences that may not be readily apparent.

The magnitude of a pressure-related accident is to the total stored energy, as well as to the pressure level. Large pressurized surfaces—even at very low pressures—can store huge amounts of energy. If released rapidly, such energy can explode forcefully, causing severe accidents and injuries.

For example, an overpressure of only 5 psig on a 4-ft-diameter manhole cover on a large tank caused two fatalities when the bolts were removed for routine maintenance.

Module 3: Pressure Safety System

Module Overview

Many pressure systems use safety manifolds, relief devices, and pressure gauges to ensure that each portion of the system operates at safe pressures. Carefully chosen pressure system components can handle the expected pressures and are compatible with the properties and temperatures of the fluids they contain. This module describes the different kinds of controls included in pressure systems to prevent accidents.

Module Objectives

When you have completed this module, you will be able to recognize

- basic pressure system terms,
- safety components built into pressure systems,
- safe work practices relating to pressure systems, and
- how to assemble and use a simple pressure system.

Terms and Definitions

The following terms are used in discussing pressure system safety:

Maximum allowable working pressure (MAWP)—the pressure that causes the stress in the container's material to reach its highest permissible value. It is determined by the weakest component (the least capable of sustaining the stress it would be subjected to under pressure) of an interconnecting system. The pressure-relief device protecting the system is set to the MAWP or lower.

Maximum operating pressure (MOP)—the actual working pressure, also called the "rated pressure," usually 10%–20% below the MAWP or 10%–20% below the set value of the relief device. This lowered pressure limit ensures that the pressure-relief device does not open unexpectedly.

Safety factor—the ratio of the component-failure burst pressure to the MAWP. The safety factors usually required are

- at least 3.5 for systems in occupied areas (until recently it was 4, but improved analysis has allowed a decrease);
- under 3 with approval from line management, generally after review by the PSC; and
- 4–8 for brittle material, such as glass window ports.

Safety Manifolds

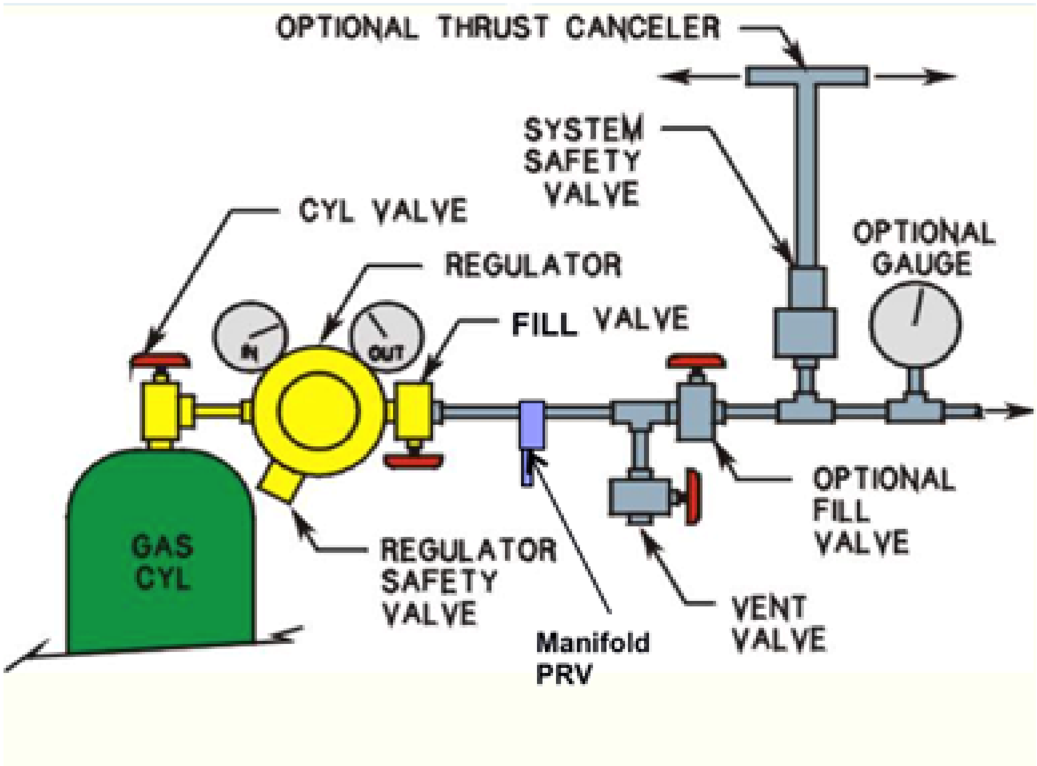
Dead-ended systems are those in which fluids are continuouslyheld under pressure. Dead-ended systems, such as a pressure vessel, require a safety manifold when undergoing pressurization from a high-pressure source.

High-pressure gas cylinders supply many dead-ended lower pressure systems at LANL.All dead-ended systems require a safety manifold to control the source gas from its entry point to its end use. Safety manifolds

- regulate delivery pressure,
- protect from overpressurization,
- indicate pressure level,
- vent unused pressurized gas, and
- are supplemented by end-use pressure gauges.

Open-ended systems sometimes do not require all of these elements. However, a regulator and a fill valve are usually used on open-ended systems. Protection from regulator failure does require a relief device just downstream of the regulator. An example of an open-ended system would be an acetylene torch in which pressurized gases flow directly into the open atmosphere. In this case, restricted flow orifices (RFOs) and/or check valves in the lines serve to limit flow.

The basic components of a safety-manifold system are shown in the diagram below.



An additional safety component is an RFO. This device limits the flow from a gas cylinder to prevent too rapid a buildup of pressure in a dead-ended system especially if a regulator failure occurs, allowing the output pressure to rise to the source pressure. The limited flow allows the relief device to exhaust adequately.

Regulators are devices that control the pressure of the system contents. Regulators reduce pressure; they do not act as positive shutoffs. A fill valve should always be used to shut off gas flow completely. When regulators malfunction, gas can creep up at a slow rate and increase downstream pressure beyond the system MAWP.

Note: *Many regulators contain built-in relief devices to protect the regulator. These devices do not protect the system. Furthermore, no credit can be taken for the regulator because it can fail open, resulting in the downstream pressure rising to the set pressure of the regulator relief device.*

Single-stage regulators are used when constant regulation of pressure is not important, as in a building's air system. These regulators provide high flow rates at moderate pressures. They allow output pressures to change slightly (drop or rise depending on the regulator design) as the source pressure diminishes.

Two-stage regulators maintain almost constant delivery pressures as the source pressure decreases. These regulators generally limit usage to lower flow rates.

Pressure Relief Devices

In addition to the regulator and the pressure-relief devices built into the gas cylinder (or other source), the pressure system as a whole must also be protected by one or more pressure-relief devices.

Pressure-relief devices for the system must

- be set below or at the maximum pressure determined by the component with the lowest MAWP,
- provide sufficient flow capacity to usually prevent pressure from rising above 110% of the MAWP,
- provide a safe discharge path,
- be placed on all parts of the pressure system that can be isolated, and
- be reset only by authorized workers.

Note: *All adjustments and other changes to a pressure-relief device must be recorded in a logbook.*

Vent Valves

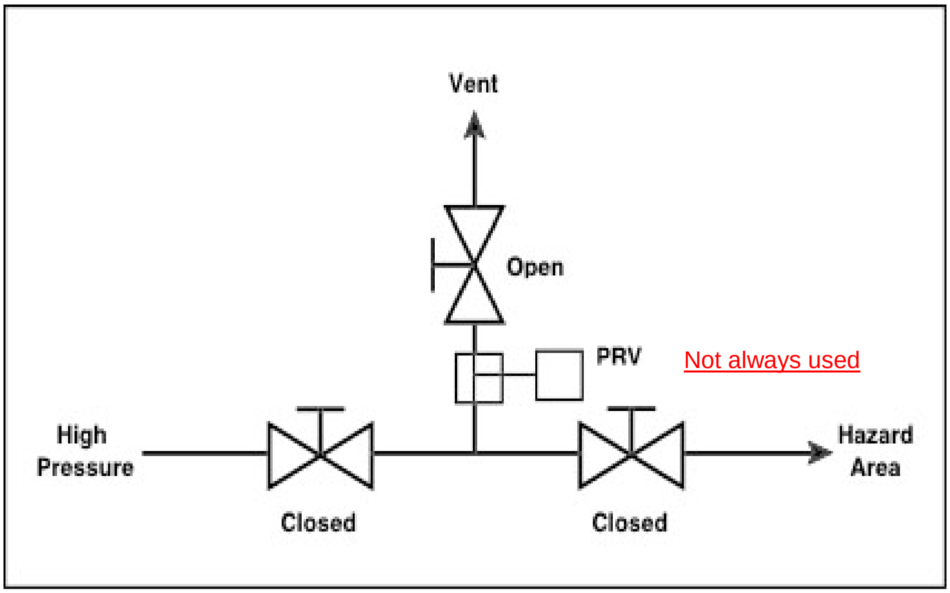
Tightening or adjusting any pressure system component while it is under pressure places undue strain on the threads and can lead to failure. Opening a threaded connection to release or vent pressure is also unsafe. Therefore, vent valves must be provided to relieve pressure in all parts of the system where pressure can build up.

Depending on the type of gas, vent valves must discharge safely away from personnel, often directly to the outdoors. These discharge paths must be maintained as originally designed.

Double Block and Bleed

All valves can and will eventually leak. Leakage may be due to wear or contamination at the seat. However, even new valves can allow some pressurized gas to seep through. When a hazardous gas must be absolutely shut off from a system, extra precautions must be taken.

In such situations, two shutoff valves are used with a vent valve between them. To close off the gas flow, both shutoff valves are closed and the vent valve is opened. Any gas passing through the first valve escapes safely through the vent valve rather than building up enough pressure to pass through the second shutoff valve.



Double Block-and-Bleed System for Incompatible Gases

Pressure Gauges

System pressure gauges are often required to provide more accurate system pressure readings than regulator gauges can provide. Pressure gauges

- are most accurate if used within midrange and therefore should have a range of about 2 **x** MAWP;
- should not be used if they read less than 1.2 **x** MAWP;
- must be made from materials that are compatible with system contents and pressures;
- must be safety-type gauges if used in high-hazard applications (for example, the gauge must have safety glass and a blowout back);
- should be protected with a snubber (a flow inhibiter) against surges or oscillating pressures; and
- should be protected with a pressure-relief device.

Caution: *Never use oil in an oxygen gauge.*

Safe Work Practices

When working on or around pressure systems, you must adhere to safe work practices, including the following:

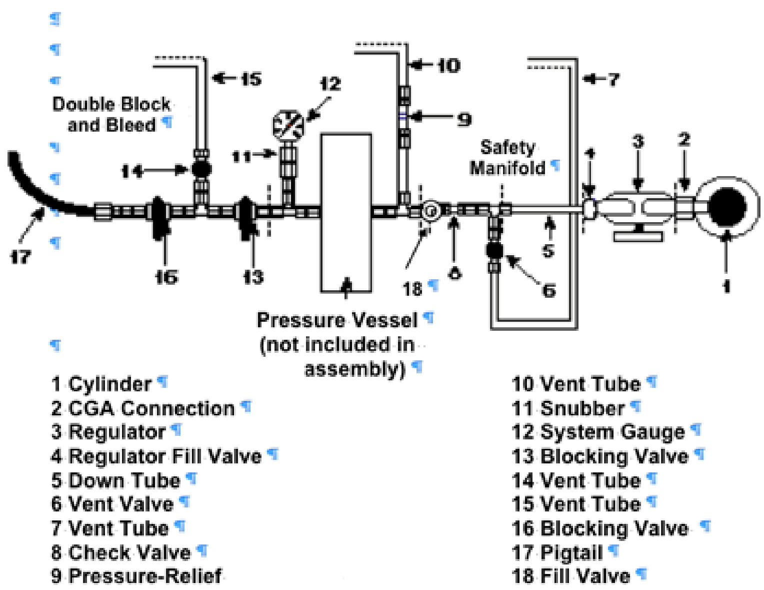
- Wear safety glasses with side shields; use a face shield also for high-hazard setups.
- Follow IWD requirements carefully.
- Use warning signs, indicate directions of flow, and mark or label pressure vessels and systems to identify the operating pressure and contents.
- Restrict access to high-pressure areas.
- Handle, store, and dispose of gas cylinders safely.
- Avoid temperature extremes, which can cause pressure changes and component failure.
- NEVER use a body part to test for pressure.
- NEVER work on a system while it is under pressure.

Caution: *NEVER, under any circumstances, work on a pressure system while it is under pressure. Instead, depressurize the system, and use lockout/tagout if appropriate.*

Exercise: Pressure System Assembly

The diagram below shows a top view of a typical pressure system. During this hands-on exercise, you will make three connections of four preassembled subsections of this system.

Pressure System Assembly



Instructions: To assemble the pressure system, follow these steps. **Note:** All connections use Swagelok® fittings, which should first be hand-tightened and then wrench-tightened, using two wrenches, with no more than a 1/10 turn. Avoid cross threading; if the pieces do not fit together easily, notify the instructor.

1. Connect the down tube (5) to the tee connected to the vent valve (6), the vent tube (7), and the check valve (8), such that the tube reaches up to where the regulator (3) will attach to the gas cylinder (1).
2. Connect the check-valve end of the system to the tee connected to the pressure-relief valve (9) and the snubber (11), which is connected to the system gauge (12). ***Note**: This second subsection contains a simple copper tube representing the pressure vessel to be served by the safety manifold.*
3. Connect the system-gauge end of the system to the double-block-and-bleed arrangement (13, 14, 16), which is connected to the pigtail (17).

This system is now ready to be connected to a regulator and mounted onto a gas cylinder in the Gas Cylinder Safety course, which follows this course.

Human Performance Improvement

Struck by Flying End Cap

Human Performance Improvement (HPI) is an approach that is used to address human error in the workplace. HPI treats human error as a symptom or a result of deeper problems within a system. One of the five basic principles of HPI is that people are fallible, and even the best make mistakes.

One of the most important approaches used in HPI to address errors in the workplace is called defense in depth. For defenses against human error to be effective, they must

- create understanding and awareness of hazards,
- give clear guidance on how to operate safely,
- provide alarms and warnings when danger is imminent,
- restore the system to a safe state in an off-normal situation,
- set up safety barriers between the hazards and the potential losses,
- contain and eliminate the hazards in case safety barriers fail, and
- provide the means of escape and rescue for workers in case hazard containment fails.

Read the incident below and see if you can identify defenses that would have reduced the likelihood of this incident.

Employee's Head Struck by Flying End Cap

Contrary to company policy, Employee #1 failed to check the pressure gauge or ballcock valve to verify the pressure status on a 6-inch water line (chiller water) prior to removing an end cap. The end cap was under approximately 50 psi of pressure. When Employee #1 released the coupling clamp that was securing the end cap, the cap flew off and struck Employee #1 in the head and face, causing severe trauma.

- *OSHA Accident Investigation Search 170717110*

Question 1. What are some of the potential defenses in depth that could have been used to reduce the likelihood of this incident?

Question 2. If you were assigned to remove the end cap, what could you do if you felt the defense in depth was not adequate?

For more information about HPI, register for *Human Performance for Workers* (#43428) by accessing the Virtual Training Center at http://int.lanl.gov/training/

Answers to HPI questions are on the following page

Human Performance Improvement: Answers

Answers — Struck by Flying End Cap

Question 1. What are some of the potential defenses in depth that could have been used to reduce the likelihood of this incident?

- Install a block-and-bleed system that would allow depressurization of the end cap.
- Develop a procedure for safely performing the task. Consider lockout/tagout for the control of hazardous energy. Include information on how to verify that the cap is not pressurized before beginning work and where a worker should stand (to the side of the cap, not in front of the cap) when loosening it.
- Require all workers who work with pressurized systems to complete required institutional pressure safety training.
- Provide task-specific training that addresses hazards, controls, and procedural steps associated with removing the end cap.
- Place warning signs on the coupling cap to alert personnel that a specific procedure must be followed when removing the cap. Indicate where the procedure can be found.
- Have a person who is qualified/authorized to perform the task give a pre-job briefing to new workers.
- Ensure that workers don the correct personal protective equipment (PPE) (eye/face/head protection, etc.) before removing the end cap.
- Use a buddy system so that peers can review each other’s work and help each other in the event of an emergency.
- Use the lessons learned from the incident as an ongoing training aid so that workers will understand what happened in this incident and how to avoid such an incident in the future.

Question 2. If you were assigned to remove the end cap, what could you do if you felt the defense in depth was not adequate?

- Ask for clarification on the defenses in place. If you felt that some defenses were missing, ask why they were not in place. If you still felt the defense in depth was not adequate, pause or stop work.

Notes. . . .

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References and Resources

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