Subject: Langley Research Center Pressure Systems Handbook

Responsible Office: Safety and Mission Assurance Office

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PREFACE

P. 1 PURPOSE

This Langley Procedural Requirement (LPR) implements the requirements of NASA Policy Directive (NPD) 8710.5, “Policy for Pressure Vessels and Pressurized Systems,” and is part of the Langley Management System (LMS). It establishes requirements and standards for pressurized systems within the framework of Langley Research Center (LaRC) safety policies and constraints. It provides a basis for safety and uniformity in the design, procurement, fabrication, and use of pressure vessels, piping, and associated equipment.

P.2 APPLICABILITY

a. This LPR is applicable to all persons performing work at LaRC, including civil service personnel, contractors and subcontractors, research associates, and others. Non-compliance with this LPR may result in appropriate disciplinary action that may include termination for a civil servant employee or exclusion from the Center for a contractor employee, research associate or others.

b. In this directive, all mandatory actions (i.e., requirements) are denoted by statements containing the term “shall.” The terms: “may” or “can” denote discretionary privilege or permission, “should” denotes a good practice and is recommended, but not required, “will” denotes expected outcome, and “are/is” denotes descriptive material.

c. All document citations are assumed to be the latest version unless otherwise noted.

P.3 AUTHORITY

a. NASA Policy Directive (NPD) 8710.5, Policy for Pressure Vessels and Pressurized Systems.

P.4 APPLICABLE DOCUMENTS AND FORMS

a. Aeronautics and Space, CFR Title 14.

b. Continuing Qualification and Maintenance of Packagings, 49 CFR pt. 180.

c. Ocupational Safety and Health Standards, 29 CFR pt. 1910.

d. NASA Procedural Requirements (NPR) 8715.3, NASA General Safety Program Requirements.

e. Langley Policy Directive (LAPD) 1150.2, Councils, Boards, Panels, Committees, Teams, and Groups.

f. LAPD 7000.2, Review Program for Langley Research Center (LaRC) Facility Projects.

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g. LAPD 8730.1, The LaRC Metrology Program.

h. LPR 1710.10, Langley Research Center Energy Control Program (Lockout/Tagout).

i. LPR 1710.11, Fire Protection Program.

j. LPR 1710.15, Wind-Tunnel Model Systems Criteria.

k. LPR 1710.41, Langley Research Center Standard for the Evaluation of Socket and Branch Connection Welds.

l. LPR 1710.42, Safety Program for the Recertification and Maintenance of Ground-Based Pressure Vessels and Piping Systems (PVS).

m. LPR 1740.2, Facility Safety Requirements.

n. LPR 1740.4, Facility System Safety Analysis.

o. LPR 1740.5, Procedures for Cleaning of Systems and Equipment for Oxygen Service.

p. LPR 1740.6, Personnel Safety Certificaiton.

q. LPR 1800.1, Langley Research Center Occupational Health Program.

r. LPR 7123.2, Facility Configuration Management.

s. Langley Management System Center Procedure (LMS-CP) 4710, Facility Change Request Process.

t. LMS-CP-5616, Computerized Maintenance Management System (CMMS) Change Request.

u. LMS-CP-7151, Obtaining Waivers for Langley Management System (LMS) Requirements.

v. NASA Technical Standard (STD) 8719.17, NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems (PVS).

w. LMS-BP-5688, Facility Systems Engineering Requirements Document Development.

x. LMS-Task Description (TD) 5569, Performing Visual Inspections.

y. Langley Form (LF) 51, Waiver Submittal Form.

z. LF 121, LaRC Safety Documentation Review for Certified Operators.

aa. LF 122, Facility Safety Awareness and Procedures Review for Certified Operators.

bb. LF 159, Appointment for Operator Certification.

cc. LF 461, Environmental Project Planning Form.

dd. LF 533, Safety Permit – Pressurized Systems.

ee. American Institute of Aeronautics and Astonautics (AIAA) S-080, Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components.

ff. AIAA S-081, Space Systems – Composite Overwrapped Pressure Vessels.
gg. American Petroleum Institute (API) Recommended Practice (RP) 521, Guide for Pressure-Relieving and Depressuring Systems.
hh. ASME B1.20.1, Pipe Threads, General Purpose (Inch).
ii. ASME B16.11, Forged Fittings, Socket-Welding and Threaded.
jj. ASME B31.1, Power Piping.
kk. ASME B31.3, Process Piping.
ll. ASME B31.5, Refrigeration Piping and Heat Transfer Components.
mm. American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code.
nn. ASTM B88, Standard Specification for Seamless Copper Water Tube.
oo. ASTM B280, Standard Specificaiton for Seamless Copper Tube for Aid Conditioning and Refrigeration Field Service.
pp. FM Global, Factory Mutual (FM) Global Property Loss Prevention Data Sheets, (https://www.fmglobal.com/research-and-resources/fm-global-data-sheets).
qq. International Code Council (ICC), International Mechanical Code.
rr. National Board of Boiler and Pressure Vessel Inspectors (NBBI), NB-23, National Board Inspection Code.
ss. National Fire Protection Association (NFPA) 30, Flammable and Combustible Liquids Code.
tt. NFPA 54, National Fuel Gas Code.
uu. NFPA 58, Liquefied Petroleum Gas Code.
vv. SAE AMS5075, Steel Tubing, Seamless 0.22 – 0.28C (SAE 1025) Cold Drawn and Stress Relieved.

P.5 MEASUREMENT/VERIFICATION

None

P.6 CANCELLATION

LPR 1710.40 L, Langley Research Center Pressure Systems Handbook, dated April 26, 2017.

/s/ Clayton P. Turner, Center Deputy Director April 26, 2017

Distribution:

Approved for public release via the Langley Management System; distribution is unlimited.

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1. PURPOSE, APPLICABILITY, AND EXCLUSIONS

1.1 Purpose

1.1.1 This LPR establishes requirements and guidelines regarding the design, procurement, fabrication, modification, repair, operation, and/or recertification of pressure systems owned by Langely Research Center (LaRC), whether located on Center or off Center, and of pressure systems owned by others that are used at LaRC.

1.1.2 This document is written on the premise that the functions and responsibilities listed in Chapter 16 are essential to provide the checks and balances indispensable to ensure pressure system safety.

1.2 Applicability

1.2.1 This LPR is applicable to all pressure systems owned by or used at LaRC, including new, existing, temporary, and permanent systems.

1.2.2 Pressurized systems in wind tunnel models shall be approved by the Standard Practice Engineer (SPE) for Wind Tunnel Models and will also comply with LPR 1710.15.

1.2.3 Ground-based pressurized systems in LaRC facilities shall also comply with LPR 1740.4 and LPR 7123.2.

1.3 Exclusions

1.3.1 The categories of pressure systems listed in Table 1-A below are not required to meet the requirements of this LPR if they meet the specified conditions for exclusion.

Table 1-A, Excluded Systems

Exclusion No.	Excluded item	Condition(s) for exclusion
X-1	Self-Contained Breathing Apparatus (SCBA) equipment.	Complies with Occupational Safety and Health Administration (OSHA) regulations, 29 Code of Federal Regulation (CFR) Part 1910, Subparts 1910.134 through 1910.140.
X-2	Water piping systems under 160 psig and 210 °F.	Water surge is not a design consideration or the risk has been mitigated.
X-3	Commercial-Off-The-Shelf (COTS) water heaters for buildings.	Pressure-temperature relief valves replaced every 5 years.

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Exclusion No.	Excluded item	Condition(s) for exclusion
X-4	Water storage tanks and small potable water heaters in heating boilers.	In accordance with the limits in the American Society of Mechanical Engineers (ASME) “Boiler & Pressure Vessel Code,” Section IV, “Heating Boilers”, paragraph HLW-101.
X-5	Packaged, COTS, facility hot water boilers and low pressure steam boilers within the scope of ASME Boiler and Pressure Vessel Code, Section IV.	H-stamped. Initial installation per ASME code requirements. Relief valves retested or replaced per the requirements of the Commonwealth of Virginia, Department of Labor and Industry.
X-6	Water deluge systems under 250 psig.	No hazard to personnel in the event of failure.
X-7	Inert gas piping systems, e.g., control air, instrument air, and shop air systems.	Design pressure not exceeding 150 psig. Line size not exceeding 1/2 inch for all methods of fabrication, or line size up to 1-1/2 inch if no welding or brazing is used in their fabrication. Relief valves periodically retested every 5 years.

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Exclusion No.	Excluded item	Condition(s) for exclusion
X-8	Steam and gravity-powered condensate return systems for building heating.	Operating pressures up to 15 psig. If the excluded steam system is fed by a higher-pressure steam system, the first relief device following the pressure-reducing regulator shall be retested yearly.
X-9	COTS prepackaged pressurized water and steam cleaning systems.	Maintained and operated in accordance with the manufacturer's recommendations.
X-10	Fire protection water systems for facilities.	None.
X-11	COTS prepackaged refrigerators, freezers, and Heating, Ventilation, and Air Conditioning (HVAC) equipment.	None.
X-12	Fire extinguishers, portable extinguishers, standpipe and hose systems, automatic sprinkler systems, fixed dry chemical extinguishing systems, carbon dioxide extinguishing systems, and halogenated extinguishing agent systems.	Complies with 29 CFR Part 1910, Subpart L, "Fire Protection."
X-13	Glove boxes.	None.
X-14	Fuel storage pressure systems.	Meets applicable U.S. Department of Transportation (DOT) requirements.

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Exclusion No.	Excluded item	Condition(s) for exclusion
X-15	COTS prepackaged hydraulic systems.	None.
X-16	COTS welding equipment.	None.
X-17	COTS laboratory equipment.	Fluid delivery system shall have suitable overpressure protection.
X-18	Vacuum vessels.	Volumes not greater than 100 cubic feet. Not connected to a positive-pressure fluid delivery system.
X-19	Vacuum piping.	Nominal diameter of less than 6 inches. Not connected to a positive-pressure fluid delivery system.
X-20	Contractor-owned pressure systems.	Used on a temporary basis for the purpose of construction activities. The owning Contractor shall meet all applicable Federal and State safety regulations.
X-21	Atmospheric storage tanks.	Subjected to hydrostatic pressure only. Complies with applicable American Petroleum Institute (API) or Underwriters Laboratories (UL) standards.

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Exclusion No.	Excluded item	Condition(s) for exclusion
X-22	COTS self-contained pressurized eye wash systems	Overpressure protection devices, if present, are periodically tested or replaced in accordance with manufacturers' recommendations.
X-23	Tube trailers.	Periodically retested and requalified in accordance with 49 CFR 180, provided that the owner's OSHA inspection requirements of 29 CFR 1910.101 are met.
X-24	Natural gas distribution systems.	Design pressure not exceeding 15 psig.
X-25	Pressurized test articles or test articles containing pressurized components.	Excluded if they have been reviewed and accepted by a formal safety review committee (see LAPD 1150.2) or by a formal Operational Readiness Review (ORR) board (see LAPD 7000.2).

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Exclusion No.	Excluded item	Condition(s) for exclusion
X-26	Temporary, test-specific pressure systems.	Excluded if risk assessment in accordance with LPR 1740.4 shows there is no risk to personnel, and any unmitigated risk to the facility has been accepted by the Organizational Director. Pressurized systems and components are not considered to fall into this category if they are used repeatedly for testing different test articles or configurations.

Note: For additional guidance on lockout/tagout procedures for pressure vessels listed in Table 1-A, see LPR 1710.10.

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2. GENERAL REQUIREMENTS

2.1 Required Codes and Standards

2.1.1 Pressure systems and components owned by or used at LaRC shall be designed, fabricated, modified, repaired, and/or recertified, as a minimum, in accordance with the following codes and standards as applicable:

a. American Institute of Aeronautics and Astronautics (AIAA)

(1) S-080, Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components

(2) S-081, Space Systems – Composite Overwrapped Pressure Vessels

b. American Society of Mechanical Engineers (ASME)

(1) Boiler and Pressure Vessel Code

(2) B31.1, Power Piping

Note: for steam and condensate piping

(3) B31.3, Process Piping

Note: for all piping other than steam and condensate

(4) B31.5, Refrigeration Piping and Heat Transfer Components

c. FM Global, Factory Mutual (FM) Data Sheets

Note: Applicable pressure equipment codes and standards in FM data sheet series 12.

d. International Code Council (ICC), International Mechanical Code

e. Langley Research Center

(1) LPR 1710.41, Langley Research Center Standard for the Evaluation of Socket and Branch Connection Welds

(2) LPR 1710.42, Safety Program for the Recertification and Maintenance of Ground-Based Pressure Vessels and Piping Systems (PVS)

(3) LPR 1710.15, Wind-Tunnel Model Systems Criteria

(4) LPR 1710.11, Fire Protection Program

(5) LPR 1740.4, Facility System Safety Analysis

(6) LPR 7123.2 Facility Configuration Management

f. NASA STD 8719.17, NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems (PVS)

g. National Board of Boiler and Pressure Vessel Inspectors (NBBI), NB-23, National Board Inspection Code

h. National Fire Protection Association (NFPA)

(1) NFPA 30, Flammable and Combustible Liquids Code

(2) NFPA 54, National Fuel Gas Code

(3) NFPA 58, Liquefied Petroleum Gas Code

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3. APPROVALS

3.1 Required Approvals

3.1.1 All new designs, procurements, fabrications, modifications, and repairs to pressure systems and system components shall be approved by the following personnel:

a. The SPE for Pressure Systems or the SPE for Flight Systems, to ensure compliance with the required codes and standards.

b. The Facility Coordinator (FC), to ensure coordination with all activities in the facility where the pressure system is located.

c. The Facility Safety Head (FSH), to ensure compliance with specific safety requirements of the facility where the pressure system is located.

3.1.2 Additionally, the following signatures may be required, depending on the scope of the required work:

a. The Authority Having Jurisdiction (AHJ), to ensure compliance with required codes and regulations for pressure systems containing flammable or combustible liquids, flammable gases, cryogenic liquids, oxidizers, pyrophoric substances, highly reactive substances, or toxic substances.

b. The cognizant Safety and Facility Assurance Branch (SFAB) Safety Engineer, to ensure compliance with all applicable facility safety requirements.

c. The SPE for Welding, for pressure systems containing welded or brazed components, to ensure compliance with welding process quality assurance requirements, procedures, and codes.

3.1.3 Approval by the above listed personnel shall be verified by their signature and date on the design drawings, sketches, procurement requisition records, or work order functional approvals, as applicable.

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4. WAIVERS AND INTERPRETATIONS

4.1 Waivers

4.1.1 Approval for a waiver from the requirements in this LPR shall be obtained by following the process described in LMS-CP-7151, “Obtaining Waivers for LMS Requirements,” and as further described herein:

a. In the “Recommending Authorities” section of LF 51, the “Other Recommendation Authority” is the chairperson of the Pressure Systems Committee and the “Engineering Technical Authority” is the applicable SPE.

b. All requests for waivers from the requirements in this LPR, including requirements in any referenced Agency standards, national consensus codes, or industry standards, shall include full justification for the waiver request and supporting data or analyses to demonstrate that safe operation can be achieved.

4.2 Interpretations

4.2.1 The SPE for Pressure Systems, the SPE for Flight Systems, the SPE for Welding, and the AHJ are granted authority to issue interpretations on the applicability of individual requirements in this LPR within their respective areas of expertise.

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5. DESIGN OF NEW PRESSURE SYSTEMS (GROUND-BASED)

5.1 General

5.1.1 All new pressure systems shall be designed in compliance with the applicable codes and standards listed in Chapter 2 of this LPR.

5.1.2 The Cognizant Engineer shall ensure that all new pressure system designs include the following documentation, as applicable for each project:

a. Requirements Document

(1) Formal Requirements Document per LMS-BP-5688

(2) Statement of Work/Work Plan

b. Engineering analyses and calculations

(1) ASME piping code calculations, such as:

(a) Pressure and temperature design calculations

(b) Flexibility analysis

(c) Relief valve and/or rupture disc sizing calculations

(d) Vent line and vent header backpressure calculations

(2) ASME BPV code pressure vessel calculations, such as:

(a) Pressure and temperature design calculations for shells, heads, nozzles, and closures

(b) Nozzle load limitations

(c) Reinforcement of openings

(d) Relief valve and/or rupture disc sizing calculations

(e) Fatigue life for pressure vessels operating with cyclic pressure and/or temperature

(3) Flow sizing calculations for valves, control orifices, flow meters, and piping components

(4) For custom-made components and for code-unlisted components, calculations using closed-form equations, finite element methods, or other generally accepted engineering analysis methods to establish structural integrity and compliance with the required safety factors

c. Catalog cuts of commercial-off-the-shelf items

d. Engineering drawings (D-size format is preferred), sketches, and/or marked-up photographs

(1) Process and instrumentation diagrams (P&ID)

(2) Plan views, elevation views, section views, and detail views as needed to describe the required scope of work

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e. Parts lists and material specification tables

f. LF 461, Environmental Project Planning Form

g. Facility Change Request (FCR)

5.1.3 Design drawing packages and sketches shall include the following information:

a. Name of the Cognizant Engineer

b. Date

c. Facility name

d. Building number

e. Drawing or sketch title

f. Drawing or sketch number

g. Applicable design code(s) and/or standard(s)

h. Relevant engineering data, such as fluid service, design pressure, design temperature, material specification, non-destructive examination and inspection requirements, testing requirements, set pressure of relief devices, set points of all interlocks and protection devices, torque values of bolted connections, and requirements for welding and/or brazing.

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6. FABRICATION OF NEW PRESSURE SYSTEMS (GROUND-BASED)

6.1 General

6.1.1 New pressure systems shall be fabricated in accordance with an approved design as per Chapters 3 and 5 of this LPR.

6.1.2 The Cognizant Engineer shall supervise the progress of pressure system fabrication to ensure compliance with this LPR.

6.2 Pressure Vessels

6.2.1 Pressure vessels shall be stamped by the fabricator in accordance with the ASME Pressure Vessel Code, Section VIII, Divisions 1 or 2.

6.2.2 The fabricator shall provide a copy of the vessel's code stamp documentation to NASA.

6.3 Piping Systems, Welded or Brazed

6.3.1 Welded or brazed piping systems shall be fabricated by organizations that are holders of an ASME (or National Board) Certificate of Authorization for the application of a code stamp, such as the "U", "U2", "N", "R", or "PP" stamps. The Certificate of Authorization ensures that the fabricator is familiar with and uses the quality control measures required by the ASME codes for pressure vessels and piping.

6.3.2 Whenever a pressure system is fabricated by welding or brazing, the fabricator shall submit the following documents for approval by the SPE for Welding or his/her designated representative prior to the start of any welding:

a. Welding or Brazing Procedure Specification (WPS/BPS)

b. Certified Procedure Qualification Records (PQR)

c. Certified Welder or Brazer Performance Qualifications (WPQ/BPQ)

6.3.3 All components installed in piping systems shall be permanently marked with legible raised lettering or stamping in order that required information (i.e., the manufacturer, pound class, model or part number, size, pressure rating, temperature rating, material of construction, and code of construction, as applicable) can be ascertained. Component markings can be limited to the manufacturer's name or trademark and the manufacturer's part number or model number if all other pertinent information as outlined above can be ascertained through the manufacturer's catalogs or data sheets.

6.4 Piping Systems, Non-Welded or Non-Brazed

6.4.1 Non-welded or non-brazed piping and tubing systems shall be fabricated by persons that have received training in the specific fabrication methods utilized, who can demonstrate they understand proper material selection and the identification, installation, fit-up, alignment, and support of components to be used in such fabrications.

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7. MODIFICATIONS AND REPAIRS TO PRESSURE SYSTEMS (GROUND-BASED)

7.1 General

7.1.1 Pressure systems shall be modified or repaired in accordance with an approved design as defined in Chapters 3 and 5 of this LPR.

7.1.2 The Cognizant Engineer shall supervise the progress of pressure system modifications and repairs to ensure compliance with this LPR.

7.2 Pressure Vessels

7.2.1 Modifications and repairs to code-stamped pressure vessels shall be performed by organizations that are holders of a National Board Certificate of Authorization for use of an “R” stamp.

7.2.2 Modifications and repairs to non-code-stamped pressure vessels shall be performed by organizations that are holders of a National Board Certificate of Authorization for use of a “U”, “U2”, “R”, “N”, or “PP” stamp.

7.3 Piping Systems (Welded or Brazed)

7.3.1 Modifications and repairs to welded or brazed piping systems shall be performed by organizations that are holders of one of the following ASME or National Board stamps: “U”, “U2”, “R”, “N”, or “PP”.

7.3.2 Whenever a piping system is modified or repaired by welding or brazing, the fabricator shall submit the following documents for approval by the SPE for Welding or his/her designated representative prior to the start of any welding:

a. Welding or Brazing Procedure Specification (WPS/BPS)

b. Certified Procedure Qualification Records (PQR)

c. Certified Welder or Brazer Performance Qualifications (WPQ/BPQ)

7.4 Piping Systems (Non-Welded or Non-Brazed)

7.4.1 Modifications and repairs to non-welded or non-brazed piping and tubing systems shall be performed by persons who have received training in the specific fabrication methods utilized, who can demonstrate they understand proper material selection, and the identification, installation, fit-up, alignment, and support of components to be used in such fabrications.

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8. PROCUREMENT OF PRESSURE SYSTEMS (GROUND-BASED)

8.1 General

8.1.1 Procurements of pressure systems or of pressure system components shall be reviewed and approved as required in Chapter 3 of this LPR.

8.1.2 The requiring organization/customer is responsible for ensuring that the all required approvals outlined in Chapter 3 are complete, and shall coordinate with the approvers in Chapter 3 and the Office of Procurement to ensure the requirements under Chapter 8 are fulfilled and included in solicitation and resultant contractual documents.

8.2 Procurement of Pressure Vessels and Tanks

8.2.1 All procurements for COTS pressure vessels and tanks for use at LaRC shall require the vessels to be code stamped by a recognized U.S. national standards organization such as ASME, API, DOT, or UL, as applicable.

8.2.2 All contracts or purchase orders for the acquisition of new, custom-built pressure vessels shall:

a. Require the vessels to be ASME code stamped

b. Contain the following wording:

"This solicitation includes fabrication of pressure vessels. A current ASME Certificate of Authorization for use of a "U" or "U2" code stamp shall be held by the organization performing the fabrication and stamping of the pressure vessels. The contract award process will be expedited by submittal of the Certificate of Authorization with the offeror's bid; however, early certification submittal is not required to ensure bid responsiveness. An offeror's ability to confirm that deliverable pressure vessels will be code stamped as required is a matter relating to the offeror's responsibility and will be determined prior to award."

8.2.3 All contracts or purchase orders for the acquisition of new, custom-built tanks shall require API or UL code stamping.

8.2.4 An approved waiver as described in Chapter 4 shall be obtained prior to procurement of non-code-stamped pressure vessels and tanks that are within the scope of this LPR.

8.2.5 The Cognizant Engineer shall require all Vendors supplying pressure vessels and tanks to furnish the following documents, as applicable:

a. Outline and Cross Sectional Drawings,

b. Bill of Materials,

c. ASME Code Calculations,

d. Welding Procedures (WPS),

e. Procedure Qualification Records (PQR),

f. Weld Maps,

g. Non-Destructive Examination (NDE) Records,

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h. Heat Treatment Records,

i. Hydrostatic Test Records,

j. Code Reports (ASME Code Forms, Manufacturer's Data Reports, Nameplate Rubbing or Facsimile),

k. Charts (Hydrostatic Test, Post Weld Heat Treatment (PWHT)), and

l. Reports (Mill Test Report (MTR), Positive Material Identification (PMI), Non-destructive examination (NDE), Radiography, Hardness Test, Safety Data Sheet (SDS)).

8.3 **Procurement of Piping Systems (Welded or Brazed)**

8.3.1 All contracts requiring fabrication, modification, or repair of ground-based, welded or brazed piping systems shall:

a. Require the fabricator to be a holder of an ASME code stamp

b. Contain the following wording:

"This solicitation requires fabrication, modification, and/or repairs to pressure systems. A current National Board or ASME Certificate of Authorization for use of any of the following stamps: "R", "U", "U2", "N", or "PP" is required. This certificate shall be held by the organization performing the work and shall be maintained valid and current throughout the contract performance period. The contract award process will be expedited by submittal of the applicable Certificate of Authorization with the offeror's bid; however, early certification submittal is not required to ensure bid responsiveness. An offeror's ability to confirm that the organization performing the work is a holder of any of the above stamps is a matter relating to the offeror's responsibility and will be determined prior to award."

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9. DESIGN, FABRICATION, AND PROCUREMENT OF FLIGHT-GRADE PRESSURE SYSTEMS

9.1 Pressure Systems for Spacecraft

9.1.1 This section is applicable for all LaRC-owned pressure systems that are used in spacecraft or suborbital experiments.

9.1.2 All new pressure systems for spacecraft or suborbital experiments shall be compliant with ANSI/AIAA S-080, “Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components.”

9.1.3 All new composite overwrapped pressure vessels with metallic liners for spacecraft or suborbital experiments shall be compliant with ANSI/AIAA S-081, “Space Systems – Composite Overwrapped Pressure Vessels (COPVs).”

9.2 Pressure Systems for Aircraft and Lighter Than Air Vehicles

9.2.1 This section is applicable for all LaRC-owned pressure systems for experiments that are used in aircraft or lighter than air vehicles.

9.2.2 All new pressure systems for experiments on aircraft or lighter than air vehicles shall be compliant with FAA regulations for Airworthiness Standards in CFR Title 14, “Aeronautics and Space.”

9.2.3 All new pressure systems for experiments on aircraft or lighter than air vehicles can use ANSI/AIAA S-080, “Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components,” as an alternative to using CFR Title 14 Airworthiness Standards. If ANSI/AIAA S-080 is used in lieu of CFR Title 14 Airworthiness Standards, then full compliance with ANSI/AIAA S-080 is required.

9.3 Ground Support Pressure Systems for Flight-Grade Pressure Systems

9.3.1 All new ground support pressure systems for flight-grade pressure systems shall be considered ground-based pressure systems and be compliant with this LPR.

9.3.2 Operation of new ground support pressure systems for Flight-Grade pressure systems during operations and testing of the flight system shall be operated in accordance with ANSI/AIAA S-080.

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10. INSPECTION AND TESTING OF PRESSURE SYSTEMS (GROUND-BASED)

10.1 General

10.1.1 Minimum inspection and testing requirements for pressure systems shall be in accordance with the applicable design codes listed in Chapter 2 of this LPR.

10.1.2 The Cognizant Engineer shall ensure that the supplemental inspection and testing requirements in this Chapter are met.

10.2 Supplemental Inspection Requirements

10.2.1 In addition to the minimum requirements of the applicable codes and standards, the following requirements shall apply:

Table 10-A, LaRC Supplemental NDE Requirements

		Joint Type				
		Butt Weld	**Socket Weld**	**Branch Weld**	**Fillet Weld**	**Threaded/Tubing**
Pressure Vessels	Code Stamped	Per Code Requirements				
	Not Code Stamped	100% VT 100% RT	100% VT 100% RT	100% VT 100% RT	100% VT 100% MT or PT	100% VT
Process Piping	All	100% VT 100% RT	100% VT 100% RT	100% VT 100% RT	100% VT 100% MT or PT	100% VT
Gas Vent Piping	All	100% VT 10% MT or PT	100% VT 10% MT or PT	100% VT 10% MT or PT	100% VT 10% MT or PT	100% VT
Liquid Drain Piping	All	100% VT	100% VT	100% VT	100% VT	100% VT

MT = Magnetic Particle Examination; PT = Dye Penetration Examination;
RT = Radiographic Examination; VT = Visual Testing

a. NDE in accordance with Table 10-A.

b. NDE shall be performed by inspectors certified to the American Society for Nondestructive Testing (ASNT) Level II or Level III requirements.

c. When heat treatment or stress relieving of a pressure retaining component is required, it shall been done after all welding, weld repairs, and required NDE are complete.

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(1) Additionally, an MT or PT examination of the heat-affected zone shall be conducted following the heat treatment but prior to the required hydrostatic test.

(2) All heat treated or stress relieved components or vessels shall be visibly marked with “Do Not Weld or Burn, Heat Treated.”

d. Inspection and acceptance criteria for socket welds and branch connection welds shall be in accordance with LPR 1710.41.

e. Acceptance criteria for butt welds in pressure systems shall be in accordance with ASME B31.3 for severe cyclic conditions.

f. For ground-based pressure system applications, film radiography shall be used.

g. Radiographic inspection of piping girth butt welds shall utilize tangential techniques wherever possible.

h. Final interpretation and acceptance of radiographs of pressure systems shall be by a qualified third party reviewer. The SPE for Pressure Systems is responsible for establishing the technical qualifications of the third party radiograph reviewers.

Note: NASA LaRC has an Official Radiograph Interpreter that can be used as the independent third party reviewer of radiographs.

(1) When film radiography is utilized in ground-based applications, all radiographic film shall be turned over to the SPE for Pressure Systems for final retention and storage.

(2) The radiographic film shall be retained in a controlled environment repository for a minimum of five years.

i. As a minimum, acceptance criteria for the evaluation of visual inspections of pressure components shall be in accordance with LMS-TD-5569.

j. Welds attaching structural elements to a pressure retaining wall shall be nondestructively examined as follows:

(1) The root pass and final weld surfaces shall be visually examined followed by either an MT or a PT examination.

(2) (2) The final weld surface shall be VT examined.

(3) Acceptance criteria shall be per ASME Boiler and Pressure Vessel (B&PV) Code Section VIII for attachments to pressure vessels and per ASME B31.3 (severe cyclic conditions) for attachments to piping.

10.3 Supplemental Hydrostatic and Pneumatic Testing Requirements

10.3.1 In addition to the minimum requirements for testing in the applicable codes, the Cognizant Engineer shall ensure that the following supplemental testing requirements are met:

a. Hydrostatic and pneumatic tests are used to qualify the structural integrity of new, modified, and repaired pressure systems. Both methods of testing are

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potentially hazardous. Adequate safety precautions shall be taken to ensure the safety of personnel and equipment.

b. Hydrostatic and pneumatic tests conducted in the field at LaRC shall be performed using written and approved test plans and operating procedures.

(1) A hydrostatic or pneumatic test plan shall include a drawing defining the extent of the system being tested; the location of high point vents and low point drains; test gauges to be used; water chloride content requirements; test blind rating requirements; test gasket requirements; and draining, drying, and closing requirements.

c. Pneumatic testing shall only be conducted when the appropriate SPE determines that hydrostatic testing is not feasible.

d. As a minimum, hydrostatic test plans shall be approved by the Cognizant Engineer and the appropriate SPE.

e. Pneumatic test procedures shall be approved by the FSH, the appropriate SPE, the Chairman of the Pressure Systems Committee, and the LaRC Safety Manager.

f. When performing pneumatic testing, a gas complying with cleanliness requirements of the pressure vessel and system shall be used.

g. A relief device of adequate capacity set to relieve at a pressure no higher than 110 percent of the test pressure shall be provided.

h. A hazard zone shall be established by engineering analysis as described in Appendix F.

i. All personnel shall be excluded from the hazard zone while the pressure exceeds the design pressure of the system being tested.

j. Appropriate personal protective equipment shall be worn by any personnel required to enter the hazard zone during the test.

k. Hydrostatic and pneumatic tests of pressure systems shall be witnessed by the appropriate SPE or his/her designated representative.

l. Following successful hydrostatic or pneumatic testing of vessels, piping, and tubing, a signed hydrostatic (or pneumatic) test certificate shall be provided by the fabricator or his or her testing agent.

m. The certificate shall include the date and time of the test, a short description of the tested system, the test pressure, holding time, and any other pertinent test parameters.

n. In the event that a required hydrostatic or pneumatic test is deemed to be impractical by the appropriate SPE, additional NDE shall be performed to ensure the structural integrity of the pressure system.

o. The SPE shall have the authority to establish the additional NDE requirements.

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11. VERIFICATION AND SHAKEDOWN OF PRESSURE SYSTEMS (GROUND-BASED)

11.1 General

11.1.1 All new, modified, or repaired pressure systems shall undergo verification and shakedown prior to being placed in operational service.

11.1.2 The Cognizant Engineer shall verify that the pressure system has been constructed, repaired, or modified in accordance with the approved design documents and that the system fabricator has provided all documentation to substantiate compliance with the requirements of the design.

11.2 Process for Verification

11.2.1 The Cognizant Engineer shall verify that:

a. All new work, modification work, or repair work has been completed in accordance with the engineering design, specifications, and drawings/sketches and complies with the requirements of thisLPR. Deviations from the original design, if any, were approved by the appropriate SPE.

b. All nondestructive examinations have been completed and accepted.

c. All hydrostatic tests, leak tests, and any other testing required by the design, repair, or modification documents have been completed and accepted.

d. All safety and interlock devices have current calibrations, have been installed, and are operating properly.

e. The operation of devices, e.g., valves, actuators, transmitters, switches, and gauges, has been properly verified prior to pressurizing the system.

f. Shakedown procedures as suitable for the complexity of the new system, modification, or repair have been developed and approved by the appropriate SPE and the FSH, or a formal design review committee. The appropriate SPE and FSH have the authority to require additional approvers by the appropriate personnel listed in Chapter 3 of this LPR.

g. A low pressure leak test has been performed on the system.

(1) If a leak test cannot be performed during the Return to Service (RTS) or Acceptance Test Plan (ATP), then an independent hazard analysis shall be performed and approved by the SPE for Pressure Systems and SFAB Safety Engineer.

h. For systems under configuration control, a Facility Change Request (FCR) has been initiated to update all affected documentation.

i. The system is ready to be pressurized as determined by the completion of the requirements above.

11.2.2 The Cognizant Engineer shall document completion of all the steps in the verification process listed in paragraph 11.2.1 through either:

a. Detailing the completion in a letter to the FSH and the appropriate SPE, or

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b. Completing and submitting an LF 438.

11.3 Process for Shakedown

11.3.1 Shakedown shall be performed after the system has been verified. The purpose of shakedown is to validate system performance, to provide an opportunity for operator training, and to develop standard operating procedures.

11.3.2 The Cognizant Engineer shall oversee shakedown. During shakedown:

a. Testing of the system operating envelope shall be conducted in accordance with approved shakedown procedures.

b. The operators shall be properly trained.

c. At the successful completion of training, the operators shall be certified in accordance with Chapter 13 of this LPR.

d. The operating procedures, if applicable, shall be completed and signed off in accordance with the facility configuration management process in LPR 7123.2.

e. The system performance shall be demonstrated with system fluids (systems containing toxic, combustible, flammable, or otherwise hazardous fluids shall use an inert fluid first).

f. For cryogenic systems, cold shock testing shall be performed to test the welds and flexibility of the piping and ensure that cold shock liquid does not contaminate the system.

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12. CERTIFICATION AND RECERTIFICATION OF PRESSURE SYSTEMS (GROUND-BASED)

12.1 Certification of New Systems

12.1.1 Based on the complexity of the new system and at the discretion of the LaRC Safety Manager, the operational certification of new pressure systems shall be performed by one of the following:

a. An Operational Readiness Review (ORR) board, or

b. The cognizant SPEs and Technical Authorities.

12.2 Recertification of Pressure Systems

12.2.1 The Pressure Systems Manager (PSM) is responsible for the recertification of pressure systems at LaRC.

12.2.2 Pressure systems shall be recertified in accordance with the requirements in LPR 1710.42 by using one of the following methods:

a. Level 1 recertification. This method is applicable to the majority of ground-based, infrastructure, high-energy systems.

b. Level 2 recertification. This abbreviated method is applicable to ground-based systems that are specifically exempted from full recertification by the PSM based on factors such as limited risk, minimum complexity, and similar factors.

c. Permit recertification. This method is primarily intended for research laboratories where a compressed gas cylinder (K-bottle) is connected to COTS laboratory equipment via a pressure regulator, relief device, and tubing system. It may also be used to certify temporary pressure system installations. Systems undergoing permit recertification are documented via a completed and approved LF 533.

d. D.O.T. recertification. This method is applicable to pressurized forged vessels mounted on transportable trailers (a.k.a., tube trailers) whether they are used in mobile or stationary applications.

e. Boiler recertification. This method is applicable to the steam boilers in the Central Heating and Steam Generation Plant, Building 1215.

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13. OPERATIONS AND MAINTENANCE OF PRESSURE SYSTEMS (GROUND-BASED)

13.1 General

13.1.1 Pressure systems under configuration control shall be operated in accordance with Standard Operating Procedures developed and approved in accordance with LPR 1740.4.

13.1.2 Facility Coordinators shall ensure that all pressure-retaining equipment (e.g., relief valves, control valves, gauges, transmitters) in pressure systems within their facility are included in the Computerized Maintenance Management System (CMMS) in accordance with LMS-CP-5616.

13.1.3 Pressure systems shall meet the requirements of NASA-STD-8719.17, LPR 1710.42, and this LPR to be certified for operation.

13.2 Operator Certification and Training

13.2.1 Pressure systems shall be run by system operators who have received training in the operational characteristics of the system and are knowledgeable of the operational procedures, checklists, inherent hazards, and operational limits associated with the system.

13.2.2 Operators of LaRC-owned pressure systems shall be certified in accordance with LPR 1740.6.

13.2.3 The FSH shall ensure that LF 121 and LF 122 include a suitable list of documents to ensure the operator has read and understands the operational procedures, checklists, inherent hazards, and operational limits associated with the system.

13.2.3.1 The certification of the operator shall be documented on LF 159.

13.2.3.2 The FSH shall ensure operator certifications are kept current.

13.2.4 The SFAB may periodically provide general pressure system awareness training that covers basic concepts, hazards, and engineering controls associated with pressure systems to interested Center organizations/personnel.

13.3 Operations and Maintenance Personnel Protection

13.3.1 When any servicing and/or maintenance operation could result in injury to personnel or serious damage to equipment due to the unexpected release of hazardous energy, the system shall be locked out/tagged out by a Safety Operator in accordance with LPR 1710.10.

13.3.2 The FSH shall ensure that the Safety Operator has met the qualifications in LPR 1710.10 to perform Lock Out/Tag Out (LOTO).

13.3.3 Any system containing toxic fluids, fuels, oxidizers, or other potentially dangerous media shall be purged in accordance with written procedures approved by the FSH.

13.3.3.1 The system shall be purged with an appropriate agent such as fresh air, water, inert gas, or a neutralizing agent, as appropriate, prior to initial use during a work

shift, following last use during a work shift, and prior to disassembly or opening up the system.

13.4 Preventive Maintenance Requirements

13.4.1 Relief valves shall be included in LaRC's Preventive Maintenance Program for retesting and verification in accordance with the frequencies specified in LPR 1710.42.

13.4.1.1 A log describing the maintenance work and test results on relief valves shall be kept at the Component Verification Facility.

13.4.2 Pressure sensing and indicating devices except for Category 1 and Category 2 devices subject to metrology requirements shall be included in LaRC's Preventive Maintenance Program for retesting in accordance with the frequencies specified in paragraph 15.13 of this LPR. A log describing the maintenance work and test results on pressure sensing and indicating devices shall be kept at the Component Verification Facility.

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14. DOCUMENTATION AND CONFIGURATION CONTROL OF PRESSURE SYSTEMS

14.1 Required System Documentation

14.1.1 All ground-based infrastructure pressure systems shall be documented by means of:

a. A Process and Instrumentation Diagram (P&ID). The P&ID drawing shall identify all pressure sources, valves, vessels, drains, vents, flow direction, instrumentation, cleanliness level, and all safety devices and their set points.

b. A recertification file containing supporting documentation for the pressure system.

14.2 Updating Configuration Controlled Documents (CCD)

14.2.1 Whenever work activities result in changes to the configuration of a pressure system under configuration control, a Facility Change Request (FCR) form shall be initiated by the Cognizant Engineer after the approval of the design.

14.2.1.1 A FCR shall be initiated to update the system's P&ID.

14.2.1.2 A separate FCR shall be initiated to update the Pressure Systems Document (PSD), if applicable.

14.3 Archiving and Retention of As-built Pressure Systems Documentation

14.3.1 Prior to completion of the construction of a new pressure system or completion of modifications to an existing pressure system, the Cognizant Engineer shall ensure that:

a. All new P&ID are field verified to show the final system configuration and are archived in Engineering Drawing Files.

b. Existing P&ID that are affected by the work are redlined to show modifications.

c. A copy of salient documentation such as construction drawings, design documents, calculations, catalog cuts, certification records, test reports, NDE records, material records, special welding procedures, and shakedown records are given to the Pressure Systems Recertification Group for archiving in the recertification file.

14.4 On-Site Documentation

14.4.1 As a minimum, the owner of a pressure system shall maintain at the facility a current copy of the following documents:

a. P&ID drawing.

b. Operations and Maintenance (O&M) manuals of the equipment in the system.

c. Certifications of calibrated devices and the frequency of the required calibrations.

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15. SUPPLEMENTAL REQUIREMENTS APPLICABLE TO SYSTEMS AND COMPONENTS

15.1 Anchoring of Components

15.1.1 All vessels and major components of a system shall be anchored to a stable foundation designed to withstand all static, dynamic, wind, and seismic loads acting on the pressure system.

15.2 Bushings (Single Step)

15.2.1 Hex-head pipe bushings of one-size reduction (single step) with dimensions conforming to ASME B16.11 shall not be used in pressure systems within the scope of this LPR.

15.2.2 Transitions requiring one-size reductions shall be made using concentric reducers, reducing couplings, or other fittings not having overlapping internal and external threads.

15.3 Cast Iron, Malleable Iron, and Ductile Iron

15.3.1 Pressure retaining components made of cast iron, malleable iron, or ductile iron shall not be used where they will be subject to vibration or shock loading.

15.4 Cleaning of Components

15.4.1 Pressurized components shall be cleaned internally before use to be compatible with their intended use. For example, proper cleaning of components to remove oils and other hydrocarbon-rich residues in systems containing oxygen gas, liquid oxygen, or high pressure air may be required to prevent the formation of flammable or explosive mixtures.

15.4.2 Systems containing oxygen and other systems requiring cleanliness to 10 parts per million or less of hydrocarbons, including systems that will be providing purge, pressurization, and test fluids to oxygen systems, shall be cleaned in accordance with LPR 1740.5.

15.5 Color Coding and Labeling

15.5.1 All pressure systems shall be labeled and color coded in accordance with LPR 1740.2 to properly identify the general hazard or risk level.

15.5.1.1 Whenever a pressure is included in the label, it shall be the normal operating pressure of the system.

15.6 CPV-Type Union Nuts

15.6.1 CPV-type unions 1-1/4" and larger in size shall not be used in compressed gas systems above 2400 psig.

15.6.2 CPV-type union nuts in systems operating above 2400 psig shall have vent holes drilled and be torqued to the values listed in Table 15-A.

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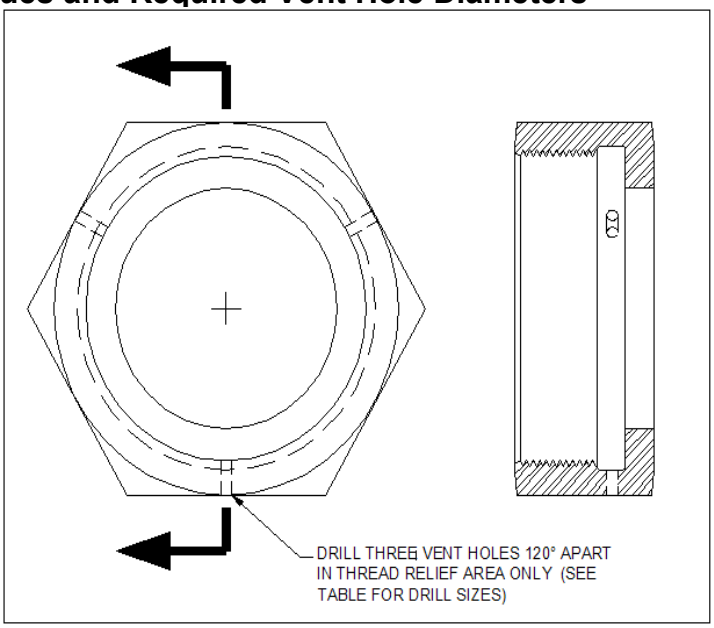
Table 15-A, CPV Nut Torques and Required Vent Hole Diameters

Size (IN.)	TORQUE (FT-LB)	VENT HOLE DIAMETER (IN.)
1/8	10 - 25	1/16
¼	10 – 25	1/16
3/8	12 – 30	1/16
1/2	15 – 40	3/32
3/4	20 – 50	3/32
1	25 – 60	3/32



15.7 Custom Filters and Filter Elements

15.7.1 Custom-built filters shall have the filter housing ASME code stamped with all welds 100 percent radiographically examined.

15.7.2 The vendor/supplier shall provide an ASME U-1A Form “Manufacturer’s Data Report” for each filter provided.

15.8 Filter-Regulators

15.8.1 Filter-regulators with see-through bowls shall not be used unless the bowl is made of impact-resistant glass or impact-resistant polycarbonate plastic.

15.9 Flexible Hoses

15.9.1 Flex hoses shall not be used in a system in lieu of rigid piping or tubing unless it is required for vibration isolation, motion allowance, component flexibility, or when the use of rigid piping or tubing has been determined by the appropriate SPE to be impractical.

15.9.2 Procurements of assembled flex hoses shall require the following:

a. The Maximum Allowable Working Pressure (MAWP) and the flex hose manufacturer’s name shall be marked on the outside of the hose.

b. When the procurement requires the manufacturer to conduct a pressure test on the flex hose prior to delivery, a signed pressure test certificate shall be supplied by the manufacturer.

c. If not tested by the manufacturer, the flex hose shall be tested by the Component Verification Facility prior to use.

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d. A tag shall be affixed to the flex hose indicating the date of the pressure test and the test pressure.

15.9.3 Flex hoses shall be restrained as follows:

a. Flex hoses with swaged end connections that could subject personnel to a whipping hazard in the event of failure of the end connections shall be fitted with anti-whip restraints and have sufficient intermediate restraint along their lengths to mitigate the hazard.

b. Flex hoses with welded or brazed end connections do not require anti-whip devices.

c. Flex hoses less than 2 feet in length do not require anti-whip restraints.

15.9.4 Flex hoses in liquid systems shall be evaluated by the appropriate SPE to determine anti-whip restraint requirements.

15.9.5 Prior to initial use, all flex hoses shall be hydrostatically tested to 150 percent of the maximum allowable working pressure stamped on the hose exterior.

15.9.6 No testing shall be performed on hoses lacking documentation, markings, or tags from the verification shop indicating the pressure rating of the hose.

15.9.7 Flex hoses shall be replaced every 5 years when:

a. The flex hose is fabricated with swaged ends and its rupture would cause unacceptable hazard to personnel or unacceptable risk to the facility or the mission.

b. The hose is exposed to agents or conditions that are known to deteriorate its inner or outer layers.

15.9.8 A pressure test tag or band shall be placed on all flex hoses indicating the date and pressure of the last test.

15.9.8.1 Flex hoses with missing test tags that are still traceable shall be retested to 150 percent of MAWP or replaced.

15.9.9 A flex hose, with leaks, flat areas, kinks, blisters, sharp ends, twists, damaged end fittings, cracks in the inner liner, severe corrosion (including the hose restraints), or has other signs of deterioration shall be removed from service and destroyed.

15.9.10 Flex hoses shall not be subjected to normal (or sustained) operating pressures greater than the manufacturer’s recommended MAWP.

15.9.10.1 Additionally, due to the probability of plastic yielding, any flex hose that experiences momentary pressures in excess of 2 times its MAWP shall be immediately removed from service and destroyed.

15.10 **Gas Cylinders**

15.10.1 Pressure systems using compressed gas cylinders as their source of fluid shall include **adequately-sized** pressure relieving devices on the downstream side of the pressure regulator.

15.10.2 All components in the system upstream of the relief device shall be rated for the full pressure stamped on the gas bottle.

15.10.3 No consideration for reduced pressure in a partially full gas bottle shall be made to meet design requirements.

Note: Compressed gas cylinders are commonly referred to as "K bottles," stemming from their D.O.T. designations, as follows in Table 15-B:

Table 15-B, Cylinder Types and Sizes

Cylinder Type	DOT Specification	Volume (ft^3)	Dimensions (H x diam.)
3K	3AA-3600	1.54	51" x 10"
4K	E9421-4500	1.61	51" x 9.25"
6K	3AA-6000	1.50	51" x 10"

15.10.4 A typical sketch of a gas cylinder connection is shown in Figure 15-1.

Note: Figure 15-1 is included for informational purposes and does I not imply that other configurations are unacceptable at the discretion of the cognizant SPE.

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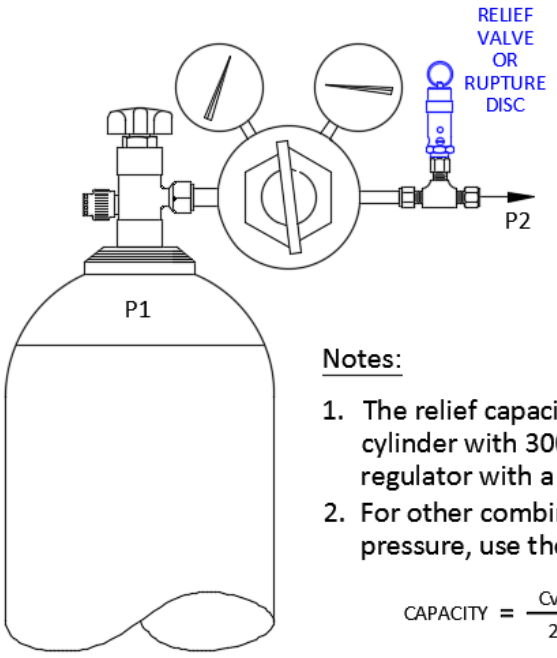

REQUIRED RELIEF CAPACITY		
TYPE OF GAS	Regulator Cv	RV FLOW, SCFM
AIR	0.06	90
NITROGEN	0.06	94
ARGON	0.06	66
OTHER (NON-TOXIC)	0.06	DIVIDE AIR CAPACITY BY THE SPECIFIC GRAVITY OF THE GAS

Notes:

1. The relief capacities shown in the table are computed assuming a gas cylinder with 3000 psig maximum nominal pressure and a pressure regulator with a maximum flow factor Cv = 0.06.
2. For other combinations of regulator flow factor and cylinder nominal pressure, use the formula below or contact the cognizant SPE.

$$\text{CAPACITY} = \frac{Cv \times P1}{2 \times \sqrt{Sg}}$$

VALID FOR UPSTREAM PRESSURE (P1) GREATER THAN 2 TIMES THE DOWNSTREAM PRESSURE (P2). ALL PRESSURES IN PSIG.

Figure 15-1, Basic design for connection of equipment to compressed gas bottles

15.10.5 Plastic tubing or rubber hose used to connect a gas cylinder to laboratory equipment shall have a maximum allowable working pressure equal to or higher than the relief valve setting.

15.11 Isolation & Depressurization

15.11.1 When a system is depressurized for the purpose of performing modifications, servicing, and/or maintenance operations, the procedures for locking and tagging out in LPR 1710.10 shall be followed.

15.11.2 Pressure gauges and pressure transmitters shall not be relied upon as the single means to verify a system is de-energized.

15.11.2.1 Depressurization of systems shall always be verified by the opening of vent valves or by other positive means.

15.12 Pressure Reducing Valves and Pressure Regulators

15.12.1 A pressure indicating device, whether a bourdon-tube gauge or a pressure transmitter, shall be installed on both the inlet and outlet sides of a pressure regulator or

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a pressure reducing valve to ensure proper monitoring of upstream and downstream pressures.

15.12.2 A pressure relief valve shall be installed on the downstream side of pressure reducing valves or pressure regulators unless all the components on the downstream side have a MAWP equal to or greater than the upstream side MAWP.

15.12.2.1 When a relief valve is required, it shall be installed as close as practical to the source of pressure without any intervening valves or closures.

15.13 **Pressure Sensing and Indicating Devices**

Table 15-C, Summary of Pressure Sensing Device Requirements

	Bourdon tube gauges with safety case	Bourdon tube gauges *lacking* safety case	Bourdon tube vacuum gauges	Pressure transmitters and transducers	Pressure Switches
Allowable Working Range	0 – 80% of full scale	0 – 60% of full scale	0 – 100% of full scale	0 – 100% of full scale	0 – 100% of full scale
Test Pressure	100% of full scale	100% of full scale	100% of full scale	100% of full scale	N / A
Type of Test (1)	Dead Weight	Dead Weight	Vacuum pump	Dead Weight	Set point and functional verification
Retest Period	5 years	5 years	Per LPR 1740.4	5 years	Per LPR 1740.4
Rejection Criteria (3)	EC, EW, ST, BG, SE	EC, EW, ST, BG, SE	EC, EW, ST, BG, SE	EC, EW, SE	EC, EW, ST, BG, SP
Test Label (2)	Required	Required	Required if tested	Required	Required

Notes for Table 15-C:

(1) Dead weight test media shall be water or oil. Oil shall not be used for gauges used with oxygen or other oxidizing agents. Oxygen-service pressure indicating devices undergoing verification shall be thoroughly dried then cleaned per LPR 1740.5 prior to returning to service.

(2) The test label shall include maximum test pressure, test date, and initials of testing personnel.

(3) EC = excessive corrosion, EW = excessive wear, ST = sticktion, BG = broken glass, SE = span error in excess of 5% of full scale, SP = setpoint error in excess of 3% of set value

15.13.1 In addition to the requirements in this LPR, pressure sensing and indicating devices identified as Category 1 or 2 Measurement and Test Equipment (M&TE) are subject to metrology requirements in LAPD 8730.1.

15.13.2 Differential pressure gauges shall be capable of withstanding full system differential pressure without failure.

15.13.3 A safety case shall include a solid front and a full-area blow out back.

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15.13.3.1 Blow out plugs shall not be considered sufficient to meet this requirement.

Note: See Figures 15-2 and 15-3 for examples of blow out plugs.

15.13.4 Bourdon-tube pressure gauges shall comply with applicable national consensus codes and the following additional requirements:

a. Gauges having a safety case shall have a maximum allowable working pressure of 80 percent of full scale.

b. Gauges lacking a safety case, except vacuum gauges, shall have a maximum allowable working pressure of 60 percent of full scale.

c. Panel mounting of bourdon-tube gauges shall allow the full-area blowout back to function properly.

15.13.5 Any bourdon-tube pressure sensing and indicating device that is subjected to pressures above 100 percent of its full scale range shall be immediately removed from service.

15.13.6 Pressure sensing and indicating devices that are critical interlocks shall be tested as required by LPR 1740.4 under the cognizance of the FSH.

15.13.7 Verification of pressure sensing and indicating devices shall be performed as follows:

a. Bourdon-tube pressure gauges shall be tested at the Component Verification Facility prior to initial installation and subsequently re-tested every 5 years to ensure proper operation.

b. Following verification, the tester shall keep a log that includes all pertinent test results, observations, the date of the test, and the device identifier listed in the CMMS.

15.13.7.1 Pressure sensing and indicating devices in excluded systems shall also be re-tested every 5 years if their reading is required in the system’s SOPs.

15.13.8 Criteria for rejection of pressure sensing and indicating devices that are not subject to metrology requirements shall be as follows:

a. Bourdon-tube gauges, pressure and vacuum – excessive corrosion or wear of the moving parts or of the pressure-retaining parts, sticktion, broken glass, and span error in excess of 5 percent of full scale.

b. Pressure transmitters and transducers – excessive corrosion or wear of the pressure-retaining parts and span error in excess of 5 percent of full scale.

c. Pressure switches – excessive corrosion or wear of the moving parts or of the pressure-retaining parts, sticktion, broken glass, and setpoint error in excess of 3 percent of set value.

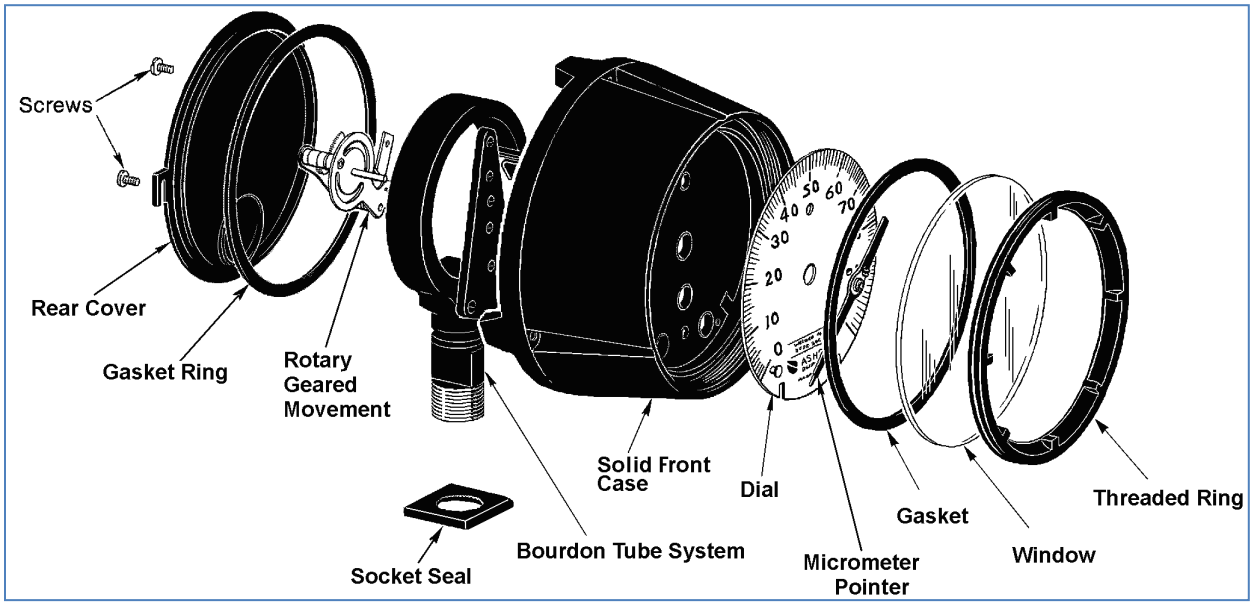

Figure 15-2, View of a bourdon-tube gauge with a solid front case and a full-area blow-out back

Figure 15-3, View of a bourdon tube gauge lacking a solid front case and having a blow-out plug

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15.14 Pressure Relieving and Venting

15.14.1 Relief valves shall be ASME code stamped. The SPE for Pressure Systems has the authority to determine when the use of code stamped relief valves is impractical for a specific application.

15.14.2 When a single pressure relief device is used, the set pressure marked on the device shall not exceed the MAWP of the system being protected. When the total required capacity is provided by utilizing more than one pressure relief device, only one pressure relief device need be set at or below the maximum allowable working pressure. The additional pressure relief devices may be set to open at higher pressures but in no case at a pressure higher than 105 percent of the maximum allowable working pressure, except as provided in the applicable code.

15.14.3 Relief valves shall be periodically tested to check for proper operation and the accuracy of the set point.

15.14.3.1 Relief valves shall be properly tagged after testing. The maximum intervals for re-testing are listed in LPR 1710.42.

15.14.3.2 Relief valve tags shall include the valve number, set pressure, and the test date.

15.14.4 New relief valves shall be tested and certified by a National Board Valve Repair (VR) code stamp certified shop or by the LaRC Component Verification Facility prior to initial use to ensure proper relief setting.

15.14.5 A relief valve shall be used in parallel with a rupture diskdisc in cryogenic systems wherever liquid cryogen entrapment could occur.

15.14.6 Piping downstream of relief valves and vent valves shall:

a. Have a nominal diameter equal to or larger than the valve outlet size.

b. Be designed and routed such as to minimize exposure of personnel to vented media and to excessive noise levels as required in LPR 1800.1.

c. Incorporate means of reacting thrust loads, including the use of equalizing tees and structural supports.

d. Be designed for the MAWP of the system to which they are connected unless engineering calculations are made to justify a lower design pressure. For example, calculations may be performed in accordance with API RP-521, “Guide for Pressure-Relieving and Depressuring Systems.”

15.15 Seam-Welded Pipe and Tubing

15.15.1 Seam-welded pipe and tubing shall not be used in pressure systems.

15.16 Torque Values

15.16.1 Torque values for all bolted connections in pressure systems shall be designated on the system’s drawings.

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15.17 Langley Research Center Identification (LaRC ID) Locator Numbering

15.17.1 Permanently installed pressure system component locations at LaRC shall be numbered and tagged in accordance with Appendix E, “LaRC Location ID” of LPR 7123.2, “Facility Configuration Management,” and the additional requirements herein.

15.17.2 Personnel performing maintenance on a valve with a suffix listed in LPR 7123.2, or disassembling a system identified by this suffix, shall positively identify the system’s media before maintenance or disassembly operations begin.

15.17.3 In addition to the requirements listed in LPR 7123.2, the four digit valve number and the one digit media identifier (3142J in the example in Figure E-1 in LPR 7123.2) found on the valve tag shall be of at least ½ inch in height (36 point size) so as to be readable from a distance of 6 feet.

15.18 Viewports and Windows in Pressure Systems:

a. All viewports and windows in pressure and vacuum vessels shall be approved by the appropriate SPE.

b. A minimum safety factor of 10 shall be used for window designs.

c. Window frames shall be designed in accordance with the applicable code and will preclude metal contact with glass surfaces.

Verify the correct version before use by checking the LMS Web site.

16. RESPONSIBILITIES

The responsibilities listed below are essential to provide the checks and balances necessary to ensure pressure system safety.

16.1 **The LaRC Center Director (or designee) is responsible for:**

a. Granting waivers from the requirements of this LPR (Chapter 4).

16.2 **The Cognizant Engineer is responsible for:**

a. Ensuring that new pressure system designs include documentation to verify that the pressure systems are in accordance with the required codes and standards (Chapter 5).

b. Supervising the progress of the procurement, fabrication, modifications, or repairs to pressure systems (Chapters 6, 7, and 8).

c. Ensuring that pressure systems are inspected and tested in accordance with this LPR (Chapter 10).

d. Performing or overseeing the performance of the verification process of pressure systems and certifying that new construction, modifications, or repairs are completed in accordance with this LPR (Chapter 11).

e. Performing or overseeing the performance of shakedown of pressure systems (Chapter 11).

f. Initiating a FCR to update all configuration controlled documentation of a pressure system (Chapter 11).

g. Ensuring that pressure system documentation is field verified, redlined, and filed following construction or installation work (Chapter 14).

16.3 **The Director of Safety and Mission Assurance Office (SMAO) is responsible for:**

a. Appointing an individual or individuals to serve as official radiographic interpreters for LaRC (Chapter 10).

b. Serving as “Accepter” in reviewing and signing requests for waivers, form LF 51 (Chapter 4).

16.4 **Facility Coordinators are responsible for:**

a. Reviewing and approving new designs, fabrication plans, modifications, and repairs to pressure systems in their facilities, as well as certifying that the pressure systems comply with facility requirements (Chapter 3).

b. Ensuring that all pressure-retaining equipment such as relief valves, control valves, gauges, and pressure transmitters in pressure systems within their facilities are included in the Computerized Maintenance Management System (CMMS) in accordance with LMS-CP-5616 (Chapter 13).

Verify the correct version before use by checking the LMS Web site.

16.5 **Facility Safety Heads are responsible for:**

a. Reviewing and approving new designs, fabrication plans, modifications, and repairs to pressure systems in their facilities, as well as certifying that the pressure systems comply with facility safety requirements (Chapter 3).

b. Approving pneumatic test procedures (Chapter 10).

c. Approving shakedown procedures (Chapter 11).

d. Ensuring that pressure system operators are properly trained and certified (Chapter 12).

e. Ensuring that Safety Operators performing LOTO at their facilities are certified in accordance with LPR 1710.10 (Chapter 13).

f. Approving procedures for purging pressure systems prior to the performance of service or maintenance activities (Chapter 13).

g. Ensuring that critical safety interlocks are tested as required by LPR 1740.4 (Chapter 15).

h. Approving blowdown procedures (Appendix C.4.1).

16.6 **The AHJ is responsible for:**

a. Reviewing and approving new designs, fabrication plans, modifications, and repairs to pressure systems containing flammable or combustible liquids, flammable gases, cryogenic liquids, oxidizers, pyrophoric substances, highly reactive substances, or toxic substances (Chapter 3).

b. Providing interpretation of the applicability requirements in this LPR related to code compliance in matters of fire protection, personnel safety, and the protection of LaRC assets (Chapter 4).

16.7 **The LaRC Safety Manager is responsible for:**

a. Approving pneumatic test procedures (Chapter 10).

b. Serving as member of the Operational Readiness Review (ORR) board that certifies new pressure systems for operation (Chapter 12).

c. Authorizing the appropriate SPE to perform the certification function of an ORR board (Chapter 12).

16.8 **Owners of pressure systems are responsible for:**

a. Serving as “Accepter” in reviewing and signing requests for waivers, form LF 51 (Chapter 4).

b. Ensuring duplicate valve numbers are not used in a pressure system (Chapter 15).

c. Keeping a current copy of all relevant pressure system documentation at the facility (Chapter 12).

Verify the correct version before use by checking the LMS Web site.

16.9 **The chairman of the Pressure Systems Committee is responsible for:**

a. Reviewing and approving pneumatic test procedures (Chapter 10).

b. Serving as “Recommending Authority” in reviewing and signing requests for waivers, form LF 51 (Chapter 4).

16.10 **The Pressure Systems Manager is responsible for:**

a. The recertification of pressure systems, as defined in LPR 1710.42.

16.11 **Pressure Systems Operators are responsible for:**

a. Reading and understanding the operational procedures and checklists of the pressure systems they work with (Chapter 13).

b. Understanding the inherent hazards of the pressure systems they work with and the engineering solutions and safety controls used to mitigate those hazards (Chapter 13).

c. Maintaining current certification in accordance with LPR 1740.6.

16.12 **The Official Radiograph Interpreter is responsible for:**

a. Serving as LaRC’s authority in the interpretation of radiographs of pressure system welds and signing for their final acceptance (Chapter 10).

16.13 **Safety Operators are responsible for:**

a. locking and tagging out a pressure system prior to the performance of any service or maintenance activity that could result in the unexpected release of hazardous energy from the system (Chapter 13).

16.14 **The Standard Practice Engineer for Pressure Systems (ground-based) is responsible for:**

a. Reviewing and approving new designs, fabrication plans, modifications, and repairs to pressure systems, certifying their compliance with required codes and standards (Chapter 3).

b. Providing interpretation of the applicability of the requirements of this LPR (Chapter 4).

c. Approving procurement of pressure systems and pressure system components (Chapter 8).

d. Establishing the required technical qualifications of the Official Radiograph Interpreters (Chapter 10).

e. Reviewing and approving plans for hydrostatic testing and for pneumatic testing (Chapter 10).

f. Witnessing hydrostatic and pneumatic tests (Chapter 10).

g. Establishing additional NDE required whenever hydrostatic testing or pneumatic testing is deemed impractical (Chapter 10).

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h. Reviewing and approving independent hazard analysis in lieu of low pressure leak tests (Chapter 10).

i. Reviewing and approving pressure system shakedown plans (Chapter 11).

j. Reviewing and approving changes to approved pressure system designs (Chapter 11).

k. Certifying new pressure systems for operation, in conjunction with the LaRC Safety Manager (Chapter 12).

l. Determining when the use of flexible hose in lieu of rigid piping is acceptable (Chapter 15).

m. Determining the need to restrain flexible hoses in systems containing pressurized liquids (Chapter 15).

n. Reviewing and approving the use of glass viewports in pressure systems (Chapter 15).

o. Approving blowdown procedures (Appendix C.4.1).

16.15 **The responsibilities of the Standard Practice Engineer for Pressurized Flight Systems parallel those of the SPE for Pressure Systems, but as applicable to flight-grade systems.**

16.16 **The SPE for Welding is responsible for:**

a. Reviewing and approving new designs, fabrication plans, modifications, and repairs to pressure systems, certifying their compliance with welding and quality assurance requirements (Chapter 3).

b. Providing interpretation of the applicability of the requirements of this LPR (Chapter 4).

c. Reviewing and approving welding documentation, i.e., WPS/BPS, PQR, and WPQ/BPQ (Chapters 6 and 7).

16.17 **The SPE for Wind Tunnel Models is responsible for:**

a. Reviewing and approving pressurized models to be tested in LaRC wind tunnels in accordance with LPR 1710.15 (Chapter 1).

Verify the correct version before use by checking the LMS Web site.

APPENDIX A. DEFINITIONS

Authority Having Jurisdiction (AHJ). An individual appointed by the Center Director to ensure regulatory and code compliance on matters involving the safety of personnel and protection of LaRC assets from fire hazards

Code stamp. A marking applied to a pressure component by a certified manufacturer to indicate compliance with a national consensus code. Available stamps include:

U – ASME B&PV Code Section VIII, Div 1 (Pressure Vessels)

U2 – ASME B&PV Code Section VIII, Div 2 (Pressure Vessels)

R – NBIC Pressure Vessel Repair

VR – NBIC Valve Repair

N – ASME B&PV Code Section III (Nuclear Facility Components)

PP – ASME Power Piping

Cognizant Engineer. The individual who is responsible for sponsoring, executing, or implementing the construction of a new pressure system or modifications to an existing pressure system. In this context, the word “engineer” is used to mean an individual with a degree in engineering or engineering technology, or an engineering technician with at least 5 years of experience in design, maintenance, or operations.

Commercial Off-The-Shelf Pressure Systems and Components. COTS pressure systems and components are systems and components routinely produced in quantity by an industrial manufacturer and adhere to one or more published national consensus standards or to manufacturer’s association standards. COTS pressure systems and components are typically furnished with a recommended pressure rating and temperature rating.

Critical interlock. An interlock that is designed specifically to mitigate an undesired event.

Design pressure. The maximum difference in pressure across the pressure retaining boundary of a pressurized component used in its design calculations.

Engineering Drawing Files. The electronic repository for LaRC drawings.

Excluded pressure system. A pressure system not required to meet the requirements of this LPR and NASA-STD-8719.17.

Facility Change Request. A FCR is an electronic form processed via the FCM website. A FCR is initiated to obtain approval for changes to systems under configuration control.

Facility Configuration Management. A LaRC website for processing FCRs or to obtain copies of Configuration Controlled Items (CCIs).

Inert gas. Refers to any non-reactive, non-toxic gaseous media, e.g., gaseous nitrogen, helium, and argon.

Interlock. A device (or devices) designed with the purpose of preventing a system from crossing a specified threshold or entering an undesirable mode of operation.

Verify the correct version before use by checking the LMS Web site.

Maximum Allowable Working Pressure (MAWP). The maximum pressure in a system, subsystem, or component as permitted by the applicable code. In general, the term “MAWP” is synonymous to the term “design pressure,” unless the MAWP is explicitly determined by calculations, testing, or recertification.

Maximum/minimum design temperature. The maximum/minimum metal temperature (averaged through-the-wall) considered in the design calculations.

Modification. An alteration or change to the original configuration of a pressure system, which may affect its pressure retaining capability. Any operational or physical change to a pressure system other than a direct replacement of a component is a modification. Operational changes may include such things as changing the normal operating pressure, temperature, or relief valve settings of the system. Physical changes may include such things as changing relief valves or adding/removing piping or components.

National Consensus Code. A document which (1) has been adopted or distributed by a nationally recognized standards developing organization using procedures such that it can be determined by the Secretary of Labor or by the Assistant Secretary of Labor for Occupational Safety and Health that persons interested and affected by the standard have reached substantial agreement on its adoption; (2) was formulated in a manner that afforded an opportunity for diverse views to be considered; and (3) has been so designated by the Secretary or the Assistant Secretary, after consultation with other appropriate Federal Agencies.

Normal operating pressure. The pressure in a piping system or pressure vessel under typical operating conditions.

Owner. The owner of a pressure system refers to the Organizational Director or his/her designated representative who is responsible for the pressure system.

Piping system. An assembly of structural components, which may include pipes, valves, fittings, and other such piping components, with the primary purpose to convey, distribute, mix, separate, discharge, meter, control, or snub the flow of a fluid. For the purpose of this definition, tubing and piping are considered to be interchangeable.

Pressure vessel. An assembly of structural components, which may include pipes, fittings, and piping components, with the primary purpose to hold, contain, or enclose a finite volume of a fluid under pressure or hold a vacuum.

Pressure system. A collection of piping systems and/or pressure vessels used jointly to convey or contain a pressurized fluid or a vacuum.

Pressure Systems Document. A configuration controlled document describing the current system configuration, including isometric sketches of the system and a database of components. PSDs are available through the FCM website.

Pressure Systems Manager. An individual responsible for managing the recertification program for pressure systems at LaRC

Relief device setting. The value of increasing inlet static pressure at which the relief device begins venting fluid. For different relief device types, this value may be called

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opening pressure, cracking pressure, popping pressure, start-to-leak pressure, burst pressure, or breaking pressure.

Repair. The work necessary to restore a pressure system to a safe and satisfactory operating condition, provided that no deviation from the original design is made.

SPE for Pressure Systems. An individual responsible for ensuring ground-based pressure systems at LaRC comply with this LPR.

SPE for Flight Systems. An individual responsible for ensuring pressure components on flight rated systems at LaRC comply with this LPR.

SPE for Welding. An individual responsible for ensuring that welding on pressure systems at LaRC complies with this LPR.

SPE for Wind Tunnel Models. An individual responsible for ensuring that wind tunnel models comply with LPR 1710.15 and this LPR as applicable.

Tank. A storage container intended to hold or store liquids, with low pressure gases or vapors in the space above the liquid surface.

Test article. An object being tested for the sole purpose of obtaining research data.

Test-Specific Pressure System. A pressure system used to perform research testing of a specific test article. Pressure systems used on a permanent basis or on a recurring basis are not considered to be test-specific. Pressure systems built up of components used repeatedly for testing different test articles or test configurations are not considered to be test-specific.

Verify the correct version before use by checking the LMS Web site.

APPENDIX B. ABBREVIATIONS AND ACRONYMS

AHJ	Authority Having Jurisdiction
AIAA	American Institute of Aeronautics and Astronautics
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
ASTM	American Society for Testing and Materials
B&PV	Boiler and Pressure Vessel
BPQ	Brazer Performance Qualifications
BPS	Brazing Procedure Specification
CCD	Configuration Controlled Document
CFR	Code of Federal Regulations
CMMS	Computerized Maintenance Management System
COTS	Commercial Off The Shelf
CP	Center Procedure
DOT	U.S. Department of Transportation
FCM	Facility Configuration Management
FCR	Facility Change Request
FM	Factory Mutual
FSH	Facility Safety Head
HVAC	Heating, Ventilation, and Air Conditioning
ICC	International Code Council
LAPD	Langley Policy Directive
LaRC	Langley Research Center
LF	Langley Form
LMS	Langley Management System
LOTO	Lock Out / Tag Out
LPR	Langley Procedural Requirement

M&TE	Measurement and Test Equipment
MAWP	Maximum Allowable Working Pressure
MT	Magnetic particle examination
NASA	National Aeronautics and Space Administration
NBIC	National Board Inspection Code
NDE	Non Destructive Examination
NPR	NASA Procedural Requirements
OSHA	Occupational Safety and Health Administration
O&M	Operations & Maintenance
ORR	Operational Readiness Review
P&ID	Process and Instrumentation Diagram
PPE	Personal Protective Equipment
PQR	Procedure Qualification Record
PSD	Pressure Systems Document
PSM	Pressure Systems Manager
PSIG	Pounds per square inch gauge
PSID	Pounds per square inch differential
PT	Dye penetrant examination
PVS	Pressure Vessels and Pressurized Systems
RT	Radiographic examination
RTS	Return To Service
SAE	Society of Automotive Engineers
SCBA	Self-Contained Breathing Apparatus
SFAB	Safety and Facility Assurance Branch
SMAO	Safety and Mission Assurance Office
SPE	Standard Practice Engineer
STD	Standard
TD	Task Description
UL	Underwriters Laboratories

Verify the correct version before use by checking the LMS Web site.

VR	Valve Repair stamp
VT	Visual Testing
WPQ	Welder Performance Qualifications
WPS	Welding Procedure Specification

Verify the correct version before use by checking the LMS Web site.

APPENDIX C. BEST PRACTICES FOR PRESSURE SYSTEM DESIGN, INSTALLATION, AND OPERATION

C.1 Bladder Accumulators

C.1.1 Bladder accumulators should be pre-charged with nitrogen gas rather than air or other gases to prevent adverse reaction or combustion.

C.2 Deactivated Pressure Systems

C.2.1 When a pressure system is deactivated or placed in standby mode, it should be pressurized up to 25 psig with a dry, inert gas to prevent contamination and internal corrosion.

C.2.2 When a pressure system is abandoned in place, the piping should be completely removed when appropriate, or the piping where exposed should be left open or cut open and fully identified with tags or labels to indicate that the pipe is abandoned.

C.3 Double Block and Bleed Isolation

C.3.1 Isolation of sections of a pressure system for the purpose of performing maintenance or for performing work requiring opening the system to atmosphere should be accomplished utilizing a double-block and bleed valve configuration. See LPR 1710.10 for additional requirements for the use of double block and bleed valve configurations.

C.4 Drying of Pressure Systems

C.4.1 Following hydrostatic testing, internal surfaces in pressure systems should be dried using mechanical means, vacuum, or by blowdown with inert gas. If blowdown is to be performed, a written procedure should be developed and approved by the FSH and the SPE for Pressure Systems. As a minimum, the procedure should address the following hazards:

a. Noise,

b. High velocity air, water, and debris.

c. Movement due to unbalanced thrust at the discharge end,

d. Asphyxiation hazard if using an inert gas, and

e. Contamination of oxygen systems, where applicable.

C.5 Filters and Filter Elements

C.5.1 Filters should use ultrasonically-cleanable metallic filter elements whenever possible.

C.5.2 Filter elements should be designed to withstand full differential pressure without collapse. In the absence of this feature, the differential pressure across the filter element should be monitored to prevent collapse.

C.5.3 Whenever a filter housing contains threaded filter elements, the filter elements should be threaded into a removable tubesheet instead of threading directly into the filter housing. This is to prevent damage to the housing in the event the threads become

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galled or cross-threaded. Lifting lugs should be provided for removal of the elements/tubesheet.

C.5.4 Welds in filter elements should be VT examined and PT examined after fabrication. Criteria for rejection of filter element welds include (a) cracks in the weld area, (b) surface porosity, (c) excessive weld reinforcement, (d) undercut, and (e) lack of fusion.

C.5.5 The filter housing should allow for an annular area between the housing and the filter elements of at least 1.5 times the inlet piping cross sectional area.

C.5.6 The design of T-type filters should not produce direct flow impingement on the filter media.

C.5.7 Manufacturers of new custom-built filters should provide calculations of the filter element's maximum allowable differential pressure, a certified as-built drawing of the filter housing, and a certified as-built drawing of the filter element and tubesheet, including part numbers.

C.6 Glass Windows in Pressure Systems

C.6.1 The use of glass windows exposed to pressure differentials should be avoided. If used, glass surfaces should be shielded or protected by quick-acting closures whenever possible. Indirect viewing using electronic cameras and monitors rather than direct viewing should be employed to the greatest extent possible.

C.6.2 Glass windows in pressure systems should not be subjected to extraneous heating or cooling sources such as ultraviolet lamps, infrared lamps, or other lighting/heat sources, cooling water or cryogenic gases, which could cause cracking and/or breakage due to thermal expansion of glass and/or frame.

C.6.3 Special consideration should be given to vacuum systems and implosion effects whereby viewing windows present potential hazards to personnel.

C.7 Normal Operating Pressure

C.7.1 The normal operating pressure of a system should be at least 10% below the relief device setting.

C.8 Pressure Relieving and Venting Systems

C.8.1 Piping downstream of relief valves and vent valves should be routed separately to the point of discharge. However, a common header that considers the effects of backpressure on the discharge capacity of the relief valves may be used when approved by the SPE for Pressure Systems.

C.8.2 Gas vent piping systems should be outfitted with screens at the point of discharge to keep out insects and animals.

C.9 Pressure Transmitters and Transducers

C.9.1 The use of pressure transmitters and pressure transducers in lieu of bourdon-tube pressure gauges should be used whenever there is a need to convey pressure data to facility control rooms.

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C.10 Reclaimed Materials

C.10.1 Reclaimed piping or tubing may be reused provided the reclaimed materials are:

a. Examined to determine if the minimum wall thickness is greater than that required by the applicable code.

b. Hydrostatically tested to 1.5 times the design pressure of the system.

c. Inspected for imperfections that would be unacceptable for its intended use.

d. Cleaned in sufficient measure to ensure compatibility with their intended use.

e. All welds in reused material should be 100% radiographically examined.

f. The material of the piping or tubing is ascertained through Positive Material

g. Identification (PMI) or material markings.

C.11 Supports

C.11.1 Piping and tubing should be firmly secured to a stable structure at or near mechanical joints and at bends to prevent violent displacement of the piping in event of joint failure.

C.12 Threaded Piping and Fittings

C.12.1 The use of threaded piping and fittings in nominal sizes greater than 1-1/2 inch is not recommended.

C.13 Valve Body Fabrication

C.13.1 Valves should be of forged construction for sizes 6 inches and larger where the flange rating is 600 pound class or above.

C.14 Valve Numbering

C.14.1 In building complexes where multiple research apparatus or facilities are fed from a common piping system, valves should not be assigned the same four digit valve number and suffix combination even if the three digit prefix is different. This is intended to facilitate proper valve identification when they are being serviced or operated.

C.14.2 When a valve is replaced, its valve number may be assigned to the replacement valve if the replacement valve performs the identical function as the original valve (system isolation, pressure control, flow control, venting, or pressure relief) and the replacement valve is in the same functional location as the original valve, as determined from the pressure system's P&ID. If the above conditions are not met, the replacement valve should be assigned a new valve number. Example: a manually operated isolation valve is replaced by a pneumatically-operated control valve. In this example, the control valve should be assigned a new valve number.

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APPENDIX D. PRESSURE RATING OF METALLIC SEAMLESS PIPING

In accordance with ASME B31.3 – 2014

This table is valid for seamless piping with allowable stress value SE=20,000 psi at design temperature. Example materials include A-53 Grade B, A-106 Grade B and A-312 Grades TP304, TP316, and TP347.

					WELDED (Note 1)		THREADED (Note 1)	
Nominal Pipe Size	Wall Schedule	Outside Diameter	Nominal Wall Thickness	Max. Thread Depth	Allowable Pressure (PSIG)	SW Fitting Pound Class	Allowable Pressure (PSIG)	Thr. Fitting Pound Class
1/8	10	0.405	0.049	(Note 6)	4641	3000#		
	30	0.405	0.057	0.02963	5479	3000#	2057	2000#
	40	0.405	0.068	0.02963	6723	3000#	3150	2000#
	STD	0.405	0.068	0.02963	6723	3000#	3150	2000#
	80	0.405	0.095	0.02963	7525	3000#	5295	2000#
	XS	0.405	0.095	0.02963	7525	3000#	5295	2000#
1/4	10	0.540	0.065	(Note 6)	4612	3000#		
	30	0.540	0.073	0.04444	5237	3000#	1448	2000#
	40	0.540	0.088	0.04444	6438	3000#	2570	2000#
	STD	0.540	0.088	0.04444	6438	3000#	2570	2000#
	80	0.540	0.119	0.04444	7182	3000#	4561	2000#
	XS	0.540	0.119	0.04444	7182	3000#	4561	2000#
3/8	10	0.675	0.065	(Note 6)	3622	3000#		
	30	0.675	0.073	0.04444	4104	3000#	1152	2000#
	40	0.675	0.091	0.04444	5237	3000#	2164	2000#
	STD	0.675	0.091	0.04444	5237	3000#	2164	2000#
	80	0.675	0.126	0.04444	7496	3000#	4243	2000#
	XS	0.675	0.126	0.04444	7496	3000#	4243	2000#
1/2	5	0.840	0.065	(Note 6)	2870	3000#		
	10	0.840	0.083	(Note 6)	3736	3000#		
	30	0.840	0.095	0.05714	4292	3000#	1270	2000#
	40	0.840	0.109	0.05714	4974	3000#	1877	2000#
	STD	0.840	0.109	0.05714	4974	3000#	1877	2000#
	80	0.840	0.147	0.05714	7003	3000#	3626	2000#
	XS	0.840	0.147	0.05714	7003	3000#	3626	2000#
	160	0.840	0.188	0.05714	7240	6000#	5113	3000#
	XXS	0.840	0.294	0.05714	9808	9000#	8378	6000#
3/4	5	1.050	0.065	(Note 6)	2270	3000#		
	10	1.050	0.083	(Note 6)	2945	3000#		
	30	1.050	0.095	0.05714	3375	3000#	1010	2000#
	40	1.050	0.113	0.05714	4079	3000#	1653	2000#
	STD	1.050	0.113	0.05714	4079	3000#	1653	2000#

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					WELDED (Note 1)		THREADED (Note 1)	
Nominal Pipe Size	Wall Schedule	Outside Diameter	Nominal Wall Thickness	Max. Thread Depth	Allowable Pressure (PSIG)	SW Fitting Pound Class	Allowable Pressure (PSIG)	Thr. Fitting Pound Class
	80	1.050	0.154	0.05714	5732	3000#	3159	2000#
	XS	1.050	0.154	0.05714	5732	3000#	3159	2000#
	160	1.050	0.219	0.05714	6887	6000#	5158	3000#
	XXS	1.050	0.308	0.05714	8812	9000#	7455	6000#
1	5	1.315	0.065	(Note 6)	1796	3000#		
	10	1.315	0.109	(Note 7)	3067	3000#		
	30	1.315	0.114	0.06957	3239	3000#	930	2000#
	40	1.315	0.133	0.06957	3796	3000#	1472	2000#
	STD	1.315	0.133	0.06957	3796	3000#	1472	2000#
	80	1.315	0.179	0.06957	5280	3000#	2794	2000#
	XS	1.315	0.179	0.06957	5280	3000#	2794	2000#
	160	1.315	0.250	0.06957	7686	6000#	4984	3000#
	XXS	1.315	0.358	0.06957	8377	9000#	6969	6000#
1-1/4	5	1.660	0.065	(Note 6)	1412	3000#		
	10	1.660	0.109	(Note 6)	2399	3000#		
	30	1.660	0.117	0.06927	2585	3000#	808	2000#
	40	1.660	0.140	0.06927	3151	3000#	1311	2000#
	STD	1.660	0.140	0.06927	3151	3000#	1311	2000#
	80	1.660	0.191	0.06927	4376	3000#	2479	2000#
	XS	1.660	0.191	0.06927	4376	3000#	2479	2000#
	160	1.660	0.250	0.06957	5900	6000#	3868	3000#
	XXS	1.660	0.382	0.06957	7423	9000#	6186	6000#
1-1/2	5	1.900	0.065	(Note 6)	1230	3000#		
	10	1.900	0.109	(Note 6)	2083	3000#		
	30	1.900	0.125	0.06957	2405	3000#	857	2000#
	40	1.900	0.145	0.06957	2825	3000#	1230	2000#
	STD	1.900	0.145	0.06957	2825	3000#	1230	2000#
	80	1.900	0.200	0.06957	3977	3000#	2313	2000#
	XS	1.900	0.200	0.06957	3977	3000#	2313	2000#
	160	1.900	0.281	0.06957	5777	6000#	4002	3000#
	XXS	1.900	0.400	0.06957	6941	9000#	5812	6000#
2	5	2.375	0.065	(Note 6)	979	3000#		
	10	2.375	0.109	(Note 6)	1653	3000#		
	30	2.375	0.125	0.06957	1906	3000#	683	2000#
	40	2.375	0.154	0.06957	2382	3000#	1119	2000#
	STD	2.375	0.154	0.06957	2382	3000#	1119	2000#
	80	2.375	0.218	0.06957	3438	3000#	2124	2000#
	XS	2.375	0.218	0.06957	3438	3000#	2124	2000#

Verify the correct version before use by checking the LMS Web site.

					WELDED (Note 1)		THREADED (Note 1)	
Nominal Pipe Size	Wall Schedule	Outside Diameter	Nominal Wall Thickness	Max. Thread Depth	Allowable Pressure (PSIG)	SW Fitting Pound Class	Allowable Pressure (PSIG)	Thr. Fitting Pound Class
	160	2.375	0.344	0.06957	5641	6000#	4219	3000#
	XXS	2.375	0.436	0.06957	7384	9000#	5872	6000#
2-1/2	5	2.875	0.083	(Note 6)	1037	3000#		
	10	2.875	0.120	(Note 6)	1505	3000#		
	30	2.875	0.188	0.1	2406	3000#	921	2000#
	40	2.875	0.203	0.1	2606	3000#	1109	2000#
	STD	2.875	0.203	0.1	2606	3000#	1109	2000#
	80	2.875	0.276	0.1	3610	3000#	2057	2000#
	XS	2.875	0.276	0.1	3610	3000#	2057	2000#
	160	2.875	0.375	0.1	5022	(Note 3)	3387	3000#
	XXS	2.875	0.552	0.1	6456	(Note 3)	5333	6000#
3	5	3.500	0.083	(Note 6)	848	3000#		
	10	3.500	0.120	(Note 6)	1230	3000#		
	30	3.500	0.188	0.1	1960	3000#	754	2000#
	40	3.500	0.216	0.1	2258	3000#	1038	2000#
	STD	3.500	0.216	0.1	2258	3000#	1038	2000#
	80	3.500	0.300	0.1	3198	3000#	1923	2000#
	XS	3.500	0.300	0.1	3198	3000#	1923	2000#
	160	3.500	0.438	0.1	4797	(Note 3)	3458	3000#
	XXS	3.500	0.600	0.1	6818	(Note 3)	5380	6000#
3-1/2	5	4.000	0.083	(Note 6)	741	3000#		
	10	4.000	0.120	(Note 6)	1073	3000#		
	30	4.000	0.188	0.1	1706	3000#	659	2000#
	40	4.000	0.226	0.1	2062	3000#	1000	2000#
	STD	4.000	0.226	0.1	2062	3000#	1000	2000#
	80	4.000	0.318	0.1	2944	3000#	1846	2000#
	XS	4.000	0.318	0.1	2944	3000#	1846	2000#
	XXS	4.000	0.636	0.1	6256	(Note 3)	5030	6000#
4	5	4.500	0.083	(Note 6)	657	3000#		
	10	4.500	0.120	(Note 6)	951	3000#		
	30	4.500	0.188	0.1	1511	3000#	585	2000#
	40	4.500	0.237	0.1	1910	3000#	970	2000#
	STD	4.500	0.237	0.1	1910	3000#	970	2000#
	80	4.500	0.337	0.1	2767	3000#	1796	2000#
	XS	4.500	0.337	0.1	2767	3000#	1796	2000#
	120	4.500	0.438	0.1	3653	(Note 2)	2649	2000#
	160	4.500	0.531	0.1	4506	(Note 3)	3470	3000#
	XXS	4.500	0.674	0.1	5859	(Note 3)	4771	6000#

Verify the correct version before use by checking the LMS Web site.

					WELDED (Note 1)		THREADED (Note 1)	
Nominal Pipe Size	Wall Schedule	Outside Diameter	Nominal Wall Thickness	Max. Thread Depth	Allowable Pressure (PSIG)	SW Fitting Pound Class	Allowable Pressure (PSIG)	Thr. Fitting Pound Class
5	5	5.563	0.109		693	(Note 3)		(Note 4)
	10	5.563	0.134		856	(Note 3)		(Note 4)
	40	5.563	0.258		1680	(Note 3)		(Note 4)
	STD	5.563	0.258		1680	(Note 3)		(Note 4)
	80	5.563	0.375		2475	(Note 3)		(Note 4)
	XS	5.563	0.375		2475	(Note 3)		(Note 4)
	120	5.563	0.500		3361	(Note 3)		(Note 4)
	160	5.563	0.625		4269	(Note 3)		(Note 4)
	XXS	5.563	0.750		5208	(Note 3)		(Note 4)
6	5	6.625	0.109		580	(Note 3)		(Note 4)
	10	6.625	0.134		717	(Note 3)		(Note 4)
	40	6.625	0.280		1524	(Note 3)		(Note 4)
	STD	6.625	0.280		1524	(Note 3)		(Note 4)
	80	6.625	0.432		2391	(Note 3)		(Note 4)
	XS	6.625	0.432		2391	(Note 3)		(Note 4)
	120	6.625	0.562		3158	(Note 3)		(Note 4)
	160	6.625	0.719		4110	(Note 3)		(Note 4)
	XXS	6.625	0.864		5023	(Note 3)		(Note 4)
8	5	8.625	0.109		444	(Note 3)		(Note 4)
	10	8.625	0.148		610	(Note 3)		(Note 4)
	20	8.625	0.250		1037	(Note 3)		(Note 4)
	30	8.625	0.277		1148	(Note 3)		(Note 4)
	40	8.625	0.322		1343	(Note 3)		(Note 4)
	STD	8.625	0.322		1343	(Note 3)		(Note 4)
	60	8.625	0.406		1702	(Note 3)		(Note 4)
	80	8.625	0.50		2117	(Note 3)		(Note 4)
	XS	8.625	0.50		2117	(Note 3)		(Note 4)
	100	8.625	0.594		2534	(Note 3)		(Note 4)
	120	8.625	0.719		3098	(Note 3)		(Note 4)
	140	8.625	0.812		3530	(Note 3)		(Note 4)
	XXS	8.625	0.875		3824	(Note 3)		(Note 4)
	160	8.625	0.906		3970	(Note 3)		(Note 4)
10	5	10.750	0.134		439	(Note 3)		(Note 4)
	10	10.750	0.165		542	(Note 3)		(Note 4)
	20	10.750	0.250		828	(Note 3)		(Note 4)
	30	10.750	0.307		1021	(Note 3)		(Note 4)
	40	10.750	0.365		1216	(Note 3)		(Note 4)
10	STD	10.750	0.365		1216	(Note 3)		(Note 4)

Verify the correct version before use by checking the LMS Web site.

					WELDED (Note 1)		THREADED (Note 1)	
Nominal Pipe Size	Wall Schedule	Outside Diameter	Nominal Wall Thickness	Max. Thread Depth	Allowable Pressure (PSIG)	SW Fitting Pound Class	Allowable Pressure (PSIG)	Thr. Fitting Pound Class
	60	10.750	0.50		1685	(Note 3)		(Note 4)
	XS	10.75	0.50		1685	(Note 3)		(Note 4)
	80	10.75	0.594		2013	(Note 3)		(Note 4)
	100	10.75	0.719		2455	(Note 3)		(Note 4)
	120	10.75	0.844		2906	(Note 3)		(Note 4)
	140	10.75	1.000		3483	(Note 3)		(Note 4)
	160	10.75	1.125		3951	(Note 3)		(Note 4)
	5	12.75	0.156		434	(Note 3)		(Note 4)
	10	12.75	0.180		501	(Note 3)		(Note 4)
	20	12.75	0.250		697	(Note 3)		(Note 4)
	30	12.75	0.330		923	(Note 3)		(Note 4)
	STD	12.75	0.375		1051	(Note 3)		(Note 4)
	40	12.75	0.406		1139	(Note 3)		(Note 4)
	XS	12.75	0.500		1413	(Note 3)		(Note 4)
12	60	12.75	0.562		1593	(Note 3)		(Note 4)
	80	12.75	0.688		1963	(Note 3)		(Note 4)
	100	12.75	0.844		2428	(Note 3)		(Note 4)
	120	12.75	1.000		2905	(Note 3)		(Note 4)
	XXS	12.75	1.000		2905	(Note 3)		(Note 4)
	140	12.75	1.125		3290	(Note 3)		(Note 4)
	160	12.75	1.312		3881	(Note 3)		(Note 4)
	5	14	0.156		395	(Note 3)		(Note 4)
	10	14	0.250		634	(Note 3)		(Note 4)
	20	14	0.312		792	(Note 3)		(Note 4)
	30	14	0.375		955	(Note 3)		(Note 4)
	STD	14	0.375		955	(Note 3)		(Note 4)
14	40	14	0.438		1119	(Note 3)		(Note 4)
	XS	14	0.500		1284	(Note 3)		(Note 4)
	60	14	0.594		1531	(Note 3)		(Note 4)
	80	14	0.750		1947	(Note 3)		(Note 4)
	100	14	0.938		2461	(Note 3)		(Note 4)
	120	14	1.094		2892	(Note 3)		(Note 4)
	140	14	1.250		3334	(Note 3)		(Note 4)
	160	14	1.406		3780	(Note 3)		(Note 4)
16	5	16	0.165		363	(Note 3)		(Note 4)
	10	16	0.250		554	(Note 3)		(Note 4)
	20	16	0.312		692	(Note 3)		(Note 4)
16	30	16	0.375		834	(Note 3)		(Note 4)
	STD	16	0.375		834	(Note 3)		(Note 4)

Verify the correct version before use by checking the LMS Web site.

					WELDED (Note 1)		THREADED (Note 1)	
Nominal Pipe Size	Wall Schedule	Outside Diameter	Nominal Wall Thickness	Max. Thread Depth	Allowable Pressure (PSIG)	SW Fitting Pound Class	Allowable Pressure (PSIG)	Thr. Fitting Pound Class
	40	16	0.500		1120	(Note 3)		(Note 4)
	XS	16	0.500		1120	(Note 3)		(Note 4)
	60	16	0.656		1477	(Note 3)		(Note 4)
	80	16	0.844		1916	(Note 3)		(Note 4)
	100	16	1.031		2362	(Note 3)		(Note 4)
	120	16	1.219		2818	(Note 3)		(Note 4)
	140	16	1.438		3356	(Note 3)		(Note 4)
	160	16	1.594		3749	(Note 3)		(Note 4)
18	5	18	0.165		322	(Note 3)		(Note 4)
	10	18	0.250		491	(Note 3)		(Note 4)
	20	18	0.312		614	(Note 3)		(Note 4)
	STD	18	0.375		740	(Note 3)		(Note 4)
	30	18	0.438		866	(Note 3)		(Note 4)
	XS	18	0.500		993	(Note 3)		(Note 4)
	40	18	0.562		1118	(Note 3)		(Note 4)
	60	18	0.750		1502	(Note 3)		(Note 4)
	80	18	0.938		1894	(Note 3)		(Note 4)
	100	18	1.156		2352	(Note 3)		(Note 4)
	120	18	1.375		2824	(Note 3)		(Note 4)
	160	18	1.781		3720	(Note 3)		(Note 4)
20	5	20	0.188		332	(Note 3)		(Note 4)
	10	20	0.250		442	(Note 3)		(Note 4)
	20	20	0.375		665	(Note 3)		(Note 4)
	STD	20	0.375		665	(Note 3)		(Note 4)
	30	20	0.500		892	(Note 3)		(Note 4)
	XS	20	0.500		892	(Note 3)		(Note 4)
	40	20	0.594		1062	(Note 3)		(Note 4)
	60	20	0.812		1464	(Note 3)		(Note 4)
	80	20	1.031		1872	(Note 3)		(Note 4)
	100	20	1.281		2347	(Note 3)		(Note 4)
	120	20	1.500		2772	(Note 3)		(Note 4)
	140	20	1.750		3262	(Note 3)		(Note 4)
	160	20	1.969		3701	(Note 3)		(Note 4)
22	5	22	0.188		302	(Note 3)		(Note 4)
	10	22	0.250		401	(Note 3)		(Note 4)
	20	22	0.375		604	(Note 3)		(Note 4)
	STD	22	0.375		604	(Note 3)		(Note 4)
	30	22	0.500		809	(Note 3)		(Note 4)
	XS	22	0.500		809	(Note 3)		(Note 4)

Verify the correct version before use by checking the LMS Web site.

					WELDED (Note 1)		THREADED (Note 1)	
Nominal Pipe Size	Wall Schedule	Outside Diameter	Nominal Wall Thickness	Max. Thread Depth	Allowable Pressure (PSIG)	SW Fitting Pound Class	Allowable Pressure (PSIG)	Thr. Fitting Pound Class
	60	22	0.875		1433	(Note 3)		(Note 4)
	80	22	1.125		1855	(Note 3)		(Note 4)
	100	22	1.375		2287	(Note 3)		(Note 4)
	120	22	1.625		2726	(Note 3)		(Note 4)
	140	22	1.875		3173	(Note 3)		(Note 4)
	160	22	2.125		3625	(Note 3)		(Note 4)
24	5	24	0.218		320	(Note 3)		(Note 4)
	10	24	0.250		368	(Note 3)		(Note 4)
	20	24	0.375		553	(Note 3)		(Note 4)
	STD	24	0.375		553	(Note 3)		(Note 4)
	XS	24	0.500		741	(Note 3)		(Note 4)
	30	24	0.562		834	(Note 3)		(Note 4)
	40	24	0.688		1024	(Note 3)		(Note 4)
	60	24	0.969		1454	(Note 3)		(Note 4)
	80	24	1.219		1844	(Note 3)		(Note 4)
	100	24	1.531		2338	(Note 3)		(Note 4)
	120	24	1.812		2791	(Note 3)		(Note 4)
	140	24	2.062		3199	(Note 3)		(Note 4)
	160	24	2.344		3669	(Note 3)		(Note 4)

Notes for Piping Pressure Rating Table:

(1) Pressure rating is shaded for thick walled pipe (t > OD / 6). The allowable pressure is based on the Von Mises-Hencky failure criterion instead of the standard ASME code equation. See paragraph 304.1.2(b) in ASME B31.3 for additional requirements.

(2) ANSI B16.11 socket welding fittings not available in sizes over NPS 2, except for 3000# class which is available up to size NPS 4.

(3) ANSI B16.11 threaded fittings not available in sizes over NPS 4.

(4) See recommended practice for threaded pipe and fittings in Appendix C, paragraph C-12.

(5) Corrosion allowance used in pressure rating calculation is C_A = 0.000 inch.

(6) Pipe schedules 5 and 10 do not allow threading per ASME B1.20.1.

(7) Pressure rating for piping made of materials with an allowable stress S_b different from the one used in the table above (S_a = 20,000 psig) can be calculated by multiplying the pressure rating listed in the table by the ratio of allowable stresses, S_b/S_a.

Verify the correct version before use by checking the LMS Web site.

APPENDIX E. PRESSURE RATING OF METALLIC SEAMLESS TUBING

In accordance with ASME B31.3 – 2014 Edition

This table is valid for seamless piping with allowable stress value SE=20,000 psi at design temperature. Example materials include ASTM A-269 Grades TP304, TP316, and TP347.

Tubing Size	Outside Diameter	Nominal Wall Thickness	Minimum Wall Thickness	Maximum Wall Thickness	Minimum Inside Diameter	Maximum Inside Diameter	Allowable Working Pressure (psig) (Notes 2, 4, 5, 6)
1/8	0.125	0.010	0.009	0.011	0.103	0.107	3,056
		0.020	0.018	0.022	0.081	0.089	6,510
		0.028	0.025	0.031	0.063	0.075	7,345
		0.035	0.032	0.039	0.047	0.061	8,751
3/16	0.188	0.020	0.018	0.022	0.144	0.152	4,147
		0.028	0.025	0.031	0.126	0.138	5,952
		0.035	0.032	0.039	0.110	0.124	6,523
1/4	0.250	0.020	0.018	0.022	0.206	0.214	3,056
		0.028	0.025	0.031	0.188	0.200	4,348
		0.035	0.032	0.039	0.172	0.186	5,704
		0.049	0.044	0.054	0.142	0.162	6,698
		0.065	0.059	0.072	0.106	0.132	8,327
5/16	0.313	0.020	0.018	0.022	0.269	0.277	2,411
		0.028	0.025	0.031	0.251	0.263	3,413
		0.035	0.032	0.039	0.235	0.249	4,454
		0.049	0.044	0.054	0.205	0.225	6,335
		0.065	0.059	0.072	0.169	0.195	7,047
3/8	0.375	0.020	0.018	0.022	0.331	0.339	1,997
		0.028	0.025	0.031	0.313	0.325	2,817
		0.035	0.032	0.039	0.297	0.311	3,663
		0.049	0.044	0.054	0.267	0.287	5,180
		0.065	0.059	0.072	0.231	0.257	7,200
1/2	0.500	0.028	0.025	0.031	0.438	0.450	2,083
		0.035	0.032	0.039	0.422	0.436	2,698
		0.049	0.044	0.054	0.392	0.412	3,787
		0.065	0.059	0.072	0.356	0.382	5,212

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Tubing Size	Outside Diameter	Nominal Wall Thickness	Minimum Wall Thickness	Maximum Wall Thickness	Minimum Inside Diameter	Maximum Inside Diameter	Allowable Working Pressure (psig) (Notes 2, 4, 5, 6)
		0.083	0.075	0.091	0.318	0.350	6,818
5/8	0.625	0.035	0.032	0.039	0.547	0.561	2,135
		0.049	0.044	0.054	0.517	0.537	2,984
		0.065	0.059	0.072	0.481	0.507	4,084
		0.083	0.075	0.091	0.443	0.475	5,310
3/4	0.750	0.035	0.032	0.039	0.672	0.686	1,767
		0.049	0.044	0.054	0.642	0.662	2,462
		0.065	0.059	0.072	0.606	0.632	3,358
		0.083	0.075	0.091	0.568	0.600	4,348
		0.095	0.086	0.105	0.540	0.578	5,050
		0.109	0.098	0.120	0.510	0.554	5,837
7/8	0.875	0.035	0.032	0.039	0.797	0.811	1,507
		0.049	0.044	0.054	0.767	0.787	2,096
		0.065	0.059	0.072	0.731	0.757	2,851
		0.083	0.075	0.091	0.693	0.725	3,681
		0.095	0.086	0.105	0.665	0.703	4,267
		0.109	0.098	0.120	0.635	0.679	4,921
1	1.000	0.035	0.032	0.039	0.922	0.936	1,314
		0.049	0.044	0.054	0.892	0.912	1,824
		0.065	0.059	0.072	0.856	0.882	2,477
		0.083	0.075	0.091	0.818	0.850	3,191
		0.095	0.086	0.105	0.790	0.828	3,694
		0.109	0.098	0.120	0.760	0.804	4,253
		0.120	0.108	0.132	0.736	0.784	4,729
1 1/4	1.250	0.049	0.044	0.054	1.142	1.162	1,449
		0.065	0.059	0.072	1.106	1.132	1,962
		0.083	0.075	0.091	1.068	1.100	2,521
		0.095	0.086	0.105	1.040	1.078	2,912
		0.109	0.098	0.120	1.010	1.054	3,346
		0.120	0.108	0.132	0.986	1.034	3,713
1 1/2	1.500	0.049	0.044	0.054	1.392	1.412	1,202
		0.065	0.059	0.072	1.356	1.382	1,624

Verify the correct version before use by checking the LMS Web site.

Tubing Size	Outside Diameter	Nominal Wall Thickness	Minimum Wall Thickness	Maximum Wall Thickness	Minimum Inside Diameter	Maximum Inside Diameter	Allowable Working Pressure (psig) (Notes 2, 4, 5, 6)
		0.083	0.075	0.091	1.318	1.350	2,083
		0.095	0.086	0.105	1.290	1.328	2,404
		0.109	0.098	0.120	1.260	1.304	2,757
		0.120	0.108	0.132	1.236	1.284	3,056
2	2.000	0.065	0.059	0.072	1.856	1.882	1,209
		0.083	0.075	0.091	1.818	1.850	1,546
		0.095	0.086	0.105	1.790	1.828	1,781
		0.109	0.098	0.120	1.760	1.804	2,040
		0.120	0.108	0.132	1.736	1.784	2,258
		0.134	0.121	0.147	1.706	1.758	2,543

Notes for Tubing Pressure Rating Table:

(1) Pressure ratings are based on ASME B31.3 Process Piping Code, 2002 Edition.

(2) Pressure rating is shaded for thick walled tubing (t > OD / 6). The allowable pressure is based on the Von Mises-Hencky failure criterion instead of the standard ASME code equation. See paragraph 304.1.2(b) in ASME B31.3 for additional requirements.

(3) Corrosion allowance used in calculating pressure ratings in this table is C_A = 0.000 inch.

(4) Pressure rating for soft copper tubing conforming to ASTM B280 (060 temper) or ASTM B88 (050 and 060 tempers) is 30% of the corresponding allowable working pressures listed in the table above.

(5) Pressure rating for non-brazed hard copper tubing conforming to ASTM B88 (H temper) is 60% of the corresponding allowable working pressures listed in the table above. Pressure rating for brazed hard copper tubing conforming to ASTM B88 is 30% of the corresponding allowable working pressures listed in the table above.

(6) Pressure rating for carbon steel tubing conforming to SAE 1025 (AMS 5075) is 84% of the corresponding allowable working pressures listed in the table above.

Verify the correct version before use by checking the LMS Web site.

Appendix F. Recommended Practice for the Establishment of Hazard Perimeters for Pneumatic Testing

F.1 General

F.1.1 The consequences of the sudden failure of a compressed gas system include the release of shock waves and the expulsion of debris. The destructive potential of these failures can be estimated using the TNT-equivalency technique that was developed by the Naval Ordnance Laboratory and documented in the technical report NOLTR 70-208 “Failure-Damage Assessment Technique for High-Pressure Gas Containment Vessels”, by V. C. D. Dawson and A. E. Seigel (1970).

F.1.2 The procedure delineated below is recommended for establishing personnel exclusion perimeters associated with pneumatic testing of pressure systems. The calculated exclusion perimeter is not intended as a means of determining how close personnel can work next to an active pressure system during normal operation.

F.1.3 The general procedure includes the following steps:

a. Establish the water volume of the vessel or piping system (**V**, cubic feet). For piping systems, use the volume of the longest run of pipe in the system with the largest diameter between mechanical discontinuities (welded joints, threaded fittings, flanges, or other structural item capable of arresting a moving crack front.)

b. Determine the system’s maximum operating pressure (**P**, pounds per square feet absolute) and temperature (**T**, degrees Rankine)

c. Calculate or look up the standard atmospheric pressure ($\mathbf{P_{atm}}$, pounds per square feet absolute)

d. Look up the specific heat ratio of the test gas ($\boldsymbol{\gamma}$, adimensional, e.g., 1.4 for air, 1.3 for nitrogen)

e. Calculate the potential energy contained in the pressurized gas by using the formula (result is in units of ft-lb_f)

$$E = \frac{PV}{\gamma - 1}\left[1 - \left(\frac{P}{P_{atm}}\right)^{\frac{1-\gamma}{\gamma}}\right]$$

f. Convert the potential energy calculated previously (units of ft- lb_f) to an equivalent mass of TNT (units of lb_m) by using the equation

$$m = \frac{E}{1{,}424{,}033}$$

g. Calculate radii of the different overpressure zones using Table F-1 and the following formula

$$R = \lambda \cdot m^{1/3}$$

Verify the correct version before use by checking the LMS Web site.

Table F-1 Effects of Blast Overpressure

Zone	ΔP, psid	λ, ft/(lb$^{1/3}$)	Comment
1	< 0.2	147.8	Safe distance for all personnel. During system pressure testing, a personnel exclusion perimeter should be normally set at this distance.
2	0.5 – 1.0	76.7 – 45.8	Slight damage may occur; glass may shatter. The exclusion perimeter may be set in this range with approval from the SPE for Pressure Systems.
3	1.0 – 5.0	45.8 – 14.7	Moderate damage to wood frame structures may occur. Corrugated asbestos siding may shatter. Corrugated steel or aluminum paneling may buckle.
4	5.0	14.7	Eardrums may rupture.
5	7.0 – 8.0	12.1 – 11.2	Non-reinforced brick walls 8" to 12" thick may shear and fail.
6	10.0	10	Lung damage may occur.

When conducting pneumatic tests above the design pressure or MAWP of a pressure system, all personnel shall be excluded from the perimeter calculated per this procedure, with the exception of the minimum number of personnel required to properly conduct the test. All personnel shall wear appropriate Personal Protective Equipment (PPE) while inside the exclusion perimeter. All personnel shall move outside of the exclusion perimeter during pressure holding times.

Example calculation:

A compressed air piping system consists of mainly 3" schedule 160 piping, operating at 4500 psig. The longest run of piping between two discontinuities is 20 feet.

$$V = \frac{\pi}{4} \cdot \left[\frac{2.624}{12}\right]^2 \cdot (20)$$ → 2.624" is nominal inside diameter of pipe

$$V = 0.751 \cdot ft^3$$ *(cubic feet)*

$$P = (4500 + 15) \cdot (144) = 650{,}160 \cdot psfa$$ *(pounds per square foot, absolute)*

Verify the correct version before use by checking the LMS Web site.

$$P_{atm} = 15 \cdot 144 = 2160 \cdot psfa$$

$$T = 520 \cdot Rankine$$

$$\gamma = 1.4$$

$$E = \frac{(650160)(0.751)}{(1.4-1)}\left[1 - \left(\frac{650160}{2160}\right)^{\frac{(1-1.4)}{1.4}}\right] \qquad E \cong 982{,}000 \cdot lb_f \cdot ft$$

$$\therefore \quad m = \frac{982000}{1424033} = 0.69 \cdot lb_m \qquad \textit{(pounds of mass)}$$

Then, the distance from the center to the 0.2 psid perimeter (Zone 1) is

$$R = \lambda \cdot m^{1/3} = 147.8 \cdot (0.69)^{1/3} = 131 feet$$

Similarly, the range of distances defining each zone can be calculated.

Verify the correct version before use by checking the LMS Web site.