CHAPTER 11 PRESSURE SYSTEMS

11.1 INTRODUCTION

This chapter outlines the policy and procedures necessary for the safe design, specification, assembly, testing, installation, and inspections of high pressure vessels, containments and systems.

11.2 SCOPE

11.2.1 General

This Chapter applies to the design, specification, assembly, testing, installation, and routine and special inspection of high pressure vessels, and systems, including those that contain toxic, radioactive, corrosive, or flammable materials, and to the containment vessels and equipment used for the protective enclosure of gas-pressurized vessels.

11.2.2 Exclusions

This chapter applies to all pressure vessels and systems, including containments, designed or operated on site, ***except*** the following:

A. Utility systems with a maximum allowable working pressure (MAWP) of no more than 300 psig (2 MPa gauge) that comply with applicable plant engineering standards and are inspected and maintained by Operations and Maintenance Division.

B. Refrigeration systems that comply with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code and applicable Air-Conditioning and Refrigeration Institute (ASHRAE) standards.

C. Vacuum systems operating at less than 15 psig (1000 kPa absolute). See Section 9, Chapter 14, for additional information on vacuum systems.

D. Air-pressure tanks, liquified-petroleum gas tanks, anhydrous ammonia tanks, and fired steam boilers that are inspected periodically in accordance with the ASME & Boiler and Pressure Vessel Code.

11.3 DEFINITIONS

11.3.1 **Brittle Vessel** - A pressure vessel fabricated from materials that do not yield extensively before failure when over-stressed at any temperature within the specified working temperature range of the vessel. Materials that rupture at a plastic strain less than 5% are generally considered brittle.

11.3.2 **Ductile Vessel** - A pressure vessel fabricated from materials that yield extensively before failure when over-stressed at any temperature range of the vessel. Materials that rupture at a plastic strain greater than 5% are generally considered ductile.

11.3.3 **Manned-Area Operation** - Environments where pressurized vessel or system component failure would not cause personal injury. Remote operation equipment must be installed in test cells or behind certified barricades, or be operated from a safe location.

11.3.4 **Maximum Allowable Working Pressure (MAWP)** - The maximum pressure at which a vessel is designed to operate safely. Working pressure, rated pressure, service pressure, and design pressure are the same as MAWP. This information may be found in the Boiler and Pressure Vessel Code, Sections I-XI (ASME).

11.3.5 **Pressure Relief Devices** - A relief device that is set to vent at a pressure determined by engineering. All manned-area, gas-pressure vessels must be protected by pressure relief devices.

11.3.6 **Pressure Vessel** - A relatively high volume pressure component (such as a spherical or cylindrical container) that has a cross-section larger than the associated pipe or tubing.

11.4 RESPONSIBILITIES

11.4.1 Department or Division Heads are responsible for ensuring implementation of this chapter.

11.4.2 Supervisors are responsible for ensuring that employees working under their direction are aware of and comply with this chapter.

11.4.3 Employees designing, fabricating, installing or operating pressure vessels or systems are responsible for complying with the guidance in this chapter.

11.4.4 Cognizant engineers must prepare required test procedures, direct testing personnel, and witness in-place pressure testing of vessels and systems for which they are responsible.

11.4.5 Responsible users are similarly accountable for in-place re-testing of pressure equipment for which they are responsible.

11.4.6 QA/QC must witness and document all pressure tests requiring inspection and label the containment vessel, if required, after successful testing and leak checking

11.4.7 Industrial Hygiene (IH) or a designee must approve pressure test setups prior to starting the test.

11.5 REQUIREMENTS

11.5.1 TFTR-FSAR

11.5.2 Engineering Standards

11.6 CONTAINMENT VESSELS

11.6.1 General

This section covers equipment used for protective enclosure of gas-pressurized vessels, including those that contain toxic radioactive, corrosive, or flammable materials. Such equipment must be designed to protect personnel from the pressure-vessel failure hazards of blast pressure and flying fragments. If hazardous materials could escape from the contained vessel (in case of media leakage), the containment vessel must be designed to prevent subsequent leakage to the atmosphere.

11.6.2 Special Shipping Requirements

A. If off-site transportation is to be permitted, design the containment vessel to withstand the normal conditions of transport as listed in "Safety Standards for the Packaging of Fissile and Other Radioactive Materials," Chapter 0529, US DOE. This includes heat, cold, pressure, vibration, water spray, free drop, corner drop, penetration, and compression. DOE requirements also state that the contained vessel be mounted securely inside the containment vessel.

B. Include suitable covers and shields to protect all valves and gauges from damage during shipment. Cap or plug all terminal valve ports. Provide accommodations for locking or wiring valve handles closed or having valve handles removed during shipment, to prevent unauthorized operation or tampering.

C. Only containers approved by the Department of Transportation (DOT) and/or by the Department of Energy (DOE) shall be used for the off-site shipment of pressure vessels containing radioactive materials. See CFR 49: Transportation, Parts 100 to 199, for pertinent details regarding DOE shipping requirements.

11.6.3 Design Safety Factors

A. If the contained pressure vessel is of ductile material and has been PPPL approved for a manned-area MAWP greater than or equal to the maximum pressure to which it could be subjected inside the containment vessel, the containment vessel shall be designed to an ultimate or burst safety factor of at least 4.

B. If the contained pressure vessel has not been PPPL approved for a manned-area MAWP of at least the maximum pressure to which it is to be subjected inside the containment vessel, the containment vessel for manned-area operation shall be designed to an ultimate or burst safety factor of at least eight.

11.6.4 General Design Requirements

The following requirements apply to all gas-pressure containment vessels, including those designed, specified, or used by PPPL personnel that will contain toxic, radioactive, corrosive, or flammable materials:

A. Design the containment vessel using the appropriate safety factor specified in Section 11.6.3. Base the design on the maximum equilibration pressure expected if the contained pressure vessel is heated to the highest temperature expected within the containment vessel or to 130 °F (55 °C), whichever value is higher.

B. In selecting materials of satisfactory fracture toughness, assume a minimum operating temperature of NDT (nil ductility temperature) +30 °F, unless a lower temperature is specified.

C. Include a compound pressure/vacuum gauge for periodically monitoring the internal pressure of the containment vessel. This gauge shall be graduated to at least 120% but not over 200% of the containment vessel MAWP. The highest credible equilibration pressure is the Maximum Allowable Working Pressure (MAWP) of the containment vessel.

D. Include two separate valve entries for safely introducing, exhausting, monitoring, and flushing gas through separate lines.

E. If the contained vessel has not been DOE approved for a manned-area MAWP greater than or equal to the maximum pressure to which it could be subjected inside the containment vessel, show that the containment vessel would not be penetrated by any flying fragments of a credible size and speed if the contained vessel failed catastrophically.

11.7 DESIGN OF PRESSURE VESSELS SYSTEMS AND CONTAINMENTS

The following precautions should be observed when designing, installing, or operating a pressure system (or vessel).

11.7.1 Pressure Sources, Regulators and Reliefs

A. Limit the pressure sources to the MAWP of the lowest rated system component. Do not consider a pressure regulator by itself as a satisfactory overpressure protection.

B. When pressure sources cannot be limited to less than the MAWP of every system component, include pressure relief devices (relief valves or rupture-disc assemblies) to protect those components that are rated at less than the system supply pressure. All manned-area gas pressure vessels must be protected by a relief device that is set at a pressure not exceeding the MAWP of the vessel.

1. Never place a valve between a relief device and the component it is installed to protect.

2. Never set a relief device above the MAWP of the lowest rated system component(s) that it is installed to protect.

3. Locate and orient relief devices so that their discharge is not hazardous to personnel.

4. Install relief devices of adequate total flow capacity. When all supply ports are open, the pressure must never exceed 110% of the MAWP.

5. Do not reset relief devices unless you are specifically authorized to do so.

6. Use ASME code-approved relief devices. Have all component relief devices rechecked at the end of the contract guarantee period if the pressure equipment was installed by an outside contractor and in accordance with manufacturer recommendations or ASME requirements.

11.7.2 Pipe and Hose

A. Use metal pipe and tubing rated at or above the MAWP. If you plan to use pipe or tubing at pressures above those indicated in applicable standards, include calculations in the Configuration Review Board (CRB) to justify your selections. Use ANSI/ASME-B31.1 to determine the MAWP for intermediate-and low-pressure pipe and tubing.

B. Use flexible hose only where it is impractical to use metal tubing or pipe.

1. Do not use hose at a pressure over one-fourth of its rated minimum burst pressure as stated by the manufacturer.

2. Keep hose lengths as short as possible.

3. Anchor hose ends to prevent whipping in case of a hose or hose-fitting failure. (This is especially true during hydrostatic testing.)

4. Avoid sharp hose bends. Do not bend hoses more sharply than recommended by the manufacturer.

5. Replace or repair any hose showing leaks, burns, wear, or other defects.

6. Do not use hose on toxic or radioactive gas systems. Gases tend to permeate through flexible hose.

11.7.3 Valves and Fittings

A. Use valves and fittings that are rated at or above the MAWP and are compatible with the system fluid. On liquefied gas systems, make sure that all terminal block valves (valves where users could attach to the system) are rated in accordance with ASME standards, or that a properly set relief valve is permanently installed on the outlet side of each such valve.

B. Make sure that all valve-stem packing nuts are kept adjusted and locked properly.

C. Make sure that all valve parts are of the right size, type, and strength for the valve and its task.

D. Make sure there are no oils or other organic materials in valves or fittings that are used on oxygen systems. Hydrocarbons and oxygen can combine explosively. Clean all valves and fittings used on high-purity gas systems.

11.7.4 Gas Pressure Gauges

A. Use gauges graduated to about twice the MAWP of the system— never graduated to less than 1.2 times the MAWP. This also applies to liquid-pressure gauges.

B. Be sure that gauge materials are compatible with the system fluid. This also applies to liquid-pressure gauges.

C. Use safety-type gauges with shatterproof faces, solid fronts, and blowout backs. Use additional supports for heavy system components.

D. Protect a gauge that is subject to excessive pressure surges or cyclic pulses by installing a throttling device such as a pulsation dampener (preferred), a pressure snubber, a gauge saver, or a restricting orifice; or use a gauge equipped with a throttle screw in the tube socket.

E. Make sure there are no oils or organic materials in gauges used on oxygen systems. Hydrocarbons and oxygen can combine explosively. Clean all gauges used on high-purity gas systems.

F. Protect the gauge with a relief device as required to prevent the pressure from exceeding the full-scale reading of the gauge.

11.7.5 Flash Arresters and Check Valves

A. Equip every flammable gas drop or regulator hose connection with a flash arrester or a check valve. If the flammable gas is to be (or could be) cross-connected with oxygen or compressed air, a flash arrester must be installed in the flammable gas line and a check valve placed in the oxygen or compressed air line. This applies to all single-and multiple-station installations and to all portable equipment.

B. Equip all oxygen drops with a check valve. This applies to single- and multiple-station installations and portable equipment.

11.7.6 Securing Components

A. Use adequate machine screws (or bolts) and nuts to secure **all** components. Wood screws are not considered adequate.

B. Support and secure hose and tubing at least every 7 feet in manned areas. Support and secure pipe according to the following table. Locate supports so that you limit strain on fittings and minimize overhang at bends taking into consideration that pipe and tubing expand and elongate when heated and contract when cooled. Use additional supports for heavy system components.

Nominal pipe size	**Maximum unsecured span**	
(inches)	**(feet)**	**(meters)**
1	7	2.0
1-1/2	9	2.5
2	10	3.0
2-1/2	11	3.5
3	12	3.5
3-1/2	13	4.0
4	14	4.5
5	16	5.0
6	17	5.0
8	19	6.0
10	22	6.5
12	23	7.0

11.8 PRESSURE TESTING

Refer to PPPL Procedure ENG-014, “Hydrostatic and Pneumatic Testing” for procedures on pressure testing. Additional information is included below.

11.8.1 Pressure Vessels and Systems

A. Test pressure vessels in accordance with this section and ENG-014 using an inert fluid (preferred) or gas. Initially test manned-area vessels at 150% of their MAWP or at the test pressure specified in the design package. Take appropriate diameter measurements, accurate to within 0.001 in. (0.025 mm), both before and after testing to show that detectable plastic yielding has not occurred during pressurization.

B. Remote-operation vessels should be tested at a pressure that is consistent with the functional reliability required (usually 125% of the MAWP).

C. If it is determined that a pressure test is not practical, the vessel must be inspected ultrasonically.

D. In addition, check the vessel for surface cracks by the magnetic particle test or (for non-magnetic vessels) the fluorescent dye penetrant test.

E. Open all internal system valves when pressure testing a system.

11.8.2 Leak Checking Pressure Vessels and Systems

Leak check pressure vessels and systems at their MAWP, as required, after successful pressure testing. Gross leakage can be detected by observing the drop in pressure on the test gauge during pressure testing, and can be pinpointed with leak-detection fluid. Small leaks can be located with commercial leak detectors.

A. If you detect a leak during pressure testing of a documented manned-area vessel or system and decide to repair it before completing the test, reduce the pressure to as low as possible. The vessel pressure should be less than one-half of the test pressure used to locate the leak.

B. Do not use an open flame for leak checking.

C. Leak check remote-operation vessels and systems remotely. Manned-area leak checking of successfully pressure-tested, remote-operation vessels and systems is limited to a maximum of 20% of the test pressure.

D. Never attempt to repair a system or vessel when it is pressurized, unless specifically authorized by a Division Head and the IH.

E. No undocumented vessels or systems may be leak checked in a manned-area mode at pressures higher than 20% of the test pressure.

11.8.3 Containment Testing and Labeling

A. Pressure test the containment vessel at 150% of its maximum possible equilibration pressure. To determine the maximum equilibration pressure, assume that the most energetic contained vessel specified equilibrates in the containment vessel, which is then heated to 130 °F (55 °C), unless a higher temperature is specified. No detectable plastic strain is permitted, as determined by measurements to within 0.0001 in. (0.025 mm), both before and after testing.

B. After successful pressure testing, leak check the containment vessel at its maximum possible equilibration pressure with a leak detector capable of detecting leakage of $1x10^{-8}$ atm cm^3/sec. No detectable leakage is permitted.

C. The cognizant engineer should specify contained-vessel rupture testing of the containment vessel if deemed advisable.

D. After successful testing and leak checking, QA/QC will label the containment vessel for the working pressure that was the basis for design calculations and tests. QA/QC will also label it for a working temperature range of -20 °F to +130 °F (-29 °C to +55 °C), unless a wider temperature range is specified.

11.9 REFERENCES

Boiler and Pressure Vessel Code, Sections I-XI (ASME)

ANSI/ASME-B31.1

"Safety Standards for the Packaging of Fissile and Other Radioactive Materials," Chapter 0529, US DOE

49 CFR 100-199, Department of Transportation, DOE shipping requirements

PPPL Procedure No. ENG-014, “Guidelines for Hydrostatic and Pneumatic Testing”