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1. Introduction

Title 10, Part 851, Code of Federal Regulations (10 CFR 851) establishes worker safety and health requirements to govern contractor activities on U.S. Department of Energy (DOE) sites. This regulation went into effect on February 9, 2007. Pressure Safety is one of the disciplines specifically covered by this regulation, as detailed in Appendix A, Section 4.

PPPL has prepared ES-MECH-015 in order to control the safety of pressure systems and thereby comply with the regulation. 10 CFR 851 does not provide a pressure limit or other variable defining a pressure system. Therefore, PPPL has established a pressure system level based upon stored energy, hazardous content and other parameters which poses minimal risk to PPPL staff during operations.

The PPPL ES-MECH-015 standard is prepared with consultations and excerpts from the PNNL's Document #18696 (Pressure Systems Stored-Energy Threshold Risk Analysis) and Thomas Jefferson National Accelerator Facility's ES&H Manual, Chapter 6151 Pressure and Vacuum Systems Safety Program.

2. Purpose

The purpose of this standard is to ensure that all personnel at PPPL involved in the design, construction, repair, alteration and operation of pressure and vacuum systems are cognizant of the hazards associated with these systems and construct, repair, alter and operate these systems in a safe manner. The hazards associated with pressure and vacuum systems include leakage, rupture, explosion or implosion and can pose risks to personnel, property and the environment. If at any time, questions arise as to the safety or proper procedures to be followed with pressure or vacuum systems, stop the activity and solicit help from a qualified source.

As defined in the "Definition" section, a pressure system includes any combination of vessels, piping, safety relief devices, instrumentation (e.g. gauges), and/or equipment (e.g. pumps or compressors) either containing a fluid under internal pressure or exposed to external fluid pressure. NOTE that vacuum systems are a subclass of pressure systems.

Examples of pressure systems used at PPPL include:

- Cryo-modules, which include both pressure and vacuum systems
- Experimental equipment with vacuum chambers
- Small experiment target vessels and piping confining pressures
- Superconducting magnets, which include both pressure and vacuum systems
- Oil removal and gas storage systems integral to the cryogenic plants
- Compressed air and pressurized air reservoirs
- Heating and cooling water systems throughout the site

3. References

10 CFR 851 - WORKER SAFETY AND HEALTH PROGRAM
ESHD 5008, PPPL ES&H Manual Section 9, Chapter 11 "Pressure Systems"
ESHD 5008, PPPL ES&H Manual Section 9, Chapter 14 "Vacuum Windows"ENG-014, PPPL Hydrostatic and Pneumatic Testing
ENG-033, Design Verification
ESH-001 Use of Safety, Accident Prevention and Equipment Protection Tags
ESH-016 Control of Hazardous Energy (Lockout/Tagout)
PTP-VAC-004, Pre Operational Test Procedure for Vacuum Windows
American Petroleum Institute (API) RP 576, Inspection of Pressure-Relieving Devices

American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) Sections I though XII
ASME Pressure Piping Code B31, including applicable addenda and code cases
ASME PTC-25 Pressure Relief Devices
National Board of Boiler and Pressure Vessel Inspectors (NBBI) National Board Inspection Code (NBIC) (NBBI NB 23)

4. Definitions

System Engineer – Individual designated by Division/Department Head or Project Administrator for a particular functional or organizational area of responsibility (usually at section head level or higher). This individual maintains equipment spot-checks, inspection program(s), disposal and other actions/problems regarding equipment within their assigned functional area.

Inspector – A person designated by the organization who has sufficient experience and/or knowledge in operating, maintaining and inspecting pressure systems, and pressure relief devices.

Maximum Allowable Working Pressure (MAWP) – maximum pressure a system may operate at.

Out of Service – A system that is formally designated inactive or not in use, vented/drained, and disconnected from the pressure source. A Caution tag shall be applied.

Pressure Relief Devices – Devices that are required by the provisions of the PPPL ES&H Manual Section 9, Chapter 11 "Pressure Systems".

Pressure Relief Systems - pressure relief devices and their inlet and outlet piping.

Pressure System – Per 10 CFR 851, all pressure vessels, and pressure sources including cryogenics, pneumatic, hydraulic, and vacuum. Any system that has a pressure differential from atmospheric pressure either positive or negative (vacuum) is considered a pressure system. Note: Vacuum systems should be considered pressure systems due to their potential for catastrophic failure due to backfill pressurization. Associated hardware (e.g., gauges and regulators), fittings, piping, pumps, and pressure relief devices are also integral parts of the pressure system.

Protected System – the piping, vessel, or system of piping and vessels for which the pressure relief system is required.

Visual Inspection - consists of verifying, to the extent possible without disassembling the relief System or removing relief devices, that:

- The relief devices are the same as those described in the engineering drawings,
- The outlet or discharge piping of relief devices has remained unrestricted,
- The inlet and outlet piping of the relief system have not been changed in a way that would reduce the relief capacity, and
- The relief devices have not undergone severe corrosion, tampering or other visible deterioration.

Testing of a Re-Closing Relief Device - verifying that the set pressure satisfies the requirements of ASME Code Section VIII Division 1 paragraphs UG-126 and UG-134 or Division 2 Article R-1 for code stamped relief valves or other Codes/Standards as required by the affected Engineering Drawing. For non-code stamped relief valves used on low pressure or vacuum vessels, use engineering judgment in determining if the set pressure and valve opening are appropriate for the service conditions. The relief device may be tested in place provided the test pressure does not exceed the MAWP (maximum allowable working pressure) of the protected system; otherwise, the relief device must be removed for testing.

5. Exclusions

5.1. Devices excluded from the requirements in this standard:

PPPL recognizes that the scope of pressure systems is very broad and many systems fitting this definition are not inherently hazardous, while other systems pose hazards that are mitigated by other programs or codes (e.g. International Building Code or US Department of Transportation (USDOT) regulations). All pressure and vacuum systems, unless explicitly excluded below, shall meet the requirements given in this standard. The following systems are excluded from the requirements of this standard:

5.1.1. Any system where all of the following criteria are met:
- The maximum system pressure cannot exceed 15 psig at any time including all credible failure modes ,
- The system fluids are nonflammable, nontoxic, and not damaging to human tissue,
- The system design temperature is greater than -20F and less than 366F [as defined in ASME B31.1, section 300.1.3],
- The total stored energy of the system is less than 10,000 ft- lbs.

5.1.2. Any system with a total stored energy (thermo mechanical and chemical combined) of less than 1,000 ft- lbs provided the system fluid is not damaging to human tissue.

5.1.3. Gas cylinders regulated by the USDOT.

5.1.4. Liquefied gas cylinders regulated by the USDOT.

5.1.5. Pressure vessels in vehicle pneumatic and hydraulic systems that are covered by USDOT.

5.1.6. Self Contained Breathing Apparatus (SCBA) Air Cylinders.

5.1.7. Domestic hot water heaters with a capacity less than 120 gallons, a water temperature less than 210°F and heat input less than 200000 BTU/hr.

5.1.8. Domestic appliances regulated by building codes and/or national industry standards.

5.1.9. American Society of Heating, Refrigerating and Air conditioning Engineers (ASHRAE) 15 compliant systems and devices.

5.1.10. Roof and floor drains, sanitation plumbing, and sewers.

5.1.11. Domestic hot, cold and grey water pressure piping governed by applicable building codes.

5.1.12. Piping for hydraulic or pneumatic hand tools and their components downstream of the first block or stop valve off the system distribution header.

5.1.13. Instruments (not instrument piping/tubing).

5.1.14. Fire protection systems constructed in compliance with recognized fire protection engineering standards and adhering to the provisions set forth in ES&H Manual 5008.

5.1.15. A system meeting another national or state recognized standard or code with approval of Pressure Systems Manager.

5.2. Stored Energy Calculation:

The stored energy for gases or vapors above the boiling point can be calculated by selecting the formula for the given property changes from the equations provided on : Lindeburg 2006, Mechanical Engineering Reference Manual for the PE Exam, 12th Ed., P25-7-9.

For liquids below their boiling point, the stored energy can be calculated using the bulk modulus of the liquid, or a conservative value if one is unknown. Equation 5.1 was implemented at PPPL due to its use at PNNL Document#18696.

$$W = \frac{1}{2}.\beta.P^2.V \tag{5.1}$$

Where:

W = Work Energy

V = Initial Volume
β = Compressibility (1/Bulk Modulus)
P = Pressure

Examples of potential energy stored in everyday items are listed in Table 5.1

Table 5.1 Stored Energy of Everyday Items

Item	Volume (ft^3)	Gas	Pressure (psig)	Stored Energy (lbf-ft)
Compressed Gas Cylinder	1.42	Air	2500	982,500
Standard Air Compressor, 50 gal	6.68	Air	125	159,000
Standard Air Compressor, 20 gal	2.67	Air	125	64,000
Propane Tank (grill, compressed gas expansion only)	0.63	Propane	200	35,000
Paint Ball Tank (20 oz)	0.02	Air	3000	21,300
M-80 (2.5 grams of powder)	N/A	N/A	N/A	17,000
State Limit for Third Party Inspection of ASME Coded Vessel	5	Air	15	9,700
Car Tire	0.97	Air	35	5100
Mountain Bike Tire	0.2	Air	65	2,230
CO2 2L Pop Bottle Bomb	0.05	CO2	150	1,750
Typical CO2 Cartridge (16 gram)	0.0047	CO2	900	1,263
STORED ENERGY LIMIT				**1000**
BMX Bike Tire	0.11	Air	50	915
Road Bike Tire	0.04	Air	110	820
Typical CO2 Cartridge (12 gram)	0.0058	CO2	420	650
Typical Firecracker (50 mg powder)	N/A	N/A	N/A	340
Dust Spray Can	0.02	Mix	85	335
Soccer Ball	0.215	Air	12	320
Party Balloon	2.42	Air	1	255
Basketball	0.26	Air	8	250

5.3. Legacy Systems built before 2007

The DOE order is not intended to require the updating of legacy systems in use for their intended design purpose. Coded vessels built before 10CFR851 (2007) will not need to produce design calculations. A coded vessel can be identified by the nameplate with an ASME Certification Mark stamped on it. The nameplate will show the design pressures and temperatures of the vessel. Examples of legacy coded vessels would be the NB HVEs, and the Pump Room cooling water system expansion tank. An example is shown in Figure 5.1.

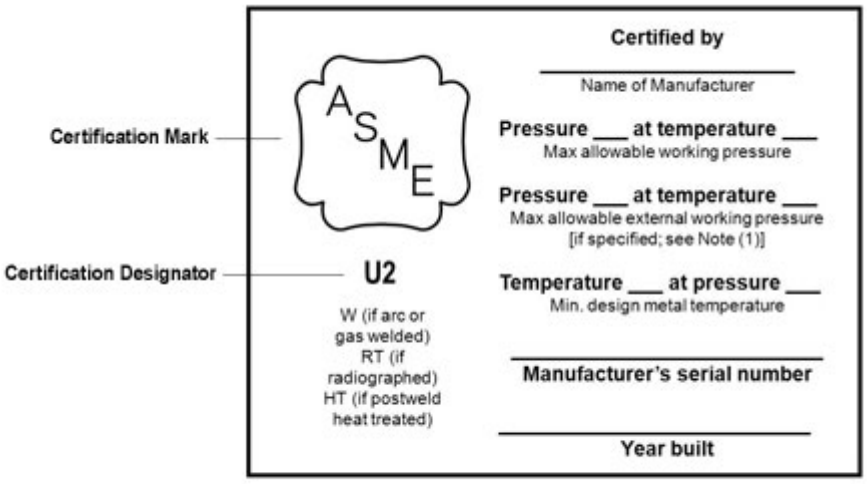

Figure 5.1 Sample ASME Product Certification Nameplate

5.4. Legacy Systems built after 2007

Appendix A, Section 4 of 10 CFR 851 states "contractors must establish safety policies and procedures to ensure that pressure systems are designed, fabricated, tested, inspected, maintained, repaired, and operated by trained and qualified personnel in accordance with applicable and sound engineering principles." The regulation goes on to state that all pressure systems and components shall conform to the applicable American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, ASME B31 (Code for Pressure Piping), and the strictest applicable state and local codes. Part (c) further states, "When national consensus codes are not applicable (because of pressure range, vessel geometry, use of special materials, etc.), contractors must implement measures to provide equivalent protection and ensure a level of safety greater than or equal to the level of protection afforded by the ASME or applicable state or local code.

Measures must include the following:

1. Design drawings, sketches, and calculations must be reviewed and approved by a qualified independent design professional (i.e., professional engineer).
2. Qualified personnel must be used to perform examinations and inspections of materials, in-process fabrications, non-destructive tests, and acceptance test.
3. Documentation, traceability, and accountability must be maintained for each pressure vessel or system, including descriptions of design,

Table 5.2 provides a checklist of the information needed systems built before and after 2007.

Table 5.2 Checklist of The Information Needed to Satisfy ES-MECH-015

System Type	Pressure System ID Card	PRV Installed	Coded vessel	P&ID	Design Calculations Filed	Periodic System Inspection	Periodic PRV Inspection/Test	Weld Inspections
Legacy (built before 2007)	x	x		x		x	x	
Pressure System (built after 2007)	x	x	x	x	x	x	x	x

6. Requirements

10 CFR 851 requires that documentation, traceability, and accountability must be maintained for each unique pressure system and/or vessel, including descriptions of design, pressure conditions, testing, inspection, operation, repair, and maintenance. A Pressure System Identification Card (Attachment 1) shall be completed and prominently attached to each pressure system and/or vessel. The following are minimum requirements.

6.1. Design

Design shall follow the requirements of PPPL ENG-033, Design Verification and comply with the instructions in this standard (ES-MECH-015). The PPPL Pressure Systems SME monitors the PPPL Pressure Systems program and is identified here: https://spportal.pppl.gov/bp/Lists/PPPL%20Experts/OSHA_CPs_ESH_POCs.aspx

A pressure system that includes an ASME code designed vessel is recommended to be equipped with ASME-rated pressure relief devices. It is recommended that ASME-rated pressure relief devices also be used on non-ASME pressure systems of more than 15 psig working pressure. Pressure relief devices on boilers shall not be isolated from the system they are protecting by a valve. The ASME BPVC provides all the formulas and calculations necessary for system design and pressure relief valve selection. There are also many reputable valve companies that offer free engineering handbooks such as http://valves.pentair.com/valves/Images/PVCMC-0296-US.pdf and software for the sizing of pressure relief valves such as Size Master at http://www.cw-valvegroup.com/Products/Engineering-Software/SizeMaster.aspx

6.1.1. Conventional Pressure Systems

All pressure vessels, boilers, and air receivers and supporting piping systems generally must be designed in accordance with applicable ASME code, which includes the Boiler and Pressure Vessel Code (BPVC) Sections I though XII, including applicable code cases and applicable ASME B31 (Pressure Piping Code) standards. Exclusions listed in Section 5 “Exclusions” apply.

6.1.2. Scientific Pressure Systems

10 CFR 851 specifies that when national consensus codes are not applicable (because of pressure range, vessel geometry, use of special materials), measures must be implemented to provide equivalent protection to ensure a level of safety greater than or equal to the level of protection afforded by the ASME code. Therefore a basic minimum design margin (safety factor) of 3.5 shall be used for any pressure system unless a lower design margin can be justified by applicable codes or stress analysis or engineering calculations.

6.1.3. Certification Marks (Stamping)

ASME-rated pressure relief devices bear the following certification mark and designators:

UV pressure relief valve for pressure vessels
UD rupture disk for pressure vessels
HV pressure relief valve for heating boilers

6.1.4. Pressure Vessels

Most of the pressure vessels, tanks, and storage systems will be designed and installed to comply with applicable ASME, ANSI, and other US codes and standards. (Others will be treated as non-coded, which must meet equivalent safety requirements as provided by the ASME code.)

All the designs will be submitted to the pressure systems SME for review and approval at the appropriate stages of design (such conceptual, engineering, and procurement readiness reviews).

- ASME-authorized inspector (AI) required
- Application of ASME BPVC to the applicable equipment
- Non-ASME systems designs verified and approved

6.1.5. Pressure Piping

All pressure piping and refrigeration piping must be designed, fabricated, tested, and inspected in accordance with ASME B31.3, “Process Piping”. Exclusions listed in Section 5 “Exclusions” apply. Piping may be designed under other code if necessary based on sound engineering judgment and proven work experience. The design specifications, drawings, lay-out plans, calculations, and stress analysis reports must be submitted to the Pressure Systems SME for verification and approval.

6.1.6. Pressure Relief Devices

Pressure Relief valves must be sized so that under worst-case failure conditions, the maximum pressure reached in any vessel is below the maximum allowable working pressure (MAWP) for the vessel. No fixed prescription can be given to determine valve sizing for all, or even most cases. Each system must be analyzed in detail to properly determine worst-case failure modes and the required relief valve sizing. Relief device calculations must be performed in according to ASME, American Petroleum Institute (API), or Compressed Gas Association (CGA) standards and appropriate published studies on vacuum failures on helium cryogenic systems.

6.1.7. Additional Requirements for Cryogenic Systems

A cryogenic system is considered a pressure system. Therefore, all of the above requirements for pressure systems apply. Cryogenic systems are protected with relief devices in the event of over pressurization or possible exposure to fire conditions. Cryogenic systems are designed under ASME BPVC Section VIII and must be designed to address all reasonable risks determined by the system and component failure modes and effects analysis. Cryogenic Dewars are protected with two relief devices to protect the inner vessel and two relief devices to protect the outer vessel. Each relief device is sized and installed in accordance with CGA S-1.1 safety devices for cylinders.

6.1.8. Additional Requirements for Vacuum Systems

A vacuum vessel can pose a potential hazard to personnel and equipment from collapse, rupture due to back-fill pressurization, or implosion due to vacuum window failure. It is important to design, fabricate, and operate vacuum systems in accordance with applicable codes and sound engineering principles. The above requirements for pressure systems apply. The following are additional PPPL requirements specific to vacuum systems.

6.1.8.1. Vacuum System Conditions

Any new vacuum system, or any legacy system that must be brought into compliance as described above, are defined as follows:

- Condition 1 includes all vacuum vessels in which the differential operating pressure can never exceed 15 pounds per square inch (psi) and is not connected to a pressure source.
- Condition 2 includes all vacuum vessels that are connected to a pressure source and are protected from pressurization exceeding 15 psi through such engineering controls as pressure relief devices.
- Condition 3 vacuum vessels include all vacuum vessels that are connected to a pressure source and are not or cannot be protected from pressurization exceeding 15 psi. **Important: Condition 3 systems are not allowed at PPPL.**

6.1.8.2. Vacuum System Shielding Requirements

The type of component most likely to fail catastrophically in a vacuum system is a brittle component such as a view port (window), glass bell jar, glass ion gauges, glass or plastic vessel, or glass or brittle plastic tubing. Vacuum Windows shall be checked per PTP-VAC-004, Pre Operational Test Procedure for Vacuum Windows prior to being placed in service. Component failure can be caused by, for example, an inadvertent blow or a scratch by a hard sharp object, and can produce sharp-edged shrapnel. Protective barriers may be used to reduce the likelihood of injury to personnel and damage to equipment. Some common shielding strategies include:

- Placing mechanical protective shielding around components such as glass or brittle plastic tubing and glass ion gauges;
- Operating a system within a hood with the hood door down (size permitting);
- Operating the system behind or within a polycarbonate (for example, Lexan) or metal shield;
- Wearing personal protective equipment (PPE) such as safety glasses or a face shield;

ESHD 5008 Section 9 Chapter 14 defines the PPPL requirements for vacuum window design and barriers.

View ports in Condition 1 and Condition 2 systems may be protected with clip-on polycarbonate covers if desired.

6.1.8.3. Protecting a Vacuum System from Overpressure

A second common cause of catastrophic vacuum vessel or system failure, particularly if there are brittle components, is the inadvertent application of internal pressure. Such pressure may be realized as a result of:

- Failure of a valve or regulator that is connected to the backfill source
- Pressure generated by a chemical reaction involving reactive gases
- Pressure realized by the accidental connection of the exhaust port of a fore pump to the inlet of the vacuum system. The vacuum pump inlet and outlet should be labeled to avoid switched connections.
- Over pressurization due to improper valve sequencing of a connected high-pressure source such as a gas cylinder.

Components that can protect a vacuum system that must be purged or backfilled with a high pressure source capable of causing the system to exceed the maximum allowable working pressure (MAWP) include:

- A safety manifold
- Relief valves
- Burst discs

A burst disk may be incorporated into a vacuum system design to limit the internal pressure to less than 15 psig following any equipment failure. Burst disks must be adequately sized for the credible identified failure mode and must be rated to fail at internal pressures of less than 15 psig in order to defend the system as intrinsically safe. The burst disk must be connected to the vacuum system and must not be isolated from the system by a valve.

6.1.9. Additional Requirements for Compressed Gas Systems

A compressed gas system is a pressure system; therefore the above requirements for pressure systems apply. The following are additional requirements specific to compressed gas systems. There are several types of compressed gas systems used at PPPL including compressed gas cylinders, tube trailer systems, house air, etc.

6.1.9.1. Compressed Gas Cylinder Systems

A compressed gas cylinder system consists of a cylinder and other associated parts such as regulator, pressure relief valve, valves, and fittings. A compressed gas cylinder system is shown in Figure 6.1.

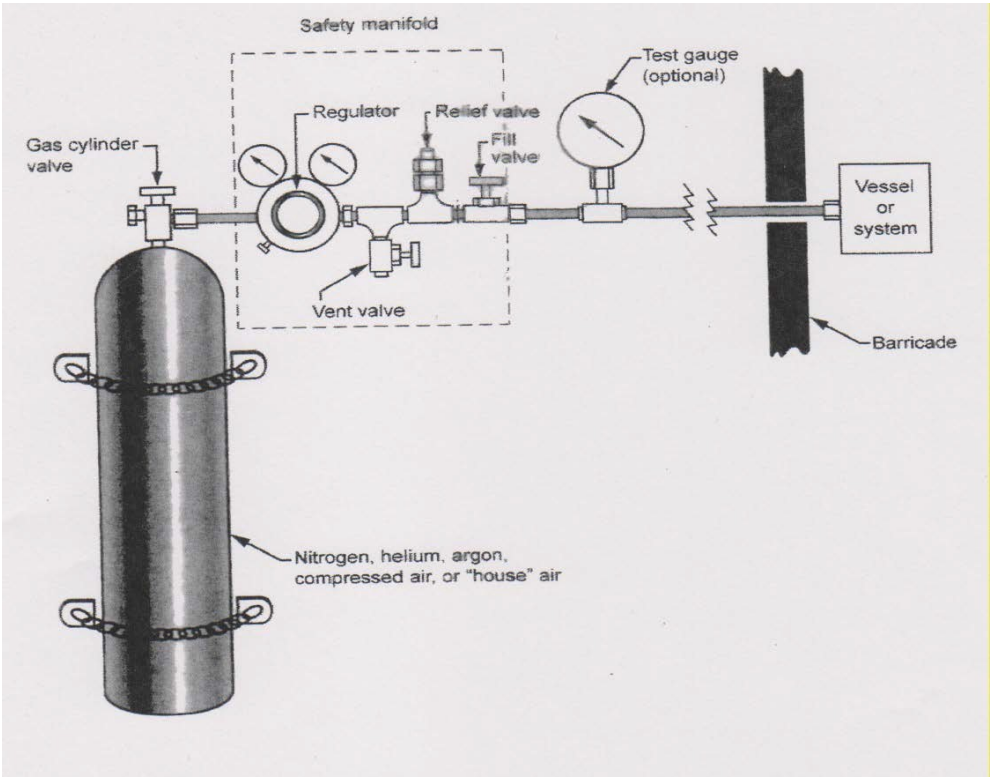

Figure 6.1 Example Compressed Gas Cylinder System

6.1.9.2. Safety Manifolds

A safety manifold (see Figure 6.1) is required to reduce the pressure from a standard cylinder and provide relief protection (relief device) for the down-stream system. The safety manifold consists of a regulator, a vent valve, a fill valve, and a relief valve. Safety manifolds must:

- Incorporate a means of shutting down or isolating the pressure source
- Address the safe venting of pressure from any and all parts of the system

A qualified ASME shop must perform maintenance and testing of set Pressure, Blowdown and Seal Tightness for ASME certified components per manufacturers' procedures (see section 6.6)

6.1.9.3. Cylinders

Cylinders for compressed gases are generally defined in US Department of Transportation (DOT) specifications (49 CFR 180.203) as containers having a maximum water capacity of 1,000 pounds or less. This is equivalent to 120 gallons. The DOT regulates the design, testing, filling, and transportation of commercially available gas cylinders.

Generally cylinders types 3A or 3AA are used for compressed gas systems. Requalification of a cylinder is required every five years per Table 1 in 49 CFR 180.209. The requalifying means an internal inspection and hydrostatic testing of the cylinder at a pressure 5/3 the service pressure of the cylinder. A cylinder that is filled before retest may remain in service until it is emptied of its charge. In other words, a cylinder that currently has a charge when the five-year retest date occurs does not have to be drained if its charge and retested. The charge can be used and the cylinder retested after the charge has been used.

Identification and Color Coding
Stencils, DOT shoulder labels, cautionary side-wall labels, or tags are used to identify the contents of all gas cylinders. Color codes are not used to identify contents.

Storage and Handling of Cylinders
The safe storage and handling of cylinders, return to vendor, disposing of damaged cylinders, and tags are covered in ESHD 5008, PPPL ES&H Manual.

6.1.9.4. Regulators

A regulator takes in gas from the cylinder and reduces the pressure to a low working pressure, simultaneously controlling the flow rate. It is important to obtain the correct regulator and ensure it is consistent with the gas involved and operation intended.

- Select a single-stage or double-stage regulator depending on your application.
- Store unused regulators in plastic bags to keep clean.
- Make sure that the threads on the regulator's CGA connection correspond to those on the cylinder valve outlet.
- Do not lubricate any part of the regulator or cylinder valve.
- Properly label the regulators with the fluid being used.
- Use only oxygen regulators for oxygen service.
- Immediately replace damaged, defective, or unreliable regulators.
- Do not attempt to make repairs or modifications to regulators.
- Inspect regulators at regular intervals, as appropriate to the application.

6.2. Installation

IMPORTANT: If any pressure source is added to the system after the installation is completed per design, a pressure system Safety Manifold approved by the Pressure Systems SME must be incorporated per Paragraph 6.1.9.2

A manufacturer, supplier, or mechanical subcontractor may install a pressure system. The installer must follow the design documentation, quality assurance, code requirements, and manufacturer's recommendations. The installer is responsible for pressure testing, installation inspection, performance testing, and acceptance testing. Qualified personnel of the manufacturer or mechanical subcontractor or a PPPL technician under the direction of the Pressure Systems SME must perform installation. After installation is complete, a pressure test must be performed and documented. The pressure test plans must be submitted to and approved by the Pressure Systems SME and Industrial Hygiene per ENG- 014 before performing the pressure test. All installation and pressure test records must be submitted to the Pressure Systems SME and the responsible Pressure System Engineer. The System Engineer will submit records to the Operations Center per ENG-032, Work Planning Procedure.

Note: The National Board Inspection Code (NBIC)*, Part I, "Installation", may be followed as a guideline for installation.*

6.3. Inspection

Prior to the activation or reactivation after a system has been out of service for any period, all safety relief device inspections shall be verified to be current. A Pressure Relief Device Description Form (Attachment 2) shall be filled out for each pressure system pressure relief device and placed on file in the Operations Center by the System Engineer.

6.3.1. Visual Inspection

A visual external inspection of each relief system must be made prior to initial operation of the protected system. The inspection must be repeated at regular intervals. Minimum inspection intervals for pressure systems are provided in Table 6.1.
Note: Certain systems require more frequent and/or internal inspection because of corrosive service or higher hazard potential. The system engineer should discuss this with the Pressure System SME.
Important: If any system shows signs of wear or a defect, steps must be taken immediately to address the problem. The system shall be tagged per ESH-001 Use of Safety, Accident Prevention and Equipment Protection Tags.

Table 6.1. Pressure System Inspection Frequency

Use Code	Fluid Service/Type	Inspection Frequency (Months)
NC	Non-corrosive gas and liquids (including LN2, kerosene, oils, etc.)	36
W	Corrosive Service; Water	24
REF	LP Gas; Propane; Refrigerant valves (e.g., Henry, Superior)	60
S1	Steam (ASME BPV Section 1)	12
S8	Steam (ASME Sec VIII)	24
S4	Steam (ASME BPV Section IV, Safety Valve Test for Steam Boilers) Monthly test; Annual Inspection	12
SP	Steam Pilot Relief Valve	24
DHW	Domestic/Commercial Water Heater	60
O2	Oxygen	24
RD	Rupture Disk: Flat/Forward Buckling and Bent/Breaking pins in non-plugging and non-lethal service	36
RDLS	Rupture Disk: Flat/Forward Buckling (Plugging or Lethal Service) or Reverse Buckling	24
DESIGN	Engineering Design and Analysis	60

The two pressure system inspection types are external and internal.

1) An external inspection is conducted while the system is operating and includes:

- Examination of system components, including structural attachments, vessel connections, inlet piping, outlet piping, drain piping, piping supports, and appurtenances.

- Identifying evidence of leakage or inadequate insulation or other coverings.

2) An internal inspection is conducted for pressure vessels used in corrosive service once the pressure has been released and the system is open for inspection. It includes inspecting for corrosion and wear around:

- Welded seams, nozzles, and areas adjacent to welds
- Vessel connections
- External fittings or controls

6.4. Testing of Pressure Relief Devices:

Pressure relief devices such as safety valves, pressure relief valves, and rupture disks prevent a system from becoming over pressurized. Their proper function is essential. Pressure relief devices must be visually inspected according to the frequency listed in Table 6.1. The inspection should verify that the device is appropriate to current use; the set pressure is correct; the installation is correct and the device functions while system is in operation (actuate lever if provided). Defective device(s) must be replaced immediately.

6.4.1. Re-closing pressure relief devices

Re-closing pressure relief devices must be tested prior to their installation. In the case of new and not previously used relief devices, certification of the set pressure by the manufacturer will be considered to constitute a test. In this case, the test date will be considered to be the date on which the relief device was delivered at PPPL and the requirement for further testing prior to installation will be waived.

6.4.2. Non-re-closing pressure relief devices

Non-re-closing (burst disk) and parallel plate pressure relief devices (used on vacuum vessels and insulating vacuum spaces) need not be tested, but must be inspected every three (3) years.

6.5. Testing of Set Pressure, Blowdown and Seal Tightness:

A qualified ASME shop must perform testing of set Pressure, Blowdown and Seal Tightness for ASME certified components per manufacturers' procedures. Attachment 3 provides a sample form to be completed for Pressure Relief Device Calibration & Tesing. Qualified PPPL Personnel may perform pressure testing; however device set points may only be set on non-coded system components. Generally, inlet pressure (see Table 6.2 for test medium) shall be increased until the valve opens. Inlet pressure shall be reduced until the valve reseats. Leakage shall be checked over a 3-min period at an inlet pressure equal to the minimum allowable blowdown pressure setting. There shall be no damage to seating surfaces and no instability (chatter). The valve shall conform to the requirements in Tables 6.2, 6.3, & 6.4.
Immediate corrective actions must be taken if any inspection indicates that a pressure relief device may not operate properly. The actions must ensure that the failure of the relief device to operate properly will not result in a safety hazard. Otherwise, the system shall be tagged per ESH-001 Use of Safety, Accident Prevention and Equipment Protection Tags.

Table 6.2: Allowable Seat Leakage Rates

Valve Type	Test Medium	Type of Seat	Maximum Allowable Seat Leakage over a period of minimum 3 min.
I	steam	metallic	no visible evidence of steam leakage when the valve outlet is viewed against a dark background
II	air or nitrogen gas	nonmetallic	no visible leakage as indicated by a submerged underwater or a soap bubble test
III	water	nonmetallic	no visible leakage

Table 6.**3**: Set Point Tolerances

Pressure Setting	Tolerance
15- 70 psig	± 2 psi
71-300 psig	± 3%
301 - 1,000 psig	± 10 psi
1,001+ psig	± 2%

Table 6.4: Blowdown Limits

Valve Type	Blowdown Limits
I and II	The maximum blowdown limit shall be 3 psi or 7 % of the set pressure, whichever is greater.
III	The maximum blowdown limit shall not exceed 15 % of the set pressure or 3 psi, whichever is greater.

6.6. Maintenance

Pressure systems must be maintained according to a schedule appropriate to system type and the operating conditions. Maintenance types include preventive or periodic, which are generally determined by the manufacturer and repair, which is an opportunity for maintenance due to unforeseen equipment shutdown or failure. Maintenance includes replacement or repair of defective or worn components. Maintenance does not include implementing modifications or alterations. Subcontracted ASME qualified technicians will perform maintenance on ASME certified components and must provide a statement of qualification to the SME.
Note All work involving hazardous energy must adhere to LOTO requirements ESH-016

6.7. Repair

Repair can take the form of restoring a non-functioning system to approved design specifications or it can include system modification or alteration (which is also referred to as *re-rating*).

All repairs that restore a system to the formerly approved design specification must be done in accordance with the code of construction, which must be in compliance with ASME code, the *National Board Inspection Code (NBIC)*, national standards, or other approved national codes. If a system is to be modified or altered, the new design specifications must be verified by engineering calculations and approved by the Pressure Systems SME. Personnel qualified to perform modifications are defined as follows:

- Repairs that require welding to ASME code stamped vessels ("U", "UM", "H", et cetera) must be performed by an organization holding an "R" stamp.
- Alterations must be performed by an organization holding an "R" stamp.
- Repairs to pressure relief or pressure safety valves with the ASME code "V", or "UV" stamps must be performed by an organization holding a "VR" stamp.
- All other repairs must be performed by a technician deemed qualified by the Pressure Systems SME.
- Completion of repairs and alterations must be verified by inspection and testing as defined by applicable ASME *Boiler and Pressure Vessel Code (BPVC)*, ASME *Pressure Piping Code*, and *National Board Inspection Code (NBIC)*.

7. Recordkeeping

7.1. Internal Records:

A database of all Pressure Systems shall be maintenanced by the Pressure Systems SME. It shall include all PPPL Pressure Systems critical information as well as all relief devices supporting those systems. Relief devices shall be affixed with a numbered brass tag linking back to the Pressure System database. Periodic inspection notifications shall be generated based on the Pressure System database per the periodicity specified above. Record of the inspection shall be maintained. A written record of any tests performed on a pressure relief system and/or pressure relief device shall be maintained by the Operations Center and the System Engineer for the protected system. These records shall contain vessel/system identification number(s), relief device specifications, and such documents as are necessary to record the results of inspections, repairs, alterations, or re-ratings of the relief system and devices. The Pressure System Identification Card (Attachment 1) and Pressure Relief Device Inspection Record Form (Attachment 2) provide records of the design and inspection information. These records shall be retained in the Operations Center with copies to the Pressure Systems SME, the Head, Fabrication and Operations Division (F&O), and the responsible System Engineer.

7.2. External Records:

All external repairs must be recorded using an appropriate supplier reporting form. In addition, the repair organization (supplier) must complete and submit the following for any work performed on ASME coded systems:

For repairs: National Board Form R-1 supplied by qualified supplier to the System Engineer, who submits a copy to the pressure systems SME.

For alterations: National Board Form R-2 supplied by qualified supplier to the System Engineer, who submits a copy to the pressure systems SME.

8. Procedure for Validating, Certifying and Removing a Pressure System

Note: Any system that has a pressure differential from atmospheric pressure either positive or negative (vacuum) is considered a pressure system. This includes any system with a pump. The following process shall be initiated for either existing or new pressure systems. In order to comply with 10CFR851, existing systems designed after 2007 and not excluded per Section 5 must comply with this standard (ES-MECH-015) by August 1st 2018.

IMPORTANT: If any pressure source is added to the system after the design is complete, a pressure system Safety Manifold approved by the Pressure System SME must be incorporated per Paragraph 6.1.9.2

Responsibility	Action

NOTE: Begin at step 14 for validating and certifying an existing pressure system.

A: Begin here for designing and certifying a new pressure system.

Cognizant Engineer/Physicist/ Technician

1. Identify a pressure system.
2. Initiate a Work Planning form per ENG-032
3. Develop a system requirements document with the help of a qualified engineer that should include the following:
   - Applicable Code(s)
   - Maximum allowable working pressure (MAWP) (internal or external)
   - Min and Max operating Temps
   - Vessel material and dimensions
   - Pressure relief system design
   - Fluids
   - Calculations
   - Location
4. Engage a qualified engineer to design the system.

Qualified Engineer

5. Design the pressure system per this procedure and applicable code(s).
6. Submits the approved Pressure System ID data to the Pressure Systems SME, obtains a temporary PS ID Card from SME, Completes the Card. Documents PS ID on Drawing.
7. Determine preoperational test requirements.
8. Conduct review(s) per Design Verification ENG-033.
9. Fabricate system.
10. Complete and affix temporary Pressure System Identification Card (Attachment 1) to the pressure system.
11. Complete Pressure Relief Device Inspection Record Form (Attachment 2) and distribute according to the instructions at the bottom of the form.
12. Perform preoperational test prior to in service use.
13. Continue to step 18.

B: Begin here for validating and certifying an existing pressure system.

System Engineer

14. Engage a qualified engineer to complete the information required on the pressure system ID card.
15. Approves the pressure system ID card.
16. Submits the Pressure System ID data to the Pressure Systems SME, obtains a temporary Pressure System ID Card from SME, completes the Card.
17. Documents Pressure System ID on system drawing.

Pressure Systems SME	18. Reviews the completed Pressure Relief Device Inspection Record Form and Pressure System Identification Card.
	19. Selects the Pressure Relief Device Inspector.
	20. Assures pertinent information provided on completed Pressure Relief Device Inspection Record Form is added to the Pressure System List.
	21. Provides System Engineer with the approved Pressure System Identification Card.
	22. Provides System Engineer with Pressure Relief Device numbered metal tag(s).
	23. Provides the Pressure Relief Device database Administrator with a copy of the Pressure Relief Device Inspection Record Form.
System Engineer	24. Attaches approved Green pressure system identification card to the pressure system.
	25. Attaches the Pressure Relief Device numbered metal tag(s) to the relief device(s).
	26. Place system in service.
Pressure Relief Device database Administrator	27. Incorporates pertinent data on the completed Pressure Relief Device Inspection Record Form into the Pressure Relief Device database with the inspection period provided by the Pressure Systems SME.
	28. Issues work-orders to initiate required inspections.
	29. Reports any overdue inspections to the Pressure Systems SME and issues an URGENT work-order to Yellow Caution Tag the system out.
Qualified Pressure Relief Device Inspector	30. Performs work-orders.
	31. Returns work-order to Pressure Relief Device database Administrator.
	32. Caution tags the system if deficiencies are found.
	33. Reports any found deficiencies to the Pressure Systems SME and the responsible System Engineer.
System Engineer	34. Initiates required repairs or pressure relief device replacement.
	35. Upon satisfactory repair notifies the Pressure Systems SME and the qualified Pressure System Relief Device Inspector.
	36. Return to step 22 for additional devices.
	37. Tags Pressure Systems being removed from service indefinitely as Out of Service.
	38. Tags Pressure Systems being removed from service indefinitely as Out of Service.
Pressure System SME	39. Removes the pressure system from the Pressure System database.

PRESSURE SYSTEM IDENTIFICATION CARD

System Name: _____

System Location: _____

Engineer / Manufacturer: _____

System Drawing No. _____

Applicable Code: _____

Contents/Fluid: _____

Maximum Allowable Working Pressure (MAWP):

Internal Pressure: _____ External Pressure: _____

Working Temperature Range: _____°F – _____°F

Test Pressure: _____ Acceptance Date: _____

Test Type: Hydraulic_____ Pneumatic _____

Approved: _____**Date**: _____
System Engineer

Accepted: _____**Date**: _____
Pressure Systems SME

Pressure Relief Device Tag # _____

Inspection Date:_____ Inspector Name: _____

System Information:

System ID Number (Unique ID from Database): _____

System Name: _____

Physical Location: _____

Protected Item Description

Vessel Identification Number(s): _____

Vessel Description: _____

MAWP of the Vessel: _____

Pressure Relief Details

Relief Device Type: _____

Relief Device Manufacturer: _____

Model / Part Number: _____

Required Set Pressure: _____

PRV Code Stamp: _____

Inspection Information

External Visual Inspection: Pass: _____ Fail: _____, Signature: _____

Notes:_____

_____

Distribute Copies of this record as follows:
Pressure Systems SME, FO Division Head, Ops Center, and System Engineer

Pressure Relief Device Calibration & Test Sample Form

Test Information (Only performed by ASME qualified personnel per Paragraph 6.5)

Test Center Name: _____

Location: _____

System Fluid: _____

Test Fluid: _____

Test Fluid Flow: _____

Tested Open Set Pressure: _____

Tested Blowdown Limit: _____

Calibration Date of Pressure Gage: _____

Relief Device Type:

_____Spring Operated, _____Pilot Operated, _____Rupture Disk,

_____Other: describe _____

Recommended Retest interval:_____

Test Performed by: _____ Signature:_____

Notes:_____

_____

NOTE: This form is a sample of the records for calibration and testing of pressure relief devices. Test Shops may use their own form.