Pressure Safety Orientation

HS5030-W

UCRL-MI-124330-HS5030

skip intro >>

Course Design

This course is designed to be taken as a sequential set of pages and takes about 1 1/2 to 2 hours. However, it can also be used as a pressure safety resource, and any section can be accessed through the menu page. You may access the menu page at any time by simply selecting the "menu" button located in the navigation bar at the bottom of the page.

Use the back and next (← →) buttons to move through the course.

Use the other buttons on the navigation bar to utilize additional features.

This course provides an introduction to pressure safety in general and to the Laboratory's Pressure Safety Program in particular. The course is a prerequisite to all other pressure safety classes at LLNL. It is also required for all pressure consultants, inspectors and installers as well as all operators of low-, intermediate- and high-pressure equipment and systems, including safety-note-exempt pressure systems.

Purpose and Objectives

This course is designed to promote safety awareness in working with pressurized equipment and systems. After completing the course, you will be able to:

- Identify LLNL's pressure-safety policies and procedures.
- Apply the principles of integrated safety management to mitigate potential pressure hazards and avoid accidents.
- Identify and apply proper practices for the safe:
  - handling, storage and use of compressed-gas cylinders
  - operation of pressurized components and systems
  - operation of cryogenic systems
  - operation of oxyacetylene systems

Module 1 Goal

The goal of this module is to define terms and teach you the elements of the Pressure Safety Program at LLNL.

Module 1 Objectives

At the completion of this module you will be able to:

- Understand the definitions and terms of the Pressure Safety Program.
- Illustrate the policies, procedures, and requirements that govern the design, procurement, and or/use of pressure vessels and systems by any LLNL employee or contractor contained in the LLNL Pressure Safety Program.
- Identify the fundamental documentation and training requirements when building, and or operating pressure systems.

Definitions

M.A.W.P.

- Maximum Allowable Working Pressure. (MAWP)
- Relief Device Setting, which is the same as ASME Code.
- Relief Device Set Point, which is determined by the lowest rated component.

M.O.P.

- Maximum operating pressure. (MOP)
- 10 to 20 percent below M.A.W.P.

Definitions

Safety Factor

S.F. = Failure Pressure/M.A.W.P

Safety Factor Example: Imagine you have a pressure vessel with a burst pressure of 22,000 psig, the system has a M.A.W.P. of 5,000 psig, the safety factor would be calculated as follows: 22,000 divided by 5,000=4.4; Safety Factor is 4.4

- A safety factor of 4 or greater is required in a manned Area (the system can be operated in the same location with personnel) with a SF 4 or greater.
- A safety factor of less than 4 can be used in a remote Area (the system is to be operated behind a barricade or in confinement) can be less than SF 4.
- Any system with a safety factor of 3 or less requires upper management approval

Definitions

Burst Pressure

- Normally the Burst pressure is four (4) times M.A.W.P.
- How to get burst pressure?
- Take up to failure by over-pressurization or calculation method, for example in a hose catalog it will give you minimum burst pressure rating, and usually MAWP.

LLNL Pressure Safety Program

The purpose behind LLNL's Pressure Safety Program is to ensure that all pressure systems at the Laboratory are designed, tested, inspected, and used in accordance with sound engineering principles by properly trained and qualified personnel.

A detailed description of the program (publication ENS92-06) is available at the Engineering Reference Center. Basically, the program is comprised of five main elements:

1. Pressure Safety Manual (policies & procedures)
2. Safety Committee
3. Trained and Qualified Personnel
4. Documentation and Accountability
5. Control of Hardware Selection and Use

LLNL Pressure Safety Program

Element 1 - Pressure Safety Manual

The Laboratory's Pressure Safety Manual can be found in Volume II, Part 18 (Pressure/Noise/Hazardous Atmospheres) of the LLNL *ES&H Manual*. In it you will find the policies, procedures, and requirements that govern the design, procurement, and/or use of pressure vessels and systems by any LLNL or contractor employee at the Laboratory.

LLNL Pressure Safety Program

Element 2 - Pressure Safety Committee

- Sets/reviews safety policies.
- Addresses unusual problems and occurrences.
- Provides advice and assistance on pressure-safety issues.
- Members:
  - Representatives from each Engineering Division
  - Department management
  - Pressure Safety Manager

LLNL Pressure Safety Program

Element 3 - Trained and Qualified Personnel

- Only personnel who have appropriate pressure-safety training and on-the-job experience shall design, build and/or operate pressure systems.

- Required training depends on a person's *job description and the pressures involved*. To view the five basic courses and three pressure ranges, see the resources page.

- A list of Authorized Individuals for pressure work is available at the pressure-safety web site. You can link to this web site from the reference page.

- With regard to pressure work, the *ES&H Manual* stipulates that Responsible Individuals shall:

  - Ensure that inspections and re-tests are performed every 3 years.
  - Notify the Pressure Safety Manager of any changes in the system.
  - Help the inspector locate the equipment when inspections are due.
  - Document pressure systems and vessels.
  - Operate systems within a specified safety range.

LLNL Pressure Safety Program

Element 4 - Documentation and Accountability

All pressure vessels and systems at the Laboratory must be documented as to their design, pressure rating, traceability, testing, operation and maintenance requirements in accordance with the documentation guide in the Pressure Safety Manual, Part 18.

Note: Unmodified commercial equipment generally requires less documentation than in-house designed and/or modified equipment.

See the LLNL Documentation Guide for Pressure Equipment by clicking the "resources" button below.

LLNL Pressure Safety Program

Element 4 - Documentation and Accountability (cont.)

Engineering Safety Notes

An ESN is a management approved document that describes anticipated hazards associated with a piece of equipment or process. It assures the design safety of the equipment, system, or process.

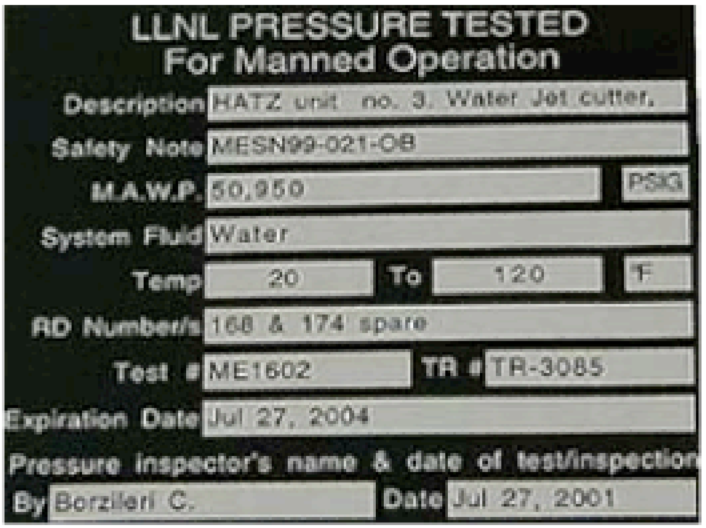
Operational Safety Plan

An OSP is used to describe work to be done, identify any hazards and/or environmental concerns, and assign responsibility for safe operations. It should also document any maintenance and/or quality assurance requirements. An OSP is used to document safety actions. Refer to the *ES&H Manual* Volume II, Part 18 for detailed information.

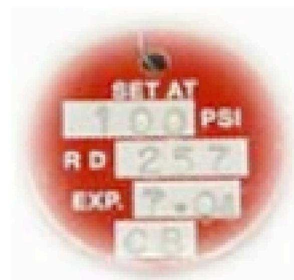
LLNL Pressure Safety Program

Element 4 - Documentation and Accountability (cont.)

The following labels are used at LLNL to document and track pressure vessels and systems.



Pressure Tested Label



Relief Device Tag

Regulator Tag

Click Here to see more pressure labels and tags.

LLNL Pressure Safety Program

Element 5 - Control of Hardware Selection and Use

- Vendors shall have quality-control requirements.

- Procurements shall be made to applicable specifications.

- Only certified installers shall assemble pressure components.

- Questions? Need help? Contact:

    - The Pressure Safety Manager (2-6076)
    - The High Pressure Laboratory (3-2745)
    - The Instrument Shop (3-1640)
    - ES&H Team in your area

LLNL Pressure Safety Program

Element 5 - Control of Hardware Selection and Use (cont.)

Low-/Intermediate-Pressure Hardware

- Can be purchased by your procurement personnel (TRR).
- Obtain regulators, safety manifolds, and relief devices through B511 Instrument Shop, B343 High Pressure Laboratory, or B871 Instrument Shop Site 300.
- Instrument Shop will also check (clean, re-test and tag) new regulators.

High-Pressure Hardware

- May be obtained only from reputable vendors-with appropriate documentation.

Salvaged Hardware

- May be used only with pressure inspector evaluation and approval.

Module 2 Goals

This module is to introduce you to compressed gas cylinders and their proper use.

Module Objectives

After completing this module, you will be able to:

- Properly identify, transport, use, and safely store compressed gas cylinders.

Compressed-Gas Cylinder Safety

Facts and Design

Compressed-gas cylinders are designed to Department of Transportation (DOT) specifications (e.g., DOT 3AA-2265).

A standard 2-ksi+ (ksi=1000 psi) cylinder has 1.5 cubic feet of water volume and holds about 200 standard cubic feet of gas.

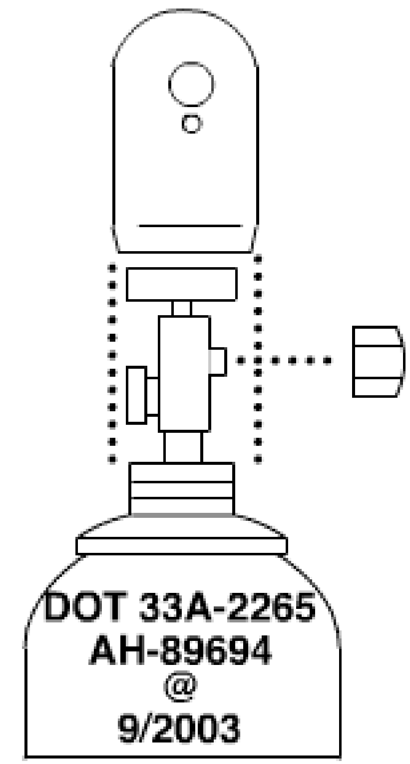
A standard cylinder has an outside diameter of 9 inches, but can vary in height-most being 50 inches tall.

A compressed-gas cylinder should not be exposed to temperatures greater than 125° F.

Facts and Design

Important features common to compressed-gas cylinders include:

- Valve: (a) handwheel, (b) CGA (compressed gas association) unique to each type of gas or fluid outlet connection, (c) pressure relief device
- Valve outlet cap
- Cylinder collar
- DOT specification (3AA) and service pressure (2,265 psig)
- Serial number
- Manufacturer's symbol
- Test date (3/82), original tester's symbol (MC), hydrostatic retesting extension allowance (* denotes a new cylinder & does not need initial re-testing for 10 years), & permission to overpressure by 10% (+)
- Cylinder cap to protect valve



Mouse over to review the cylinder components

Specialty- and Sample-Gas Cylinders

Typically 15 inches long by 2 inches in diameter, these cylinders hold around 500 cubic centimeters of gas.

They are desvigned to DOT Specification 3E-1800. Any modification to the cylinder (such as welding on a valve) voids the DOT certification (refer to LLNL pressure safety program).

As these cylinders are non-returnable, no vendor retest is required (refer to LLNL pressure safety program).

The user is responsible for properly identifying and disposing of the cylinder and any remaining contents (refer to the Laboratory's ES&H Manual, Appendix 32-C: " Compressed Gas Cylinder Return and Disposal Procedure Flowchart.")

Vendor-Owned Cylinders

Vendors must hydro-test their cylinders every 5 years. In a hydro test, a cylinder's ductility (flexibility) is measured by pressurizing the cylinder to 5/3 times its working pressure, then lowering the pressure to atmosphere and evaluate the results.

If the cylinder is still adequately ductile, it is re-stamped for continued use. If not, it is disposed of.

If a cylinder is out of date, it can still be transported and its contents used. However, it cannot be refilled until it is hydro-tested.

If there is any question about corrosion, proper compressed gas association (CGA), or labeling, return the cylinder to the vendor.

Identification and Content

DOT Shoulder Label - Is the best way to identify cylinder content. A shoulder label is REQUIRED by DOT for shipping. It provides information on chemical content, health hazards, and reactivity (e.g., whether the cylinder's content is an oxidizer or non-flammable).

Color Codes - Are NOT RELIABLE for cylinder content; DO NOT rely on color codes.

Product Labels - Are helpful in determining uses; MSDSs can provide
additional information.

Proper Handling/Transporting

When moving or transporting a compressed-gas cylinder, make sure the regulator is off and a cap is installed to protect the valve. Never lift a cylinder by the protective cap as it can come off unexpectedly causing you to drop the cylinder.

Use proper lifting procedures. Use a cylinder cart-not your back-when moving a cylinder. Cylinders must always be adequately secured whether transporting, handling, or in use. When transporting cylinders horizontally on a wooden pallet, secure them with double bands and wooden blocks between the cylinders.

Mouse over to see how it should be secured.

Identification and Content

Status Tags - These tags Identify whether a cylinder is full, in service, or has residual pressure. They are installed by the Industrial Gasses section before a cylinder is delivered, and must remain on the cylinder when it is returned (return cylinder with positive pressure - 100 psig to prevent suckback or contaminations).

Labeling - A variety of labels and tags are used on compressed-gas cylinders and manifolds at the Laboratory. They are identified and serviced by the Plant Engineering instrument Shop.

Proper Use and Refill

Always secure a cylinder before using (double chains, where available).

Do not place cylinders in walkways.

Flammable and oxidizing cylinders may be used side-by-side ONLY when in use (e.g., oxyacetylene welder carts, bottle manifolds).

Never empty a cylinder completely; always leave some positive pressure (typically 100 psi, but not less than 50 psi). This is to keep the cylinder clean and dry.

Only vendors can refill vendor-owned cylinders.

Proper Storage

Detailed guidelines for the proper storage of gas cylinders can be found in Volume II, Part 18. 1 Pressure of the *ES&H Manual.* In general:

- Store out of direct sunlight when possible.
- Store cylinders containing toxics in ventilated enclosures.
- Provide warning signs for toxic/corrosive gasses.
- Separate full cylinders from empty cylinders. And remember: Empty cylinders should always be left with some positive pressure (around 100 psi).
- Separate oxidizers from flammables by AT LEAST 20 feet or by a half-hour firewall.

Mouse over to see more detail on the notice sign.

Cylinder Relief Devices

Various types of cylinder-relief devices are used on compressed-gas cylinders, depending on the type of gas involved.

Spring-loaded valve-Used with propane and mapp gas (similar to natural or LP gas); spring reseals valve when pressure drops below the set point.

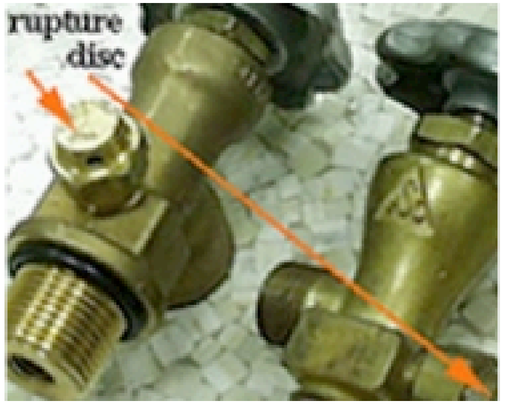
No relief device-With toxic, corrosive, or poisonous gases that cannot be released to the atmosphere (arsine, fluiorine, and phosgene, for example), no relief device is used. Instead, the cylinder is filled well below its rated capacity.

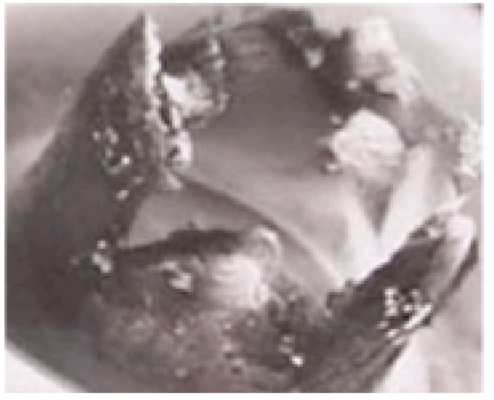
Other relief devices would be frangible disc or fusible metal, or combination of the two.

Cylinder Relief Devices

Frangible (rupture) disc- Does not reseal when pressure drops; used for CO_2, N_2, and argon. Frangible disc backed by fusible plug. Hydrogen, methane - prevents the cylinder from venting unless it is in a fire.

Fusible plug - Soft-metal plug melts at low temperature; used with acetylene and chlorine.





Failed rupture disc

Module 3 Goals

This module will illustrate the features of the LLNL Pressure Safety Manifold.

Module Objectives

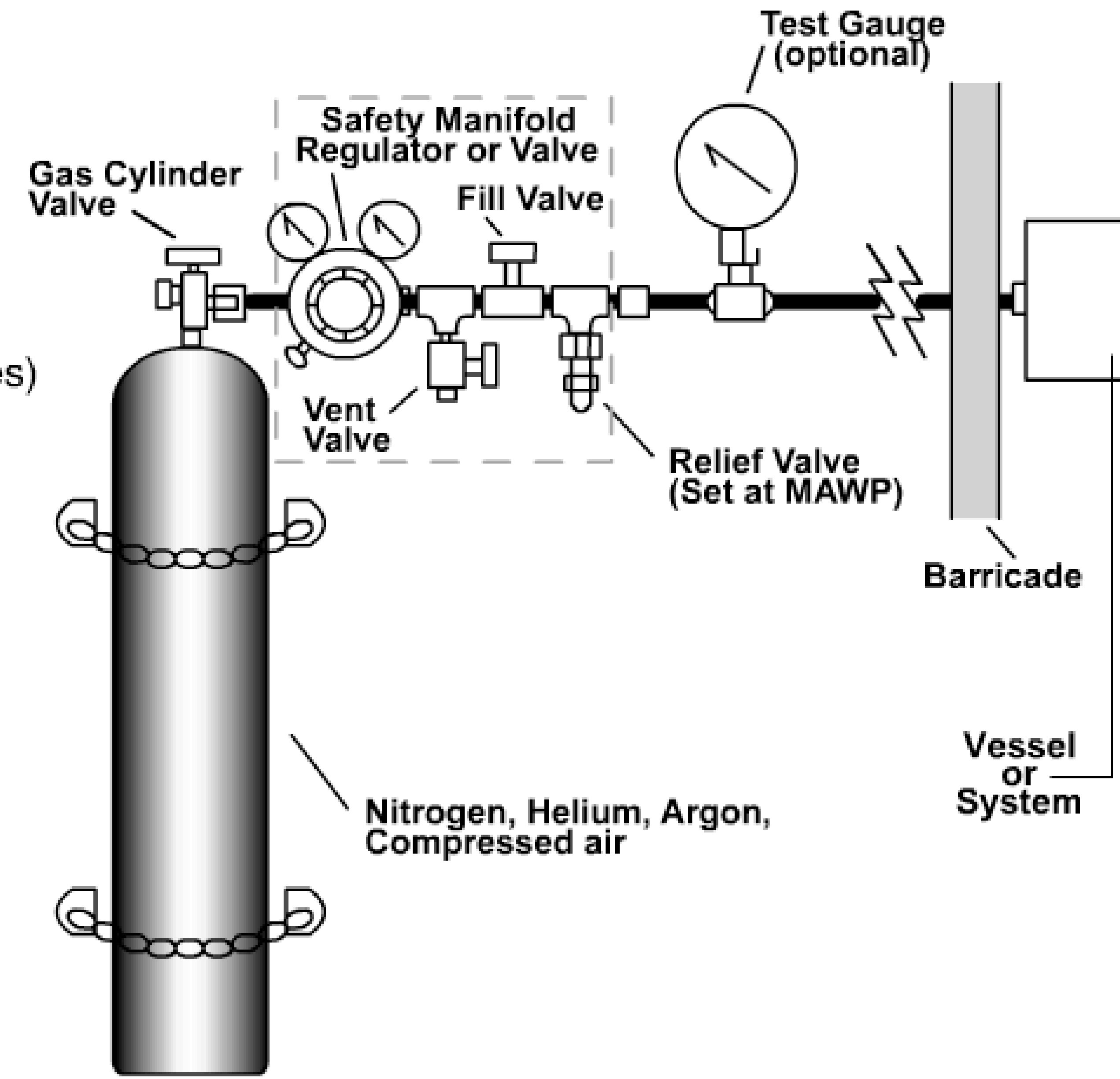
After completing this module, you will be able to:

- Identify components, obtain systems and properly use safety manifolds.

Safety Manifolds - Bridge Between Source Gas and End Use

Safety manifolds serve several functions:

- Regulate delivery pressure (pressure regulators)
- Protect against overpressure (relief devices)
- Monitor pressure level (pressure gauges)
- Vent unused excess gas
- Fill or throttle gas to its end use



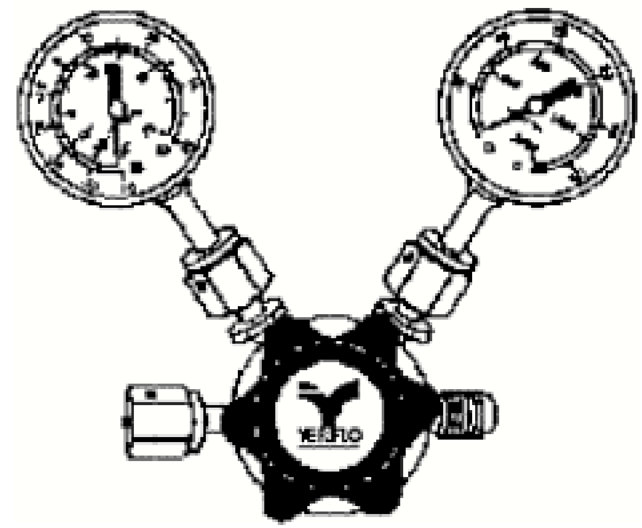
Pressure Regulators

Serve to regulate cylinder pressure to the system/end use. NOTE: Regulators only reduce pressure. They are not pressure-limiting (relief) devices.

Regulators and information about regulators may be obtained from the B511 Instrument Shop (x-23614) and from the B343 High Pressure Laboratory (x-32745).

Contact either the Instrument Shop or the High Pressure Laboratory with any questions you may have about regulators.

Note: It is **recommended** that regulators be inspected every five years for reliability and safety. Aluminum tag will have last inspection date.



Pressure Regulators

Single- Versus Two-Stage Regulators

Use a single-stage regulator when:

- Precise regulation is not important.
- High flow rates are needed.
- Required delivery pressure is above 200 psig.
- Example: 2200 psig source pressure to delivery pressure of 360 psig in one stage.

2 stage regulator with safety manifold

Use a two-stage regulator when:

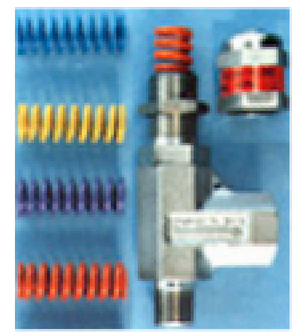
- Precise regulation is important.
- Low flow rates are needed.
- Required delivery pressure is from 0 to 200 psig.
- A relief device protects the system.
- Example: 2200 psig source pressure to delivery pressure of 50 psig in two stages (300 psig in middle stage protects first stage at 360 psig; second stage protects 1-100 psig guage).

Relief Devices

Use a relief device when the maximum allowable working pressure (MAWP) of the source is greater than the MAWP of the system.

- Relief device setting should be the MAWP of the system.
- Maximum setting is the component MAWP.
- Discharge a relief device safely (i.e., point it away from people).
- There should be no valve between a relief device and the components it is supposed to protect (i.e., do not isolate the relief device).
- Do not reset a relief device unless authorized. Note, however, that such devices are to be tested and reset at least every 3 years.
- Check relief device tag: set pressure, date, and expiration date.

Click here for FAQs



relief device

rupture assembly

Relief Devices (cont.)

Setting and Retesting Relief Devices

Relief devices are to be tested and reset at least every 3 years by an LLNL Pressure Inspector. However, it is up to the responsible user (same as responsible individual) to ensure that this happens.

In addition, the responsible user shall:

- Notify the Pressure Safety Manager whenever there is a change in the system.
- Help the inspector locate the equipment when an inspection is due.
- Maintain documentation of the pressure system and vessels.
- Operate the system safely within a specified range.

Pressure Gauges

Protect against surges, as required.

Provide relief-device protection.

Should be graduated to about 2 times the MAWP, but never less than 1.2 times MAWP. Example: For a 100-psig operating system, the pressure gauge should be graduated to 200 psig.

In high-hazard situations, use a "safety-type" pressure gauge (i.e., one with a blow-out back and a securely attached plastic face). Gauges more than 4 inches in diameter must be of the safety type.

Be aware that a gauge can fail if the gauge's material and the system's fluid are not compatible. Example: Hydrogen is incompatible with steel or Iconel X material in a gauge.

Oil is **NEVER** to be used with oxygen gauges; the two together can create spontaneous combustion! Also, when having an oxygen gauge cleaned, ask for "cleaned for oxygen" service, document that this was done, and keep oxygen gauges separate from other gauges.

Lock and Tag Devices

The purpose of lock and tag is to isolate any energy source from personnel exposure. And, since pressurized gases are stored energy, lock and tag applies. See *ES&H Manual* Volume II: Health & Safety--Hazards and Controls -- Part 12: General H&S Controls--Safety Equipment and Facilities in the references section for lock and tag specific requirements.

Module 4 Goal

This module is to introduce you to the elements of Cryogenic Safety.

Module Objectives

After completing this module, you will be able to:

- Identify that pressure buildup is the greatest hazard with cryogenic systems
- Recognize that back injuries, freezing, ice build-up, and asphyxiation are other common hazards associated with cryogenics

Cryogenic Safety

About Cryogenics

Cryogenics are included in the Lab's Pressure Safety Program because:

- A cryogenic system is a pressure system waiting to happen.
- Knowledge of cryogen types, characteristics, and hazards will heighten safety awareness.

Cryogenic Liquids

- Are gases that have been transformed into extremely cold, refrigerated liquids that are stored at temperatures below -100 degrees Fahrenheit.
- Are normally stored at low pressures in specially constructed, multi--walled, vacuum-insulated containers.

(Note: For safety considerations, liquid carbon-dioxide and liquid ammonia are included in this classification.)

Cryogenic Safety

K °F

300
250
200
150
100
50
0

°F	Cryogen	Liquid/gas expansion	Pressure to maintain liquid density at room temperature
32	ice melts		
-109	liquid carbon dioxide	553.1	850psi
-258	liquid methane	578:1	
-297	liquid oxygen	860:1	
-302	liquid argon	847:1	
-320	liquid nitrogen	696:1	43,000 psi
-423	liquid hydrogen	851:1	28,000 psi
-452	liquid helium	757:1	18,000 psi

Common Cryogenic Applications

Cryogenics uses are:

- Low-volume storage and shipping containers
- Refrigeration (e.g., food transport)
- Cold traps/sorption pumps
- Superconductor industry
- Low-temperature materials research
- Rocketry (e.g., space shuttle)

Examples at LLNL:

- LN2 traps
- Vacuum systems
- Maintaining detectors at constant temperature (e.g., HC Whole Body Counter)

Cryogenic Hazards

There are five main safety hazards associated with the use of cryogenics at LLNL.

They are:

- Pressure buildup
- Back injuries
- Freezing (thermal) hazards
- Ice buildup
- Asphyxiation

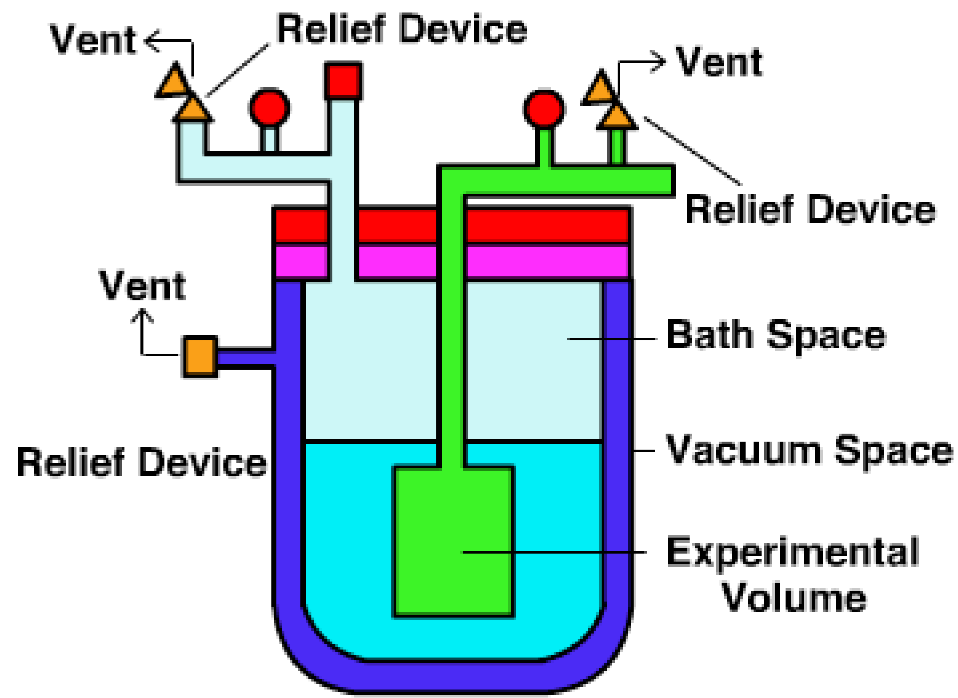
Cryogenic Hazards (cont.)

Pressure Buildup

This is the greatest cryogenic hazard. Cryogens expand in volume as they heat up. One unit of liquid nitrogen, for example, can quickly become 700 units of nitrogen gas.

Remedy:

Each space in contact with the cold must have a pressure-relief device.



Cryogenic Hazards (cont.)

Back Injuries

Back strain/sprain from moving cryogenic containers is the most frequent type of "cryogenic injury."

Remedies:

- Local dewar fill stations - to minimize the need to move cryogen.
- Automatic fill stations - to eliminate the need to move cryogen.
- Carts, dollies, trucks - to make moving cryogen easier.

Cryogenic Hazards (cont.)

Freezing (Thermal) Hazards

Cryogens can freeze tissue:

- Rarely occurs due to gas film, but don't handle too long.
- No film protection with CO_2, ammonia.

Cold metal parts can freeze tissue:

- No protective gas film.
- Skin moisture freezes (like tongue on a frozen railroad track).

Remedy:

Wear protective gear/clothing as specified in the following pages.

Cryogenic Hazards (cont.)

Freezing (Thermal) Hazards

Personal Protective Equipment

- Wear eye, hand, and body protection to prevent contact with liquid cryogens.
- At a minimum, wear safety glasses with side shields any time crygenic liquids, exposed to the atmosphere, are present. Chemical splash goggles provide the best protection for the eyes.
- In addition to safety glasses, full face shields shall be used in the following situations:

    - When a cryogen is poured;

    - For open transfers;

    - If fluid in an open container is likely to bubble.

The table on the next page (Table 2, *ES&H Manual*, Document 18.5, Cryogens) provides guidelines for selecting additional PPE. Review the IWS/HAC and consult with your ES&H Team for assistance.

Guidelines for Selection of Personal Protective Equipment (PPE)

Hands
- Loose, nonasbestos insulating gloves that can be tossed off readily.
- Special gloves made for cryogenic work.
- Leather gloves without gauntlets that can be tossed off readily.
- Tongs or other tools to lift objects out of the liquid or liquid baths.

Feet
- Closed-toe shoes that cover the top of the foot.
- Boots (extend trousers over the boot)

Body
- Long-sleeved clothing made of nonabsorbent material.
- Cuffless trousers worn outside boots or over high-top boots.
- Leather or other nonasbestos apron when handling large quantities of cryogens.
- Full protective suits where exposure to drenching is possible.

Respiratory
- Supplied air where drenchingis possible and where oxygen deficiency or organs asphyxiation may occur. (These types of exposures should be prevented through the implementation of engineered controls.)

Ears
- Ear plugs or ear muffs where excessive noise levels may occur near filling and venting operations.

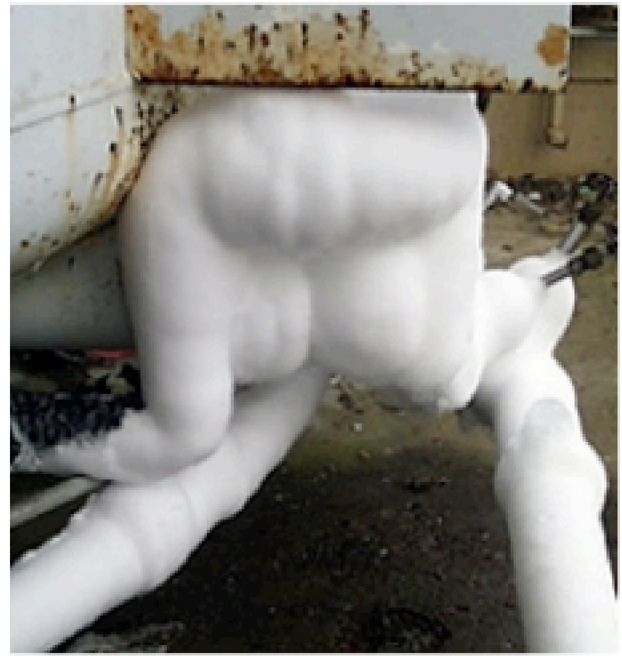
Cryogenic Hazards (cont.)

Ice Buildup

Ice buildup, the most common atmospheric effect of cryogenic systems, can become a serious hazard. This is because, at low temperature, some materials become brittle and can break.

Remedies:

- Keep elements (pressure reliefs, valve packing, etc.) above 32 degrees Fahrenheit.
- Cover critical vent areas or point them downward using Dewar necks, pressure reliefs to prevent water and debris from setting in the relief device preventing it from working.
- Most common solution is extended length of poorly conducting material, i.e., É.SST instead of copper to prevent cold liquid from freezing relief devices.



Cryogenic Hazards (cont.)

Asphyxiation

Asphyxiation can happen around cryogenic systems because cryogens can flash into very large volumes of gas. And, if more dense than air, the cold vapor will displace the air, traveling to the lowest point of elevation creating a seriously oxygen-lean environment.

Remedies:

- Ensure good ventilation.
- Avoid low places, confined spaces, air intakes.
- Use oxygen monitors, as required.

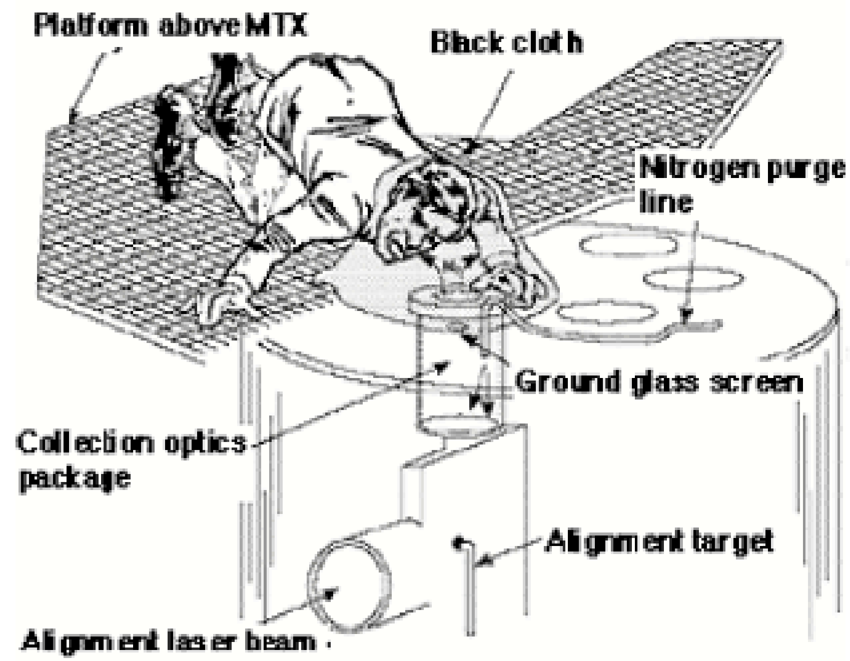


Diagram illustrates an actual MTX accident that happened at LLNL when an experimenter created a confined space with a cloth. For more information go to the Safety Wise site.

Module 5 Goal

This module is to introduce you to the elements of Oxyacetylene Safety.

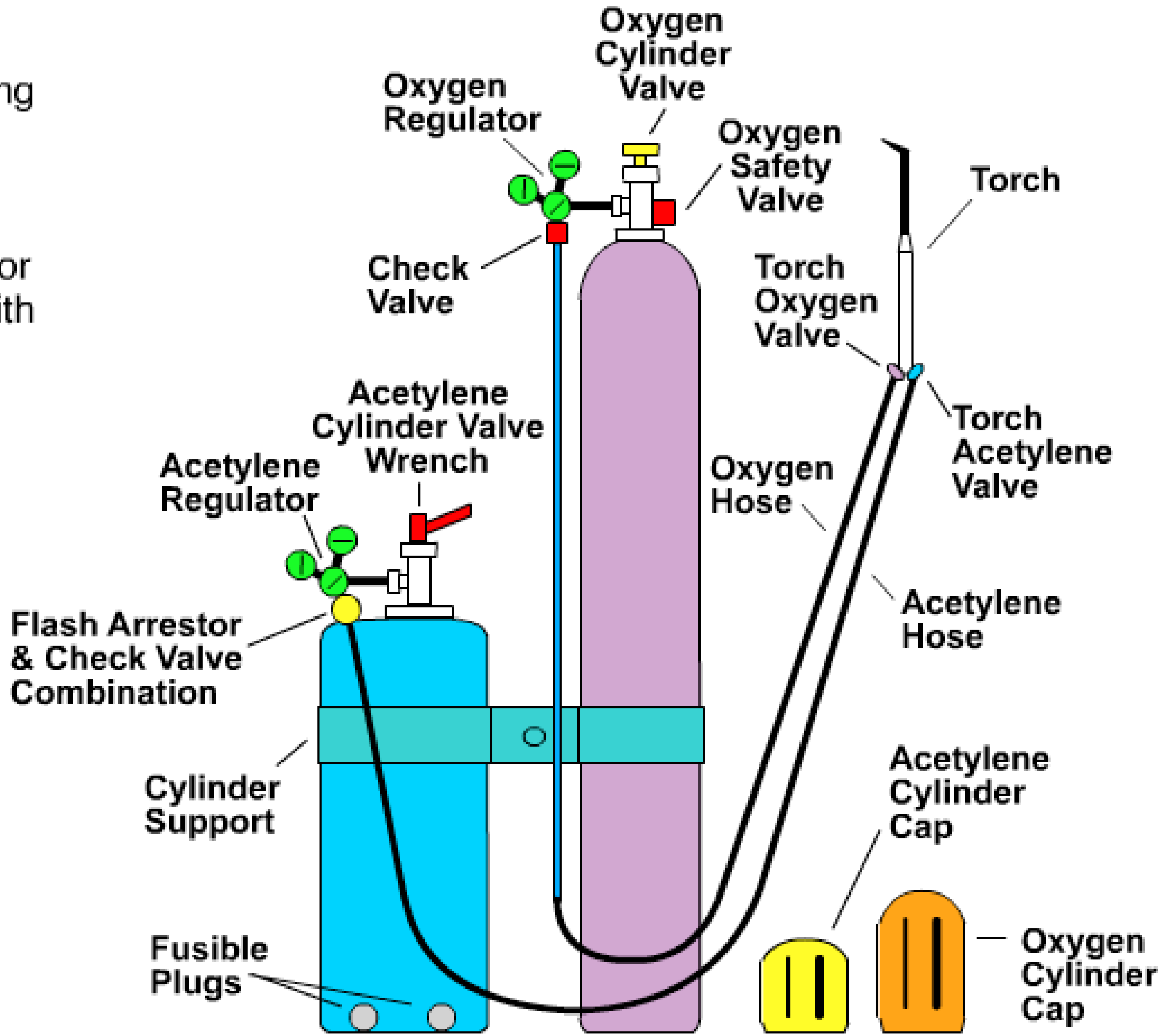
Module Objectives

After completing this module, you will be able to:

- Recognize and identify the basic safety rules for oxyacetylene safety

Oxyacetylene Welding Equipment

Properly used, oxyacetylene welding equipment is safe. However, used improperly, it has the potential for great destructive power. It is important, therefore, for the operator of such equipment to be familiar with all its potential dangers.



Flash Arrestors and Check Valves

Any system with an oxydizer and flammable gas (such as an oxyacetylene system) must have a flash arrestor (see photo) in case of a fire in the hose. If this happens, the arrestor will sense the back pressure and shut off the back flow of gas to the source (like a one-way check valve).

[Side Note: When installing a flash arrestor, remember that lines carrying flammable gases will have left-hand threads.]

Note, too, that the oxygen system must have a check valve.

Precautions and Tips for Acetylene Cylinders

Always store and use acetylene cylinders in the upright position. Otherwise, you will draw acetone, not acetylene. Acetone is used in the cylinder as a stabilizing solution for the acetylene. If a cylinder has been tipped over or stored horizontally, stand it upright for at least one hour before using. This will give the acetone a chance to settle.

Likewise, if the draw rate is too fast, you will withdraw some acetone. If a high draw rate is required, you might need to use two acetylene tanks to achieve the necessary flow rate. See photo.

Eleven Commandments of Safety for Fuel Gas and Oxygen

1. Blow out manifold or cylinder valves before attaching hoses or regulators.

2. Release (back off-counter clockwise) the regulator adjusting screw before opening the manifold or cylinder valve.

3. Don't stand in front of the regulator when opening the valve.

4. Open the valve SLOWLY.

Commandment 2

"I never release the adjusting screw, takes too much time. OOPS!" - Smith Equipment

All cartoons courtesy of **Smith Equipment**

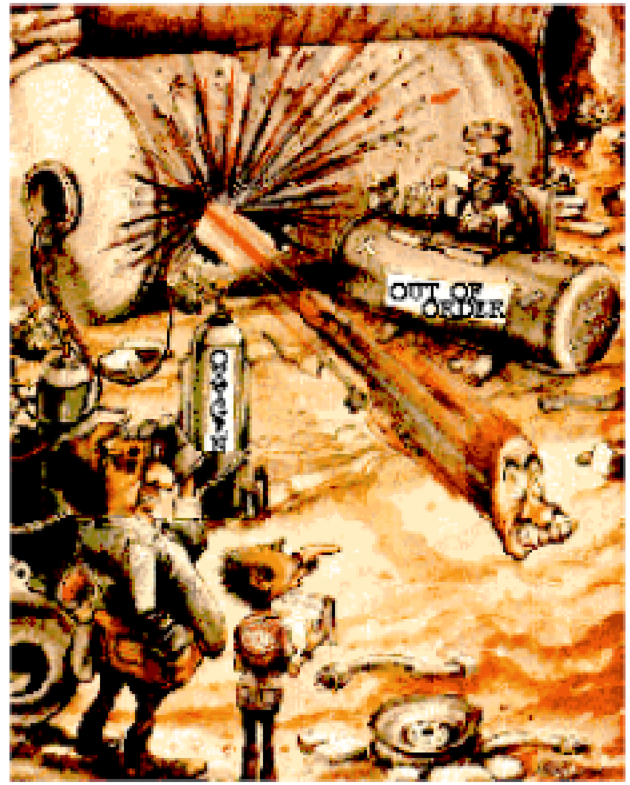
Eleven Commandments of Safety for Fuel Gas and Oxygen

5. Never use oxygen as a substitute for compressed air (note: Fatal Facts in accident section).

6. Don't use fuel gas from cylinders at pressure settings over 15 psi.

7. Purge your fuel-gas and oxygen lines.

Commandment 5



"There goes Lumis now...and his theory on using oxygen for ventilation." - Smith Equipment

All cartoons courtesy of **Smith Equipment**

Eleven Commandments of Safety for Fuel Gas and Oxygen

8. Always light the fuel gas before opening the oxygen line.

9. Never use oil or grease around fuel-gas/oxygen equipment.

Commandment 9

"I told you, some of the welders were using oil on their regulators." - Smith Equipment

All cartoons courtesy of **Smith Equipment**

Eleven Commandments of Safety for Fuel Gas and Oxygen

10. Keep heat, flames, and sparks away from hoses, regulators, tanks, and combustibles.

11. Make sure all hose, cylinder, and regulator attachments are tight and not leaking.

Commandment 10

"When you light up, you don't miss much, do you Jonesy" - Smith Equipment

All cartoons courtesy of **Smith Equipment**

Module 6 Goal

This goal is to relate pressure accidents and how to avoid them. It will also identify references and frequently asked questions of the LLNL Pressure Safety Program.

Module Objectives

By presenting several accident case histories, you can plug in ISM principles to illustrate how these accidents could have been prevented.

The reference material is to familiarize you with the pressure safety standards, both national consensus and LLNL specific.

Pressure Accidents

The severity of a pressure accident is not so much a function of pressure. Rather, it is related to energy and force. With that in mind, the most common pressure accidents are those that involve low pressure, but high volume. This is becausev, with low pressure, it is easy to underestimate the hazard potential. It's easy to:

- Fail to recognize the potential hazard.
- Fail to consider the hazard sufficiently.
- Fail to follow safe operating procedures.

Pressure Accidents

Accident Causes

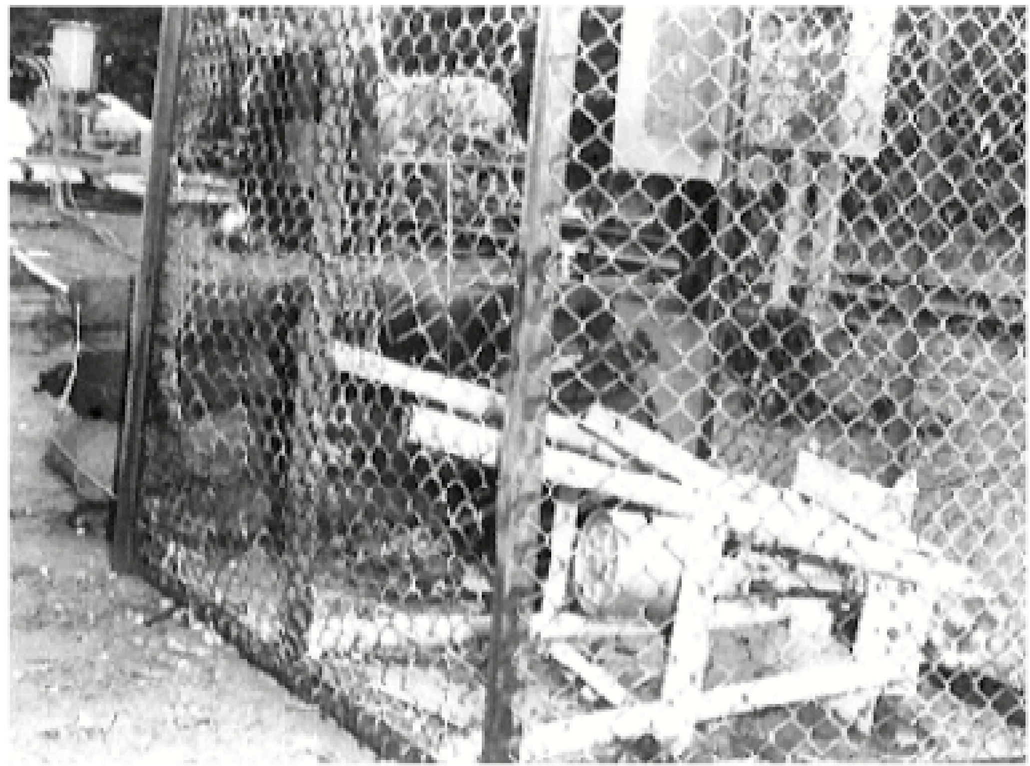
In general, the causes of pressure accidents can be grouped into two categories: equipment (engineering) errors and operator (user) errors.

Engineering Causes

- Poor design
  - Control and safety devices
  - Material strength
  - Material compatibility
- Faulty component manufacture

Technician/User Causes

- Faulty assembly/installation
- Poor maintenance
- Poor operating practices
  - Failure to follow established procedures
  - Use of wrong materials
  - Misuse of equipment



Pressure Accidents (cont.)

Accident Causes

An LLNL Example

Employees were doing a pressure check on a two-stage gas gun in Building 212. During the check, a thread plug blew out and hit a door. It seems an employee had used a T-bar to install the thread plug into the first-stage part of the gun, and he met resistance, he thought the plug was fully engaged. Apparently, it was not-hence the accident. No one was hurt, because they were operating the pressure check remotely.

A vacuum system can become a pressurized system if you are not aware of the hazards. Incorporate ISM into the planning stages of your experiment.

Click here for another pressure accident

Pressure Accidents (cont.)

Accident Scenarios

Always Use A Regulator

Researchers needed to create a 10-psi gas flow through a glass reservoir. No pressure relief device or pressure regulator were used. The pressure was to be regulated using the cylinder valve. The first time the cylinder valve was opened, the glass reservoir burst and both researchers suffered multiple lacerations.

Key points:

- Excess supply pressure (2,000 psig)
- No regulator (reduces pressure)
- No pressure relief device (protects lowest M.A.W.P. 10 psig)
- No shielding for glass system (protects personnel)

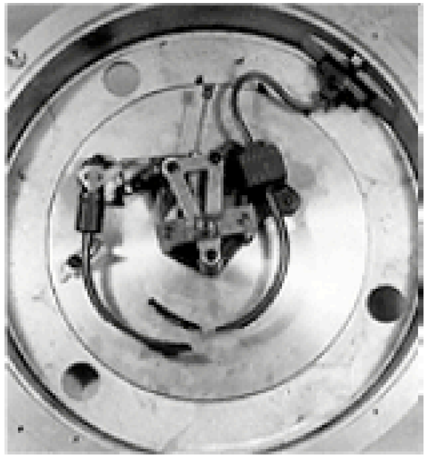
Pressure Accidents (cont.)

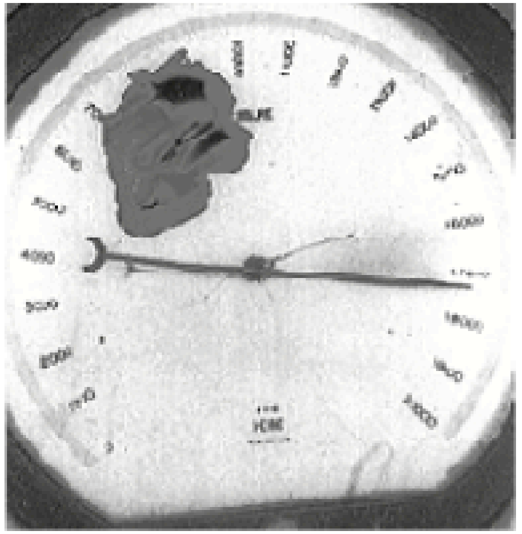
Make Sure Materials Are Compatible

A Heise gauge with a face value of 20,000 psi was used with hydrogen, it failed at 17,500 psi.

Key points:

- Materials (hydrogen and gauge materials) were incompatible.
- Hydrogen embrittled the gauge.
- Gauge was used at too high of a pressure.
- Gauges are generally the weakest component in a pressure system.





- Take care to understand the pressure gauge section of this course and all of its rules for pressure gauges.

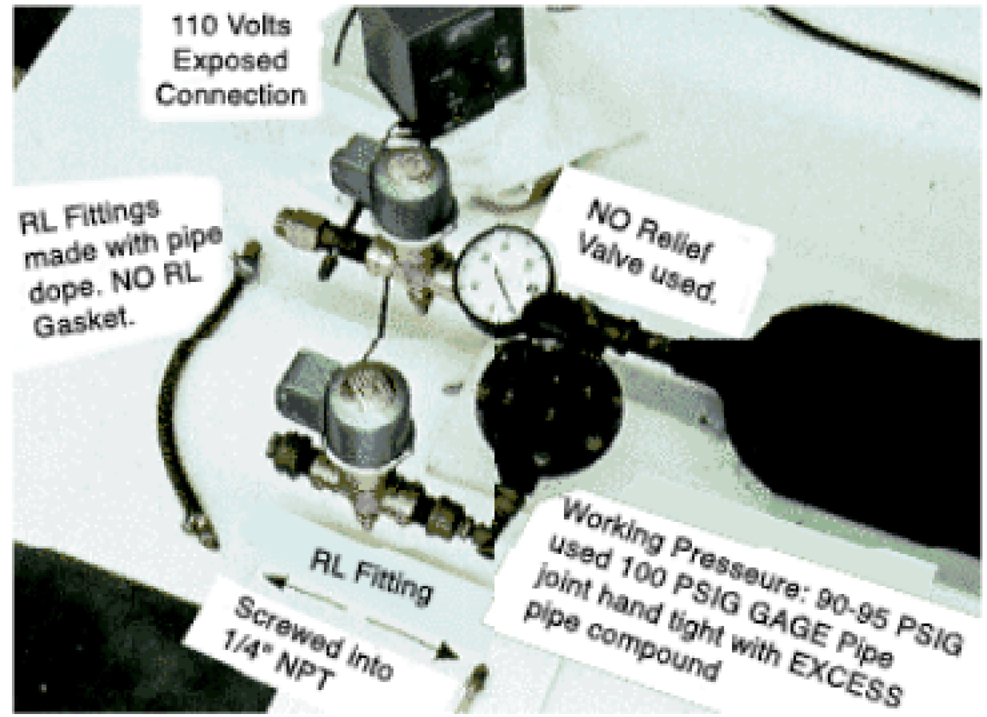
Pressure Accidents (cont.)

A Safe Assembly Is Critical - Have It Checked Out

A researcher pieced together a pressure system for an experiment he was planning. To be safe, he had the assembly checked out by the High Pressure Lab before running the experiment.

Good thing he did, because it had several problems:

- Vessel had been retrieved from the salvage yard. (no previous documentation)
- Working pressure was to be 95 psi, but the gauge was only rated to 100 psi (supposed to be at least 1.2 times MAWP).
- No relief protection was provided.
- Rad Lab (RL) straight-thread fittings were used with tapered pipe threads and pipe dope instead of using correct gaskets or matching threads.
- Excess pipe dope used to seal hand-tight fittings.
- There were electrical hazards with the setup.



Pressure Accidents (cont.)

Never Misuse Equipment

A researcher filled a fire extinguisher with acetone to do an experiment; then, simply put the extinguisher back on the wall when finished. This was a disaster waiting to happen! The label (acetone) was put on by the investigators.

Key points:

- Think of the consequences if someone had tried to use the extinguisher to fight a fire.
- When doing something clever, consider the consequences!

Pressure Accidents (cont.)

Low Pressure/High Volume Can Be Dangerous

An air supply was used to separate a lay-up from a hollow wooden mold. When the mold did not separate, the pressure built up. And then, when it did separate, it really took off!

The air supply was 75 psi. The mold had a cross-section of 133 square inches. So, the force - pressure times area - was 10,000 pounds! When the mold finally separated, it broke one worker's hand, lacerated the scalp of a co-worker, and broke a ceiling fixture 20 feet away.

Again, the lesson:

- Low pressure and large volume (or large area) generate a huge force, which can be quite dangerous in a seemingly tame situation.

Pressure Accidents (cont.)

Do Not Mix Oil and Oxygen

While generally not as drastic as this cartoon depiction, oil contamination of oxygen equipment (see photo) can have explosive consequences. Compressors and regulators used for air and many other gasses have oil seals. The oil from these seals can be carried in the gas stream and deposited on internal parts. That's why it is so important to keep oxygen equipment completely separate from other pressure equipment. Had the regulator shown here been used with oxygen, it would have exploded.

Key points:

- Keep oxygen equipment completely separate.
- Inspect prior to use.

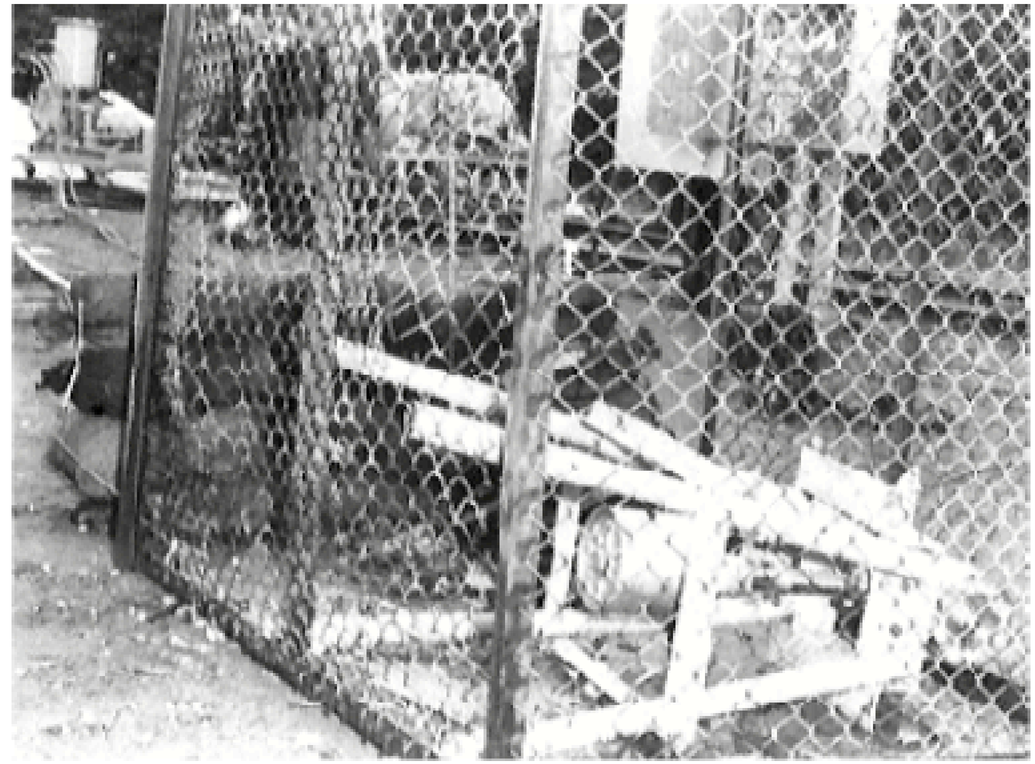
Commandment 9

"I told you, some of the welders were using oil on their regulators." - Smith Equipment

Pressure Accidents (cont.)

Stay Behind the Safety Barricade

At Aerojet in Sacramento a large pressure vessel was being tested to destruction. The vessel was on a pad surrounded by cyclone fence. The failure point was estimated to be between 1,400 and 1,700 psi. The control bunker was 375 feet away, protected by sandbags. The vessel failed at 884 psi, and an engineer who had moved out from behind the barricade was killed by a 1-inch-by-1 1/2-inch fragment.



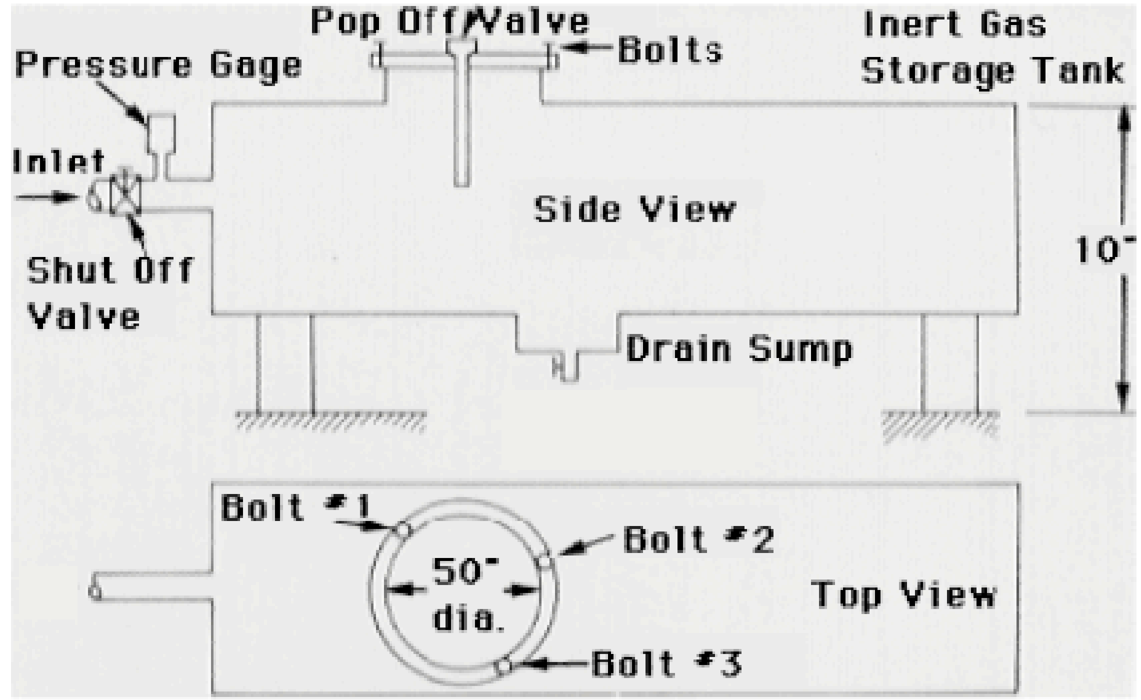
Key points:

- Expect the unexpected
- Establish stringent controls
- Adhere to established procedures

Pressure Accidents (cont.)

Maintain and Understand Your Equipment

This diagram of a large-volume, stainless-steel-lined tank relates to a fatal pressure accident in Kent, Washington. The tank had been completely vented, after which the valve was closed. Later, a workman began to remove the hatch. Upon removing the second of three bolts, the hatch cover blew off, killing the workman instantly and landing on a car 40 feet away killing the occupant.



The accident investigation found that thermal expansion, after venting, had produced some 3 to 5 psi of pressure inside the tank- which had not been detected due to a defective pressure gauge.

Pressure Accidents (cont.)

Always Use a Relief Device with Liquid Nitrogen

At a new installation in Centralia, Washington, a vendor filled a LN2 stationary dewar from a liquid nitrogen truck. Ten minutes after the truck had left, the 2-inch copper pipe blew up. Liquid nitrogen had been trapped between the manual shutoff valve on the dewar and the two check valves in the line, with no pressure-relief protection.

Key points:

- Understand your system
- Use relief protection

Mouse over the red box to see a close-up of the copper pipe.

Pressure Accidents (cont.)

Other Lessons Learned from Pressure Accidents

- Always secure flexible pressure hoses. A pressurized hose whipping around can cause serious injury.
- Keep your regulator in a plastic bag, clearly identified.
- Oil in an oxygen regulator can cause it to explode.
- When changing a regulator from one bottle to another, keep in mind that the weakest part of the regulator is the bonnet, which can blow out. Always back off the regulating screw gently so it doesn't get shocked.
- Do not rely on someone else. Verify whether or not there is pressure youself.

Frequently Asked Questions

Question: In several places the course mentions High Energy content of a pressurized gas volume. This is not identified, defined, or otherwise presented to the student in such a way that he/she can estimate the energy content of a typical gas-filled system.

Answer: High energy content is mentioned as an awareness that even low pressure, but high volume systems can be dangerous. In the following courses HS5040-W, HS5050-W, and especially HS5060-W Pressure Seminar for Engineers stored energy, the formulas and examples are given, i.e. HS5040-W talks about force on the end of a drum. HS5050-W explains ideal gas law and the stored energy in a cylinder. HS5060-W goes into gases at higher pressures and using the formulas in safety notes. Browse through those classes.

As an example of stored energy, the two copper tubes below were burst tested.
The one on the left with water, the one on the right with gas. They both failed at approximately 3200 PSIG, over four times their rated MAWP of 580 psig. However, the one on the left with water had only .0016 lbs of TNT equivalent stored energy. The one on the right with gas had .424 lbs. of TNT equivalent stored energy and much more violent reaction at burst.

- Check out a lesson on purchasing tubing.

Frequently Asked Questions

Questions asked about MAWP and Burst Pressure of a Hose

Question: Can you operate at your M.A.W.P. setting?

Answer: No, because the relief device is set at M.A.W.P. and will vent the system.

Question: What is weakest part of hose?

Answer: The fitting. Be sure to tie down the end of hose with kellum grips. This can stop the whip of the hose if the fitting breaks.

Question: What type of hose should I use?

Answer:

- For cryogens, use flexible stainless steel that is Teflon lined.
- For flammable, corrosives, poison, and toxics, and oxygen, DON'T USE TEFLON because Teflon is permeable; oxygen picks up Teflon, accelerates it and can cause spontaneous combustion or an explosion.
- Always check with the manufacturers specifications for hose type and fluid compatibility before ordering.

Additional Resources

The following items can be found in the resources section. Click on the "resources" buttton below.

- Work Smart Standards (WSS) for pressure safety are located in the back of the *ES&H Manual*, Volume II, Part 18.1 Pressure.

- *ES&H Manual*, Volume II, Part 18: Pressure/Noise/Hazardous Atmospheres
    - Pressure 18.1 (Chapter 32)
    - Pressure Vessel and System Design, 18.2 (Supplement 32.03)
    - Pressure Testing, 18.3 (Supplement 32.05)
    - Hydrogen, 18.4 (Chapter 21)
    - Cryogens, 18.5 (Chapter 22)

- Pressure-Safety web site

- Operational & Facility Safety Plan

- *ES&H Manual* Volume II: Health & Safety--Hazards and Controls -- Part 12: General H&S Controls-Safety Equipment and Facilities

- Volume II, Part 18: Cryogenics for guidelines on Personal Protective Equipment

- http://www-r.llnl.gov/hc_dept/Pressure/Accident7.html