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RECORD OF REVISIONS

Rev.	Date	Description	POC	RM
0	9/22/2023	Initial issue as section PS-GENERAL, essentially replacing previous Section GEN R0.1 and with similar attachments.	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards point of contact (POC) for upkeep, interpretation, and variance issues.

Chapter 17	**Pressure Safety POC**

This document is online at https://engstandards.lanl.gov

ESM Usage

(Requirement 17-0XYZ): Where this phrase appears it is a LANL-internal reference in a basis file that captures and categorizes ESM drivers—and is not relevant to most users.

Italics use: Where appropriate throughout the ESM, guidance is provided to aid in the implementation of requirements. Guidance will be *italicized* text and/or otherwise clearly indicated (e.g., by headings). Document titles in italics is normally simply a formatting style. Likewise, words and short phrases in italics and/or capitalized indicates them as a defined term (defined either in this document, the CoE Glossary (future), or the ESM chapter in which it appears).

1.0 INTRODUCTION AND APPLICABILITY

A. The primary goal of the LANL Pressure Safety Program is to protect worker safety and health while working on or around pressure systems. Engineering Standards Manual (ESM) Chapter 17, *Pressure Safety*, establishes the design, fabrication, assembly, testing, inspection, and examination requirements of new pressure systems and modification of existing pressure systems for use by Los Alamos National Laboratory (LANL) personnel at any location.

B. ESM Chapter 17 is governed by P101-34, *Pressure Safety*, which establishes LANL's overall pressure safety program requirements. ESM Ch. 17 establishes requirements to ensure that new or modified pressure systems are designed, fabricated, tested, examined, and inspected by trained and qualified personnel in accordance with applicable and sound engineering principles as required by 10 CFR 851.23, *Safety and Health Standards,* and 10 CFR 851 Appendix A, Part 4, *Pressure Safety*. 10 CFR 851 is contractually required by the U.S. Department of Energy (DOE) and is implemented at LANL in PD100 - *DOE/NNSA Approved Los Alamos National Laboratory 10 CFR 851 Worker Safety and Health Program Description*.

C. Definitions and acronyms used throughout the chapter are defined in Attachment GEN-1, *Definitions and Acronyms*.

D. Per P101-34, *Pressure Safety*, all new or modified pressure and vacuum systems are subject to the requirements of this chapter (except for those excluded from the Lab's P101-34 pressure safety program). The following is from Section 1.2 of P101-34:

> *"Pressure systems means all pressure vessels, and pressure sources including cryogenics, pneumatic, hydraulic, and vacuum. Vacuum systems should be considered pressure systems due to their potential for catastrophic failure due to backfill pressurization. Associated hardware (e.g., gauges and regulators), fittings, piping, pumps, and pressure relief devices are also integral parts of the pressure system."*

E. ESM Chapter 17 is divided into three sections:

PS-GENERAL	General Information (this document)
PS-REQUIREMENTS	Pressure Safety Requirements for New and Modified System Design
PS-GUIDE	Pressure System Design Guidance

2.0 NATIONAL BOARD INSPECTION CODE (NBIC)

(Requirement 17-0100)

A. National Board Inspection Code (NBIC) NB-23 Parts 1 through 4 are required for boilers and pressure vessels. Attachment GEN-2 provides a summary of the scopes of each part and discussion on how the mandates are applied at LANL.

1. Part 1, Installation
2. Part 2, Inspection
3. Part 3, Repairs and Alterations

4. Part 4, Pressure Relief Devices

Guidance: Reference the [LANL Pressure Safety Program Quality Control Systems Manual (QCSM) website] for information on LANL's R Stamp and Federal Inspection Agency Programs:

5. PS-GEN-NBIC-RSP – *Quality Control Systems Manual (R Stamp Program)*

6. PS-GEN-NBIC-FIA – *Quality Control Systems Manual (Federal Inspection Agency)*

3.0 ALTERNATE METHOD/VARIANCE OR CLARIFICATION/INTERPRETATION

A. All variance and alternate method requests must be submitted to ESM Chapter 17 POC for processing. Approval is requested per LANL ESM, Chapter 1, Section Z10 using LANL Form 2137, *Conduct of Engineering Request for Variance or Alternate Method*. If approved by the Chapter 17 POC, [the chief pressure safety officer (CPSO) or deputy chief pressure safety officer (DCPSO) if the CPSO is unavailable] will sign or return with explanation. Conflicts that arise between the Chapter 17 POC and a variance/alternate method requestor will be resolved by the Pressure Safety Committee (PSC).

B. An official clarification or interpretation approval is requested per the LANL ESM, Chapter 1, Section Z10 using LANL Form 2176*, Conduct of Engineering Formal Clarification or Interpretation Request*. A clarification or interpretation only requires the approval of the Chapter 17 POC.

C. An informal clarification or interpretation may be processed by the ESM Chapter 17 POC for ESM Chapter 17 as allowed by ESM, Chapter 1, Section Z10.

D. Approval of a variance or alternate method can occur under the following circumstances:

1. To permit continued operation prior to correction of deficiencies, or

2. To permit a long-term operation with a condition that deviates from this ESM chapter.

E. Variances that violate code are not allowed for new American Society of Mechanical Engineers (ASME) code (B31 or Boiler and Pressure Vessel Code) Design Basis pressure systems.

F. Approval of an alternate method must be based on establishing a level of worker safety consistent with the requirements of 10 CFR 851.

G. Variance and alternate method approvals must be documented and maintained with the pressure system documentation package.

H. The CPSO and the site chief engineer must approve the alternate method (with duration, if applicable) before proceeding.

I. Other concurrence reviews may be required, e.g., policies outside of engineering, project manager, facility operations director (FOD), or associate lab director (ALD).

J. The master list of approved variances and alternate methods is maintained on the Conduct of Engineering website. Additionally, an unofficial list of approved ESM Ch 17 variances, alternate methods, clarifications, and interpretations is normally maintained on the Pressure Safety Program website.

K. Variances and alternate methods cannot conflict with Safety Basis requirements. Those that affect Vital Safety Systems must meet the requirements of ESM Chapter 1 Z10, or successor document.

L. Extensions of existing alternate methods/variances shall be processed as a revision to the original request and must include proper justification, compensatory methods, and a new end date.

M. NNSA Field Office will be copied on all LANL approved variances and alternate methods associated with FS1, safety class, or safety significant pressure systems.

4.0 TRAINING AND QUALIFICATIONS; ROLES AND RESPONSIBILITIES

A. Introduction

1. The following training and qualifications/roles and responsibilities are solely within the scope of ESM Chapter 17. Some shown below may have additional roles in other LANL documents e.g., P101-34, *Pressure Safety*.

B. ASME Owner

1. The ASME Owner is the DOE Los Alamos Site Office.

2. The responsibilities of the ASME Owner have been delegated by DOE to LANL. Ref. ESM Chapter 1, Section Z10.

3. The LANL Owner has further delegated the role of day-to-day operations to the chief pressure safety officer, which includes approval of ASME unlisted components.

4. The LANL Owner shall designate the Owner's Inspector. Click for the LANL Owner's Inspector database.

C. ASME Pressure System Designer (aka Designer, sometimes called the Engineer in the ASME Code) *(Requirement 17-0101):*

1. Shall be qualified in accordance with the ASME code of record (COR).

2. Shall be familiar with the ASME COR.

3. Is responsible for the design of pressure systems for the applicable ASME COR.

4. Is responsible for generating system calculations, sketches, drawings, piping and instrumentation diagrams, specifications, and/or isometrics to meet the Design Criteria. Examples include, but are not limited to, overpressure protection calculations (e.g., relief device sizing), flexibility analysis, wall thickness, static loads, dynamic loads, piping supports, and anchors.

   NOTE: Additional calculations may be required to ensure the design meets all applicable design requirements, including those outside the scope of ESM Ch. 17. Examples include, but are not limited to sizing, flow, pressure drop calculations of a process flow or a building compressed air system, a refrigeration system heat load design, a hydronic thermal calculation, or specialized evaluations for instrumentation, experimental systems, or R&D systems.

5. Is responsible for defining any additional Design Criteria if necessary to ensure a safe pressure system for the proposed installation in addition to the Design Basis. Examples include, but are not limited to, specification of additional nondestructive examination (NDE) and pass/fail criteria, evaluating and specifying materials of construction to ensure system integrity, and specifying necessary construction techniques for radioactive material handling service. Designs or practices known to be unsafe are prohibited.

D. ASME Examiners *(Requirement 17-0102)*

1. Shall be qualified for NDE as required by the ASME COR.
2. Shall perform examinations of pressure system construction as defined by the ASME COR and as defined by the Engineering design.
3. Will provide records of examinations and tests to the Owner's Inspector or Owner's Inspector delegate.
4. Will work with the Owner's Inspector or the Owner's Inspector delegate to have access to and observe any examinations and testing being performed on pressure systems.

E. ASME Owner's Inspector *(Requirement 17-0103)*

1. Owner's Inspector shall be qualified per the ASME COR.
2. The Owner's Inspector shall designate the Owner's Inspector delegate.
3. Owner's Inspector or delegate shall have access to any and all design, fabrication, manufacture, fabrication, heat treatment, assembly, erection, examination, testing, records, documentation or other project information or activities to verify that all required examinations and testing have been completed and to inspect the piping to the extent necessary to be satisfied that it conforms to all applicable examination requirements of the ASME Code and of the engineering design and to perform the role defined in the COR.
4. Owner's Inspector is the final authority on acceptance of the project examination or test.
5. Owner's Inspector is responsible for determining that a person to whom an inspection function is delegated is qualified to perform that function.

F. ASME Owner's Inspector Delegate *(Requirement 17-0104)*

1. Perform Owner's Inspector delegate duties as assigned by the LANL Owner's Inspector.
2. The Owner's Inspector delegate shall be trained and qualified as required by the Owner's Inspector.

G. Pressure Safety Officer *(Requirement 17-0105)*

1. The pressure safety officer (PSO) may be responsible for review of system designs for compliance to the applicable design basis.

NOTE: The use of PSO here includes all PSO Duty Areas, DCPSOs, and the CPSO.

2. The PSO may act as a subject matter expert (SME) within their qualification limit.
3. PSOs shall be qualified per ESD-QS-001, *Qualification Standard for Pressure Safety Personnel*, or successor document.
4. Aids pressure system representative (PSR) in compliance with the ESM, Chapter 17, *Pressure Safety*, and the use of the ASME Codes.
5. May serve as a SME for review of integrated work documents (IWDs)/work control documents (WCDs) involving pressure systems within their qualification.

6. May serve as an SME for hazards analysis of work per P300, *Integrated Work Management*, and P300-1, *Integrated Work Management for R&D*, (and SD601, *Conduct of Research and Development*).

7. Reviews pressure or leak test plan as part of system design review.

8. Reviews pressure safety calculations as part of design review.

H. Peer Reviewer *(Requirement 17-0106)*

1. A trained peer reviewer may be responsible for Design Review of FS-3 and FS3-ULH programmatic (non-Safety Basis) system designs for compliance to the applicable Design Basis.

2. Peer reviewers shall be trained per Pressure Safety Peer Review Curricula 13046.

I. Pressure System Designer (aka Designer) *(Requirement 17-0107)*

1. Shall be qualified in accordance with the Design Basis, as applicable.

2. Shall be familiar with the Design Basis.

3. Is responsible for the design of pressure systems to meet the applicable Design Basis.

4. Is responsible for generating system calculations, sketches, drawings, piping and instrumentation diagrams, specifications, and/or isometrics to meet the Design Criteria. Examples include, but are not limited to, overpressure protection calculations (e.g., relief device sizing), flexibility analysis, wall thickness, static loads, dynamic loads, piping supports, and anchors.

NOTE: Additional calculations may be required to ensure the design meets all applicable design requirements, including those outside the scope of ESM Ch. 17. Examples include, but are not limited to sizing, flow, pressure drop calculations of a process flow or a building compressed air system, a refrigeration system heat load design, a hydronic thermal calculation, or specialized evaluations for instrumentation, experimental systems, or R&D systems.

5.0 ATTACHMENTS

GEN-1 – *Definitions and Acronyms*

GEN-2 – *National Board Inspection Code NB-23 Application*

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Rev	Date	Description	POC	RM
0	9/17/2014	Initial issue as GEN-1. Formerly Subsection 5.0 of Section I of chapter.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
1	3/15/2016	Removed reference to ML-1/2 for NCRs.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
2	9/22/2023	Fully revised and renumbered (formerly known as Section GEN General Requirements, Attachment GEN-1 – Definitions and Acronyms).	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards point of contact (POC) for upkeep, interpretation, and variance issues.

Chapter 17	**Pressure Safety POC**

This document is online at https://engstandards.lanl.gov

DEFINITIONS

Alteration – The change of a pressure boundary that changes the original design structure. Does not include the removal and replacement of components, but modification of the component itself (e.g., welding an additional port to a U-stamped vessel).

ASME B31 – American Society of Mechanical Engineers Piping Codes.

ASME BPVC – American Society of Mechanical Engineers Boiler and Pressure Vessel Code.

Authorized Inspector (AI) – An inspector regularly employed by an ASME accredited Authorized Inspection Agency in accordance with the requirements in the latest edition of ASME QAI-1, *Qualifications for Authorized Inspection*.

Boiler – A closed vessel in which water or other liquid is heated, steam or vapor is generated, steam or vapor is superheated, or any combination thereof, under pressure or vacuum for use external to itself, by the direct application of heat from the combustion of fuels or from electricity.

Check Valve – A poppet or swing disk (may or may not be spring loaded) valve that has one-way flow direction to keep system contents from back flowing.

Chief Pressure Safety Officer (CPSO) – Point of contact (POC) for this chapter. Is a subject matter expert (SME) in pressure systems design, will assist Designers with applicable codes for pressure system design. Reviews and approves variances and alternate methods related to ESM Chapter 17. May delegate certain functions to deputy chief pressure safety officers or pressure safety officers (PSOs).

Code Equivalent – A pressure vessel or other component that, through documentation, proves that the design meets all the design, fabrication, test, and inspection requirements established by the applicable code, but does not have a code stamp and does not require a code certified Inspector.

Code of Record (COR) – The codes and standards (by year) used to perform the design and construction are considered the code of record. (See Engineering Standards Manual (ESM) Chapter 1 Section Z10 - General Requirements for all Disciplines/Chapters.)

Components – The set of items within a piping system that are joined together to make up a functioning process. Piping components are a sub-set of all components in a piping system. See definition of piping components below for those components which are within the scope of the B31 pressure piping codes.

Cryogenic – A liquid with a normal (i.e., at standard temperature and pressure) boiling point below approximately 120 K (–238°F, –150°C) that can be used as a working fluid in mechanical refrigerators or as a cooling bath in cryostats. Other fluids (e.g., CO2, refrigerants, etc.) also known as pseudo-cryogenic liquids that are not cryogenic must be taken into consideration as having similar pressure hazards as that of cryogenics.

Deputy Chief Pressure Safety Officer (DCPSO) – qualified in accordance with ESD-QS-001 (or successor). Delegated duties of the CPSO for specific locations by the CPSO.

Design – The total documentation package created to satisfy the Design Criteria and meet the Design Basis.

Design Basis – The codes, standards and/or equivalent safety evaluations that ensure that new or modified pressure systems are designed, fabricated, tested, and inspected by trained and qualified personnel in accordance with applicable and sound engineering principle*s* that will protect workers.

Design Criteria – The set of minimum requirements that bound the design of systems, structures, and components. Design Criteria is most often identified in a Scope of Work, Requirements and Criteria Document, or similar.

Design Review – Verification by a qualified or trained reviewer (i.e., pressure safety subject matter expert) that the design meets the Design Basis and Design Criteria associated with pressure safety scope.

Pressure System Designer (aka Designer) – The personnel or organization in responsible charge of the engineering design.

ASME Pressure System Designer – The personnel or organization qualified as required by the ASME Code of Record (COR) that is in responsible charge of the engineering design. This is sometimes referred to as the Engineer in the ASME piping codes or the User or Designated Agent in ASME BPVC Section VIII Division 1 (see Nonmandatory Appendix NN, Guidance to The Responsibilities of the User and Designated Agent).

Design Pressure – The pressure at the most severe condition of coincident internal or external pressure and temperature (minimum or maximum) expected during service (see Design temperature).

Design Temperature – The temperature at which, under the coincident pressure, the greatest thickness or highest component rating is required during the expected service (see Design pressure).

Dewar – A double-walled flask of metal or silvered glass with a vacuum between the walls, used to hold liquids at well below ambient temperature (cryogenic).

> The simplest Dewars are open-mouthed, non-pressurized, vacuum-jacketed or otherwise insulated vessel designed to hold cryogenic liquids that allow the gas to escape either through an open top or past a loose-fitting stopper to prevent the risk of explosion.

More sophisticated Dewars trap the gas above the liquid and hold it at high pressure. This increases the boiling point of the liquid, allowing it to be stored for extended periods. Excessive vapor pressure is released automatically through safety valves.

Double Block and Bleed (DBB) – The practice of shutting in a section of pipe on both sides of the valve rather than just one. Occupational Safety and Health Administration (OSHA) describes DBB as "the closure of a line, duct, or pipe by closing and locking or tagging two inline valves and by opening and locking or tagging a drain or vent valve in the line between the two closed valves."

Emergency Isolation Valve (EIV) – A valve located outside a building for a flammable gas distribution system.

Examiner – An individual with the training and experience commensurate with the needs of the specified examinations. It is the person who performs the quality control examinations and is performed by the manufacturer, fabricator, or erector.

Existing Pressure System – A pressure system with at least one year of operating history on the effective date of Rev. 10 of P101-34, *Pressure Safety*.

Facility Pressure System – Any pressure system that is owned by the facility operations directorate, or where the cost of maintenance or repair is paid for by the facility or institution, not directly by the program it supports. Normally either a utility proper or found in utility/mechanical rooms that provide building services (e.g., building heating boilers, instrument air system, etc.).

Failure Modes and Effects Analysis (FMEA) – A step-by-step approach for identifying all possible failures in a design, a manufacturing or assembly process, or a product or service. For more information see FSD-300-3-001, *Hazard Analysis Manual.* This Functional Series Document (FSD) is related to P300, *Integrated Work Management*.

Fault Condition – Any failure caused by component failure, human error, chemical reaction, or environmental conditions that may cause an increase in pressure above the maximum allowable working pressure (MAWP) of code-stamped items or the pressure rating of a component or system. Los Alamos National Laboratory (LANL) uses a single fault condition design evaluation approach unless there is a potential for Latent Failure.

Flammable Gas — A gas having a flammable range with air at 20°C (68°F) and a standard pressure of 101.3 kPa (14.7 psi). See 29CFR1910, *Occupational Safety and Health Administration*, Appendix B to 1910.1200 B.2 for additional classification criteria of flammable gases.

Flexible – Flexible refers to an element of a pressure or vacuum system, used in place of a pipe or rigid metal tubing. May also referred to as expansion joints, flexible tubing, or flex hoses.

Fluid – A substance which can be pressurized or be the pressure source in a pressure system. Pressure system fluids are most commonly gas or liquid but could also be a solid used to generate pressure via chemical reactions.

Fluid Service (FS) Categories – LANL-specific fluid service category which allows a graded approach for design review. See P101-34 Section 9.1 for detailed definitions and examples of FS1 High Hazard, FS2 Moderate Hazard, FS3 Low Hazard, and FS3-ULH Ultra-Low Hazard.

Hydrostatic Test – A test performed on a pressure system or component where a liquid (usually water) is introduced, without void space, pressurized to a designated level in a manner prescribed in the applicable code.

Hydro-Pneumatic Test – A test performed on a near liquid full pressure system where the pressure is provided by pressurized gas.

In-Service Leak Test – An ESM Chapter 17 defined test performed on a new joint (from modification or maintenance) to an existing pressure system performed after initial construction. This term is not an ASME term but is only under the jurisdiction of ESM Chapter 17.

Initial Service Test – A test at the normal operating conditions of the system.

Inspector – A qualified person who verifies all required examinations and testing have been completed and inspects to the extent necessary to be satisfied that the design of the system conforms to all applicable examination requirements of the code and of the engineering design.

Latent Failure – Less apparent failures in the design of organizational systems, the environment, or equipment that are often hidden until they contribute to the occurrence of errors or allow errors to go unrecognized until failure occurs. An example of a latent failure is a dual stage regulator. The first stage failure is not detectable, and the regulator itself must be evaluated as a single failure.

Leak Test – A pressure test which proves the integrity of a pressure boundary. Specific types of leak tests include hydrostatic leak test, hydro-pneumatic leak test, pneumatic leak test, initial service leak test, and sensitive leak test.

Lockout/Tagout (LO/TO) – (defined by P101-3) The placement of a lock and/or tag on an energy isolating device or lockout device by an authorized worker in accordance with the requirements of this procedure to ensure that the machinery, systems, and equipment being controlled cannot be operated until the lock is removed.

Lower Explosive Limit (LEL) – The lowest concentration (percentage by volume) of a gas or vapor in air capable of producing combustion in the presence of an ignition source (flame, heat, etc.). It can also be referred to as the Lower Flammability Limit (LFL).

Manufacturer's Pressure Rating – The pressure rating of a piping component published by the manufacturer. Usually includes coincident temperature ratings.

Maximum Allowable Working Pressure (MAWP) – (Defined by ASME BPVC Section VIII Division 1 Mandatory Appendix 3) The maximum gauge pressure permissible at the top of a completed vessel in its normal operating position at the designated coincident temperature for that pressure.

Maximum Operating Pressure (MOP) – The maximum intended operating pressure. MOP may equal design pressure unless there is a relief device then MOP is usually 10% to 20% below the design pressure to prevent a relief device from opening during normal operation.

Modification – (Defined by P101-34) A change in the form, fit, or function of a pressure system, and typically involves one related to design parameters (e.g., requirements, criteria, characteristics), physical configuration, and/or operational conditions.

Nondestructive Examination (NDE) – Examinations including (but not limited to) visual examination (VT), radiographic examination (RT), ultrasonic examination (UT), and dye-penetrant testing (PT) used to qualify the condition of a pressure vessel or component. Also known as nondestructive testing (NDT).

Non-Hazardous Fluids – Any fluid or mixture that is nonflammable, nontoxic, and is not corrosive.

Non-Reclosing Pressure Relief Device - A pressure relief device designed to actuate and remain open after operation. A manual resetting means may be provided.

Rupture Disk Device – Also known as burst disk. A non-reclosing pressure relief device actuated by inlet pressure and designed to remain open after operation. The device performs its function by bursting a pressure-containing disk. An ASME rupture disk includes the disk and the disk holder.

Damage Ratio – A damaged rupture disk will burst at some pressure other than predicted. This disparity can be reported by a value called the "damage ratio." The damage ratio is equal to the actual burst pressure of a damaged disk divided by the stamped burst pressure. A damage ratio of one or less provides assurance that the disk, even damaged, will burst at or below the stamped burst pressure, while a value higher than one would indicate the actual burst pressure could exceed the stamped burst pressure. As an example, a damaged disk with a 100-psig stamped burst pressure and a damage ratio of 1.5 could have an actual burst pressure of 150 psig. This information can be provided by the burst disk manufacturer.

Reversal Ratio – Is equal to the actual burst pressure of a rupture disk installed in reverse divided by stamped burst pressure. If the value is one or less, the disk will relieve at or below its stamped burst pressure even when installed in reverse. If the value is greater than one, the actual burst pressure will be greater than the stamped burst pressure. This information can be provided by the rupture disk manufacturer.

Operating Ratio – A manufacturer specified de-rating of rupture disk to provide a good service life from the bursting disk, and to prevent premature failures or nuisance bursts under continuous usage.

Guidance: Rupture disk life is generally tied to the stress history (pressure and temperature) applied to the disk. Relatively low pressures and static conditions will generally result in very long disk life, while cyclic conditions approaching the burst pressure will result in shorter disk life.

Example: If the disk being used has an operating ratio of 90% and has a rated burst pressure of 5 Barg @ 22°C, with a total performance burst tolerance of +/- 10%. This would mean the min/max burst pressure for this disk would be: Min 4.5, to max 5.5 Barg @ 22°C. With the operating ratio of the disk being 90% of the minimum rated burst pressure, this means the disk should not be subjected to a system operating pressure of more than 4.05 Barg.

Pressure Ratio – The long-term pressure rating of a rupture disk divided by its stamped rating.

Operating Pressure – The normal operating pressure of a pressure system. This may be a range of values.

Operating Temperature – The normal operating temperature of a pressure system. This may be a range of values.

Owner – Department of Energy (DOE) National Nuclear Security Administration (NNSA) owns the LANL pressure systems. NNSA delegates the Owner of ESM Chapter 17 pressure systems to the LANL Building Code Official [see ESM Chapter 1 Section Z10, Table Z10-2, LANL Authorities (e.g., from Delegation by NNSA)].

Owner's Inspector or ASME Owner's Inspector – The Owner's Inspector is responsible to the Owner for ensuring that the requirements of the applicable Code for inspection, examination, and testing are met. If a Quality System is specified by the Owner to be employed, the Owner's Inspector is responsible for verifying that it is implemented. This role is also known as the Owner's Representative or Owner's Agent, etc. Not to be confused with an Authorized Inspector.

Owner's Inspector Delegate or ASME Owner's Inspector's Delegate: The delegate of the Owner's Inspector that is qualified and responsible to perform inspection(s).

Oxygen Hazards Analysis – The documented evaluation of an oxygen system design including materials, testing, cleaning, and assembly to reduce the likelihood of a fire. Typically follows a Failure Mode and Effect Analysis (FMEA) to evaluate all oxygen system failure modes.

Permanent Pressure System – A pressure system that does not meet the definition/criteria of a temporary pressure system.

Pilot-Operated Pressure Relief Valve – A pressure relief valve in which the disk is held closed by system pressure, and the holding pressure is controlled by a pilot valve actuated by system pressure (BPVC Section XIII).

Piping Components – (Defined by ASME B31.3) Mechanical elements suitable for joining or assembly into pressure-tight fluid-containing piping systems. Components include pipe, tubing, fittings, flanges, gaskets, bolting, valves, and devices such as expansion joints, flexible joints, pressure hoses, traps, strainers, inline portions of instruments, and separators.

Pneumatic Test – A test performed on a pressure system or component where a gas is introduced and pressurized to a designated level in a manner prescribed in the applicable code.

Pressure Relief Device (PRD) – (Defined by ASME BPVC Section XIII) a device designed to prevent pressure or vacuum from exceeding a predetermined value in a pressure vessel by the transfer of fluid during emergency or abnormal conditions.

Pressure Relief Valve (PRV) – (Defined by ASME BPVC Section XIII) a pressure relief device designed to actuate on inlet static pressure and reclose after normal conditions have been restored.

Pressure Source – The pressure supply source that provides pressure to a system. Examples include gas cylinder, compressor, pump, heated vessel (boiler), cryogen Dewar, trapped cryogen expansion, chemical reaction, etc. is not a regulated pressure.

Pressure System – All pressure vessels and pressure sources including cryogenics, pneumatic, hydraulic, and vacuum. Vacuum systems should be considered pressure systems due to their potential for catastrophic failure from backfill pressurization. Associated hardware (*e.g.*, gauges and regulators), fittings, piping, pumps, and pressure relief devices are also integral parts of the pressure system (10CFR851).

Pressure Vessel – Containers for the containment of pressure, either internal or external.

Pressure System Database (PSD) – The LANL Conduct of Engineering Office (CENG) managed database for pressure systems.

Peer Reviewer – An employee who has completed training curriculum 13046 (or successor) and is authorized to review designs associated with programmatic (non-safety basis) FS3 and FS3-ULH category pressure systems.

Pressure Safety Officer (PSO) – Pressure safety officer qualified in accordance with ESD-QS-001 (or successor). Person familiar with ASME code and who performs design reviews (per this document) of pressure systems. Not required to perform design calculations, but aids Designers in compliance with this chapter and the use of the ASME code. A PSO can request an alternate or designee to help perform the functions defined in this document upon approval of the CPSO.

Pyrophoric – A chemical with an autoignition temperature in air at or below 130°F.

Reputable Manufacturers List (RML) – Approved listing of components for use in NASME applications.

Sensitive Test – A test where leakage may be measured to at least $1x10^{-3}$ std mL/s under test conditions.

Set Pressure – The value of increasing (or decreasing) inlet static pressure at which a pressure relief device displays one of the operational characteristics as defined by *opening pressure*, *popping pressure*, *start-to-leak pressure*, *burst pressure*, or *breaking pressure*. Measured at the pressure relief valve inlet, at which there is a measurable lift, or at which discharge of a fluid becomes continuous. The terms open pressure, relief pressure, cracking pressure, and set points are equivalent when testing valves. (ASME BPVC Section XIII)

Stop Valve – A valve that is installed between the piping or component being protected and its PRD, or between the PRD and the point of discharge. Although allowed by some ASME B31 codes, this design scenario is discouraged.

Supporting Piping Systems – Any and or all the piping necessary for the function of the boiler, pressure vessels, or air receivers. Piping that is attached, exceeding that required for the function of the boiler, pressure vessel, or air receiver, is not "supporting piping." This is analogous to the application of Boiler External Piping under ASME B31.1 and B31.9.

System – For this chapter, a combination of multiple components (and possibly subcomponents) which together make a pressure system.

System Interaction – Interactions among pressure systems that may cause a system to be over pressurized or cause unwanted mixture of separate fluids, which necessitates the evaluation of all system interfaces (e.g., determination of check valve installation and placement). In extreme cases could warrant the use of dual check valves placed in series.

Tank – A container whose contents are always maintained at between atmospheric pressure and 15 psig, and cannot be pressurized above 15 psig, even during fault conditions.

Temporary Pressure System – A pressure system that meets one the following Fluid Service (FS) Hazard Category and operational life span criteria:

- Categorized as FS1 and has a maximum operational life span of one year.
- Categorized as FS2 and has a maximum operational life span of two years.
- Categorized as FS3 and has a maximum operational life span of three years.
- Categorized as FS3-ULH and has a maximum operational life span of five years.

Test Article – A component or system of components provided by a vendor or is part of a research and design deliverable. It is temporarily installed in LANL facilities exclusively for the purpose of being tested for data purposes, or destructive purposes. Included in this definition are those test articles that are being designed by LANL personnel, which are considered product, and must undergo numerous design changes, modifications, and alterations. Test articles are not subject to the design requirements of this chapter.

Examples of excluded test article systems include flight hardware such as: weapons research pressure components and systems (e.g., vehicle-specific flight-weight tritium reservoirs and associated flight-weight plumbing/components), or space vehicle pressure components and systems (e.g., vehicle flight-weight propulsion or hydraulic systems/components). However, pressure systems that support the design, testing and/or evaluation of such hardware are not excluded.

Tubing – Thin-walled pipe.

Upper Explosive Limit (UEL) – The maximum concentration (percentage by volume) of gas or vapor that will burn in air in the presence of an ignition source (flame, heat, etc.). It can also be referred to as the Upper Flammability Limit (UFL).

Vacuum System – An assembly of components which may include vessels, piping, valves, relief devices, flex hoses, gages, etc., operated with the internal pressure reduced to a level less than that of the surrounding atmosphere. See PS-REQUIREMENTS, *Specific Requirements by System Type* paragraphs for further information on what is and is not considered a vacuum system in the scope of this chapter.

Vacuum Vessel – A vessel operated with the internal pressure reduced to a level less than that of the surrounding atmosphere.

ACRONYMS

Acronym	Definition
ACFM	Actual Cubic Feet Per Minute
AFU	Acceptance for Use
AI	Authorized Inspector
ALD	Associate Lab Director (or Directorate)
ALDFO LOG-PT	Facilities & Operations (Associate Lab Directorate) Readiness, Packaging, and Transportation Division Office
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS CWI	American Welding Society Certified Welding Inspector
BPVC	Boiler and Pressure Vessel Code
BRmp	Melting Point Burn Ratio
CAD	Computer Aided Drafting
CENG	Conduct of Engineering
CGA	Compressed Gas Association
CGD	Commercial Grade Dedication

CFR	Code of Federal Regulations
COR	Code of Record
COTS	Commercially Available Off-The-Shelf
CPSO	Chief Pressure Safety Officer
CRN	Canadian Registry Number
CSA	Canadian Standards Association
CSCC	Chloride Stress Corrosion Cracking
DBB	Double Block and Bleed
DOE/NNSA	Department of Energy/National Nuclear Security Administration
DCPSO	Deputy Chief Pressure Safety Officer
DOT	Department of Transportation
EIGA/IGC	European Industrial Gases Association / Industrial Gases Council
EIV	Emergency Isolation Valve
ESM	Engineering Standards Manual (LANL)
ES-UI	Engineering Services, Utilities and Infrastructure (LANL Group)
EU	European Union
FAD	Free Air Delivery
FEA	Engineering Finite Analysis
FMEA	Failure Modes and Effects Analysis
FOD	Facility Operations Directorate (or Director)
FS	LANL Fluid Service Categories
FSD	Functional Series Document
GPM	Gallons Per Minute
HDB	Hydrostatic Design Basis
HDD	Horizonal Directional Drilling

IESL	Institutional Evaluation Suppliers List
IRT	Integrated Review Tool
IWD/WCD	Integrated Work Document / Work Control Document
LANL	Los Alamos National Laboratory
LEL	Lower Explosive Limit
LFL	Lower Flammability Limit
LO/TO	Lockout/Tagout
LOX	Liquid Oxygen
MAWP	Maximum Allowable Working Pressure
MOP	Maximum Operating Pressure
MSS	Maintenance and Site Services
MSS	Manufacturers Standardization Society
M&TE	Measuring and Test Equipment
NACE	National Association of Corrosion Engineers
NASME	Non-ASME Code Equivalency
NB	National Board
NBBI	National Board of Boiler Inspectors
NBIC	National Board Inspection Code
NDE	Nondestructive Examination
NDT	Nondestructive Testing
NEC	National Electric Code
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NPS	Nominal Pipe Size
OSH	Occupational Safety and Health (LANL Division)

OSH-ISH	Occupational Safety and Health, Industrial Safety and Hygiene (LANL Group)
PA	Polyamide
PCTFE	Polychlorotrifluoroethylene
PED	Pressure Equipment Directive (European Union)
PIP	Process Industry Practices
PMT	Post Modification Testing / Post Maintenance Testing
POC	Point of Contact
PRD	Pressure Relief Device
PRID	Permits and Requirements Identification
PRV	Pressure Relief Valve
PSC	Pressure Safety Committee
PSD	Pressure Safety Database
PSID	Pressure System ID
PSIP	Pressure Safety Implementation Plan
PSO	Pressure Safety Officer
PSR	Pressure System Representative
PT	Dye-Penetrant Testing
PTFE	Polytetrafluoroethylene
QCSM	Quality Control Systems Manual
QR	Qualitative Risk
RFO	Restricted Flow Orifice
RML	Reputable Manufacturers List
RT	Radiographic Examination
SCC	Stress Corrosion Cracking
SCFM	Standard Cubic Feet Per Minute

SDS / MSDS	Safety Data Sheet / Material Safety Data Sheet
SME	Subject Matter Expert
SMYS	Specified Minimum Yield Strength
SPOF	Single Point-Of-Failure
SSCs	Structures, Systems, and Components
T&P	Temperature and Pressure
UEL	Upper Explosive Limit
UFL	Upper Flammability Limit
UL	Underwriters Laboratories
ULH	Ultra-Low Hazard
UT	Ultrasonic Examination
VFD	Variable Frequency Drive
VT	Visual Examination

RECORD OF REVISIONS

Rev	Date	Description	POC	RM
0	11/09/18	Initial issue.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
1	09/22/23	Updated Section and Attachment name (formerly known as Section ASME – New ASME System Requirements, Attachment ASME-2) for revised ESM Ch 17 format. Content reworded.	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards point of contact (POC) for upkeep, interpretation, and variance issues.

Chapter 17	**Pressure Safety POC**

This document is online at https://engstandards.lanl.gov

National Board Inspection Code NB-23 Application

This attachment contains code scope summaries from NB-23 with discussion of how these mandates shall be applied at LANL. It is based on the 2021 edition; later editions must be evaluated for impact.

Part 1 Installation
This part provides requirements and guidance to ensure all types of pressure-retaining items are installed and function properly. Installation includes meeting specific safety criteria for construction, materials, design, supports, safety devices, operation, testing, and maintenance. Engineering Standards Manual (ESM) Chapter 17 requires adherence to National Board Inspection Code (NBIC) NB-23 Part 1 *Installation* for the installation of all boilers and pressure vessels.
Part 2 Inspection
This part provides information and guidance needed to perform and document inspections for all types of pressure-retaining items. This part includes information on personnel safety, nondestructive examination, tests, failure mechanisms, types of pressure equipment, fitness for service, risk-based assessments, and performance-based standards. ESM Chapter 17 requires adherence to NBIC NB-23 Part 2 *Inspection* for the in-service inspection and repair/alteration inspection of all boilers and associated pressure vessels like superheaters. PS-GEN-NBIC-FIA, QCSM, *Quality Control Systems Manual (Federal Inspection Agency)*, exists to ensure that these inspections meet the requirements of the NBIC NB-23 and Engineering Standards Manual (ESM) Ch. 17. These National Board of Boiler and Pressure Vessel Inspectors (NBBI) inspections require an NBBI Commissioned Inspector.

Part 3 Repairs and Alterations
This part provides requirements and guidance to perform, verify, and document acceptable repairs or alterations to pressure retaining items regardless of code of construction. Alternative methods for examination, testing, heat treatment, etc. are provided when the original code of construction requirements cannot be met. Specific acceptable and proven repair methods are also provided. ESM Ch. 17 requires adherence to NBIC NB-23 Part 3 *Repairs and Alterations* for repairs or alterations to American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) Section I and Section IV boilers, and Section VIII Div. 1 pressure vessels. PS-GEN-NBIC-RSP, QCSM, *Quality Control Systems Manual (R Stamp Program)*, exists to ensure that these repairs or alterations meet the requirements of the NBIC NB-23, original code of construction, and ESM Chapter 17. The repair and alteration portion of the API 510 is not used; all pressure vessel repairs/alterations shall follow PS-GEN-NBIC-RSP.
Part 4 Pressure Relief Devices
This part provides information and guidance to ensure pressure relief devices are installed properly, information and guidance needed to perform and document inspections for pressure relief devices, and information and guidance to perform, verify, and document acceptable repairs to pressure relief devices. NBIC NB-23 Part 4 *Pressure Relief Devices* has three primary sections that contain requirements: Section 2: Installation of Pressure Relief Devices • The requirements of this Section are integrated into ESM Chapter 17. Section 3: In-service Inspection of Pressure Relief Devices • Maintenance and Site Services (MSS) Operations & Maintenance Criteria (403 and 419) integrate the requirements in Section 3. Section 4: Repair of Pressure Relief Devices • Los Alamos National Laboratory (LANL) does not hold a "VR" stamp at this time, and therefore is not authorized to repair ASME/National Board (NB) stamped relief devices. This Section will not be followed unless LANL becomes an authorized "VR" stamp holder.

TABLE OF CONTENTS

RECORD OF REVISIONS

Rev.	Date	Description	POC	RM
0	9/22/2023	Initial issue as section PS-REQUIREMENTS. Replaced most of the requirements in previous Sections ASME, NASME, and ADMIN that did not move to P101-34 and its subordinate documents.	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards point of contact (POC) for upkeep, interpretation, and variance issues.

Chapter 17	**Pressure Safety POC**

This document is online at https://engstandards.lanl.gov

ESM Usage

(Requirement 17-0XYZ): Where this phrase appears it is a LANL-internal reference in a basis file that captures and categorizes ESM drivers—and is not relevant to most users.

Fonts

Italics use: Where appropriate throughout the ESM, guidance is provided to aid in the implementation of requirements. Guidance will be *italicized* text and/or otherwise clearly indicated (e.g., by headings). Document titles in italics is normally simply a formatting style. Likewise, words and short phrases in italics and/or capitalized indicates them as a defined term (defined either in this document, the CoE Glossary (future), or the ESM chapter in which it appears).

All other text (plain type) indicates mandatory requirements (usually with "shall" or "must", or directive statement–e.g., "Provide …"

1.0 INTRODUCTION

The purpose of this document is to define the requirements to be used when performing pressure system design in the areas of planning, design, fabrication, assembly, examination, inspection and testing, and commissioning as well as decommissioning.

This document aims to seamlessly combine pressure safety requirements that originate from the Prime Contract (e.g., Title 10 CFR 851, Title 29 CFR, Department of Energy (DOE) O 420.1C, etc.), national consensus codes and standards, Los Alamos National Laboratory- (LANL) specific directives, and sound engineering and pressure safety design practices.

2.0 PRESSURE SAFETY IMPLEMENTATION PLAN

(Requirement 17-0201)

A. The purpose of the Pressure Safety Implementation Plan (PSIP) is for the Designer to provide a clear and concise summary of the pressure system(s) being designed and to demonstrate their understanding of the design requirements of Engineering Standards Manual (ESM) Chapter 17. These requirements apply to all pressure systems.

B. Each Designer must assess and plan for compliance with ESM Chapter 17 Pressure Safety. The design-specific PSIP shall be submitted to a qualified design reviewer (see Table 2 —*Authorized Reviewer/Approver for-fluid service (FS) Hazard Category Activities*, below) for review and approval in the early stages of project design (e.g., 30% complete) and resubmitted at later review phases (e.g., 60%, 90%) if/as it matures. If the design does not follow a 30/60/90-style design lifecycle, the PSIP shall be submitted at each applicable design stage (e.g., conceptual, preliminary, baseline, and final).

C. The pressure system Designer is responsible for issuing the PSIP. There are examples in the Chapter 17 SharePoint page.

D. The PSIP shall address all areas of pressure safety design compliance including the following items:

1. Design Criteria reference - Requirements and Criteria Document (RCD), Statement of Work (SOW), etc.

2. Service life of the installation

3. Define who is responsible for each work phase: design, fabrication, examination, and testing, and data input to the Pressure System Database (PSD)

Guidance: It is recommended that the PSIP identify a pressure system representative (PSR) as required by P101-34 to ensure the PSIDs are created in the PSD and updated with information as required for Acceptance for Use per P101-34 Attachment A, Acceptance for Use (AFU) of Pressure Systems.

4. Design pressure and design temperature ranges

5. Identification of the Design Basis. If more than one code of record (COR) is used, define the location of the code changes in applicable drawings, sketches, isometrics, etc.

6. Design output expectations (specifications, drawings, calculations, etc.)

7. Fabrication expectations (methods and qualification of fabrication personnel)

8. American Society of Mechanical Engineers (ASME) quality (procurement, inspection, examination, and testing requirements), if applicable.

9. Required Records

   a. Welding inspection, examination, and testing records shall be maintained in the pressure system design documentation package.

   b. Manufacturer's data reports (e.g., ASME U-1) shall be maintained as a record for all boilers and pressure vessels.

10. Review and define the required items from Attachment REQ-2, *New or Modified System Design Document Requirements*. This attachment includes two "Verification" columns for Designer and Design Reviewer that may be optionally utilized to aid in ensuring that all required documentation has been provided in the design package.

   a. For example, B31.3 Code requires retention of examination records:

      1) Examination procedures

      2) Examination personnel qualifications

      3) Examination reports

11. State whether the pressure system is a new system or an existing system modification. Obtain the pressure system ID (PSID) number(s) from the Pressure Safety Program and assign it to system design documentation.

    NOTE: For new pressure systems or existing pressure systems without an assigned PSID, obtain a PSID by emailing PSIDrequest@lanl.gov.

3.0 FLUID SERVICE DETERMINATION

(Requirement 17-0202)

A. General

1. LANL Fluid Service (FS) is defined by the best fit for each pressure system or sub-system and provides a sense of the hazard level of the pressure system.

LANL FS is generally driven by system pressure, temperature, fluid contents, or a combination of the three. (See Figure 1 below)

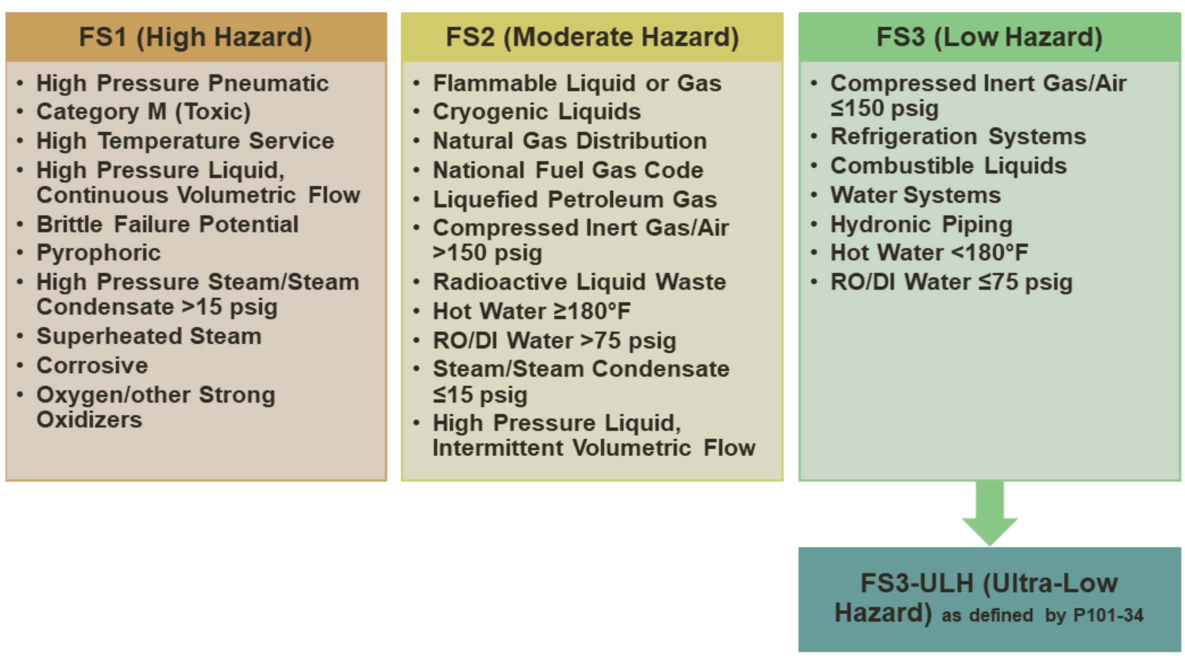
2. LANL FS also determines the minimum level of qualification required of the design reviewer, discussed in the Design Review section below. There may be more than one Fluid Service for a pressure system (or sub-system). If there is more than one Fluid Service for the pressure system, the most hazardous Fluid Service will be used to identify the pressure systems in the PSD.

3. Figure 1 provides a summary of common types of pressure systems and their LANL FS categories. P101-34 Section 9.1 and ESM Ch. 17 Att-GEN-1 provides detailed definitions.

4. The pressure safety committee (PSC) may evaluate the FS of a pressure system on an individual basis to determine if it meets Fig. M300 in B31.3 — even if listed in ESM Chapter 17 Attachment REQ-1, *Category M Fluid Service and Lethal Service* — and will consider relevant information in the evaluation, including protection of personnel from exposure during system operation.

5. The chief pressure safety officer (CPSO) — or delegated CPSO (DCPSO) if the CPSO is unavailable — will make the final determination of fluid category for a pressure system if there is any uncertainty.

Figure 1 Pressure Systems within Each FS Category



4.0 DESIGN REVIEW

(Requirement 17-0203)

NOTE: Reviewers should be identified early in the design process.

A. Design review of new or modified pressure systems is required for all pressure systems in the scope of ESM Ch. 17.

B. Design Review and Acceptance will be performed in accordance with Table 1 — authorized reviewer/approver for FS Hazard Category Activities (below).

C. The minimum required level of reviewer may be replaced by a higher hazard reviewer.

D. Reviewer shall be independent from the design.

E. Pressure safety officers (PSOs) will be trained and qualified to the applicable code(s) of record or work under a qualified individual.

F. Trained peer reviewers may only perform design reviews for FS3 & FS3-ULH fluid service programmatic systems that are not tied to a safety basis.

G. Peer reviewers may perform the role of examiner and inspector for applicable programmatic low and ultra-low risk pressure systems. The examiner is the person that does the work, and the inspector is the person that verifies the work is adequate. For example, the examiner would use the correct parts and fabricate and test the system to be leak-free, and the Inspector would verify as much of the work as necessary to ensure the work was done correctly.

H. The Designer shall ensure that Occupational Safety and Health (OSH) and/or Fire Protection subject matter experts (SMEs) be included as part of the design review. OSH is responsible for evaluating pressure system hazards related to occupational safety and health that are not in the scope of Pressure Safety (ref. P101-34 Section 3.3.1.a for a description of OSH's role for pressure systems). Fire Protection evaluates the fire risk of pressure systems and their impact on the location in which the pressure systems are placed.

I. Attachment REQ-2, *New or Modified System Design Document Requirements*, contains a comprehensive list of the base set of design documentation required to review and approve pressure systems. This attachment is intended for all pressure systems except FS3 and FS3-ULH temporary pressure systems that are not tied to a safety basis.

J. The AFU prior to operation of a pressure system shall be in accordance with P101-34 Attachment A, *Acceptance for Use (AFU) of Pressure Systems*.

Table 1. Authorized Reviewer/Approver for FS Hazard Category Activities

PSP SME	FS Hazard Category			
	FS1 (High)	FS2 (Moderate)	FS3 & FS3-ULH (Low & Ultra-Low)	
			Facilities, Utilities, and Programmatic (safety basis)	Programmatic
CPSO/DCPSO	R	√	√	√
PSO Duty Area B	-	R	√	√
PSO Duty Area A	-	-	R	√
Peer Reviewer	-	-	-	R

R Minimum required level of reviewer/approver

√ May approve/review

- May NOT approve/review

PSO Duty Area A and B are defined by and qualified as described in ESD-QS-001.

5.0 PERMITS AND REQUIREMENTS IDENTIFICATION

(Requirement 17-0204)

A. The Permits and Requirements Identification (PRID) process is a project planning Integrated Review Tool [see P351, *Integrated Review Tool (IRT)*] used by project leaders to identify required permits, requirements, and facilitate subject matter expert (SME) reviews in the early planning stages of a project. Pressure system designs should be included for PRID review when applicable.

B. Unless otherwise delegated, all PRID reviews shall be performed by the CPSO.

6.0 DESIGN CRITERIA

A. The Design Criteria is provided by the customer as input for the Designer.

B. The Designer is responsible for implementing the defined Design Criteria.

C. It is the responsibility of the Designer for defining any additional Design Criteria if necessary to assure a safe pressure system for the proposed installation in addition to the Design Basis. Examples include, but are not limited to, specification of additional nondestructive examination (NDE) and pass/fail criteria, evaluating and specifying materials of construction to ensure system integrity, and specifying necessary construction techniques for radioactive material handling service.

D. Designs or practices known to be unsafe are prohibited.

7.0 DESIGN BASIS

(Requirement 17-0205)

A. Design Basis, as defined by DOE G 413.3-12 Chg 1 (Admin Chg), *U.S. Department of Energy Project Definition Rating Index Guide for Traditional Nuclear and Non-Nuclear Construction Projects,* is "The set of requirements that bound the design of systems, structures, and components within the facility. Those design requirements include consideration of safety, plant availability, efficiency, reliability, and maintainability."

B. For ESM Ch. 17, Design Basis is considered the codes, standards and/or equivalent safety evaluations that ensure that new or modified pressure systems are designed, fabricated, tested, and inspected in a manner that will protect workers. The Design Basis also ensures that pressure systems can be maintained, repaired, and operated safely throughout its lifecycle in accordance with P101-34, Pressure Safety.

C. It is the responsibility of the Designer to define the Design Basis of a pressure system that meets the Design Criteria. See Attachment GEN-1, *Definitions and Acronyms*.

D. A pressure system design may contain multiple required codes and/or standards (e.g., ASME Boiler and Pressure Vessel Code (BPVC) vessels associated with ASME B31 piping).

E. A summary of the Design Basis options is provided below in Table 2. Detailed explanations of each Design Basis option and additional requirements that may affect the Design Basis are provided below the table.

Table 2, Design Basis

	Application of Design Basis		
Design Basis	**Boilers, Pressure Vessels, Air Receivers, and Supporting Piping**	**Non-Supporting Piping**	**Temporary Programmatic (not Safety Basis)**
ASME BPVC Section I through XIII	Required for BPVC Section I through XIII	Not allowed	Required for BPVC Section I through XIII
ASME B31 or NFPA 54/58 Piping Codes	Required for Supporting Piping	Allowed for Non-Supporting Piping	Required for Supporting Piping
LANL Ch. 17 NASME B31 Code Equivalencies	Not allowed	Allowed for Non-Supporting Piping	Allowed for Non-Supporting Piping
Title 10 CFR 851 Compliant Evaluation	Allowed for Pressure Vessels and Supporting Piping that cannot otherwise meet ASME code	Allowed for Non-Supporting Piping that cannot otherwise meet ASME code	Allowed for systems that cannot otherwise meet ASME code

7.1 APPLICATION OF ASME BOILER AND PRESSURE VESSEL CODE

When an ASME BPVC item is required (e.g., Section I, IV, VIII, X, XII, or XIII) the Design Basis of that item will be the ASME BPVC itself. Attachment REQ-3, *ASME Boiler and Pressure Vessel Code Application*, contains a summarized description of the scope of the ASME Boiler and Pressure Vessel Codes and their applicability at LANL. Additionally, the following applies to all ASME BPVC equipment in the scope of ESM Chapter 17:

A. BOILERS

1. Heating boilers that are included under the scope of ASME BPVC Section IV *Rules for Construction of Heating Boilers* shall meet same and be National Board Inspection Code (NBIC) numbered and registered *(Requirement 17-0206).*

2. Power boilers that are included under the scope of ASME BPVC Section I, *Rules for Construction of Power Boilers*, shall meet same and be NBIC numbered and registered *(Requirement 17-0207).*

   NOTE: Water heaters that are not considered boilers (outside the scope of ASME Section I or IV) shall meet other codes or standards (e.g., UL 1453).

3. Controls, safety devices, and gas train for boilers with fuel input rating <u>less than</u> 12.5 MBTU/hr fall shall comply with ASME CSD-1, *Controls and Safety Devices for Automatically Fired Boilers (Requirement 17-0208)*.

4. Controls, safety devices, and gas train for boilers with fuel input rating <u>greater than or equal</u> to 12.5 MBTU/hr fall within the scope of the National Fire Protection Association (NFPA) 85, *Boiler and Combustion Systems Hazard Code (Requirement 17-0209).*

5. Installation of new boilers shall comply with NBIC NB-23 Part 1, *Installation (Requirement 17-0210).*

6. Boilers providing hot water shall have the high temperature fuel cutoff set no higher than 195 ˚F. This ensures that discharge from the relief devices is only water, not a water and steam mixture, at LANL elevation. *Guidance: LANL elevation is conservatively estimated at 7500 feet, Ref. ESM Ch. 1 Section Z10, 9.0 "Constants"*

7. Boiler External Piping shall meet either ASME B31.1, *Power Piping*, or B31.9, *Building Services Piping*, as defined within the scope of each code.

B. PRESSURE VESSELS

1. Installation of new pressure vessels shall comply with NBIC NB-23 Part 1, *Installation. (Requirement 17-0211)*

2. Pressure vessels that are included under the scope of ASME BPVC Section VIII, *Rules for Construction of Pressure Vessels*, shall meet same and be NBIC numbered and registered. *(Requirement 17-0212)*

   NOTE: Pressure vessels may be built to Division 1, 2, or 3.

3. Pressure vessels that are included under the scope of ASME BPVC Section X, *Fiber-Reinforced Plastic Pressure Vessels*, shall meet same and be NBIC numbered and registered. *(Requirement 17-0213)*

4. Non-code stamped pressure vessels (i.e., vessels in the scope of Section VIII or X but not code stamped) are discouraged but may be permitted when documentation can be provided that the vessel design provides an equivalent

level of safety to the applicable ASME BPVC Section. See Attachment REQ-2, *New or Modified System Design Document Requirements*, for detailed information on the equivalency requirements. *(Requirement 17-0214)*

C. TRANSPORT TANKS

1. Transport tanks that are included under the scope ASME BPVC Section XII, *Rules for Construction and Continued Service of Transport Tanks*, shall meet same and be NBIC numbered and registered. *(Requirement 17-0215)*

2. Mobile pressure systems or vacuum systems must comply with Department of Transportation Code of Federal Regulations (Reference 49CFR) per P151-1, LANL Packaging and Transportation Program Procedure as administered by ALDFO, Facility and Operations (Associate Laboratory Directorate), Packaging and Transportation LOG-PT (or successor organization), and are not included in the ESM Chapter 17 unless they are under the criteria defined in this subsection. *(Requirement 17-0216)*

3. Fabrication of pressurized trailer cylinders in accordance with ASME BPVC Section XII, Rules for Construction and Continued Service of Transport Tanks, may be applied to satisfy the Department of Transportation (DOT) Code of Federal Regulations (CFR) requirements when approved by ALDFO LOG-PT (or successor organization) per P151-1, *LANL Packaging and Transportation Program Procedure*, except for dangerous goods (see below).

4. The rules of ASME BPVC Section XII, Rules for Construction and Continued Service of Transport Tanks, shall be applied to the construction and continued service of pressure vessels for the transportation of dangerous goods via highway, rail, air, or water. The general requirements given in Part TG of Section XII shall be met for all vessels within the scope of this Section. This Section shall apply specifically to pressure vessels intended for transporting dangerous goods (see Mandatory Appendix III) with design pressures appropriate for the transportation mode and volumes greater than 450 L (120 gal). 49CFR Parts 100 through 185, Transportation, covering the construction and continued service of pressure vessels intended for transporting dangerous goods shall be reviewed to determine if the requirements are more restrictive than the rules of this Section. Applicable state and local laws and regulations may contain additional requirements for pressure vessels used in the transportation of dangerous goods, which are not addressed in this subsection.

D. RELIEF DEVICES

1. When required by ASME BPVC or ASME B31 code, relief devices shall meet ASME BPVC Section XIII and be code stamped (e.g., relief valves for Section I boilers shall be "V" stamped). *(Requirement 17-0217)*

   Guidance: For applicable relief device marking see ASME BPVC Section XIII, Table 2.1-1, Permitted Pressure Relief Devices or Methods by ASME BPVC Section

E. REPAIRS AND/OR ALTERATIONS OF EXISTING ASME BPVC EQUIPMENT

1. ASME boilers and pressure vessels are to be repaired or altered as required by NBIC NB-23 Part 3, *Repairs and Alterations*, and must be performed by an institution holding an "R" stamp *(Requirement 17-0218)*. Note that repairs/alterations may require additional design information prior to approval for work to proceed (e.g., updated drawings, calculations, etc.).

Guidance: LANL holds an "R" stamp at time of writing; see LANL Quality Control Systems Manual (QCSM) (R Stamp Program).

F. NON-CODE TANKS

1. Atmospheric tanks intended for service less than 15 psig are outside the scope of ASME BPVC but shall meet other applicable codes or standards (e.g., API 620, 625, 650 or UL 142, 2085). *(Requirement 17-0219)*

2. System designs that utilize DOT vessels as fixed pressure vessels must plan either to maintain the DOT certification inspection intervals or qualify them as a non-code pressure vessel.

3. Atmospheric tanks or vacuum vessels are not required to be, but may be, fabricated to ASME BPVC Section VIII.

7.2 APPLICATION OF ASME B31 AND NFPA PIPING CODES

Attachment REQ-4, *Piping Code and Regulation Application*, contains a summarized description of the scope of ASME B31 and NFPA piping codes and their applicability to LANL. It is the responsibility of the Designer to assign the most applicable piping code(s) of record to their pressure system design, though Attachment REQ-4 provides guidance regarding the most common applications of the piping codes.

ASME B31.1 Boiler External Piping requires ASME quality marking (i.e., code stamp) and ASME SA and SB materials from BPVC Section II.

ASME B31.9 Boiler External Piping requires ASME SA and SB materials from BPVC Section II (quality marking is not required).

7.3 APPLICATION OF NON-ASME (NASME) CODE EQUIVALENCY EVALUATIONS

ESM Ch. 17 provides equivalent level of safety evaluations for pressure systems in the scope of either ASME B31.3 (Fluid Categories D and Normal, Metallic and Non-Metallic) or ASME B31.9. Use of these provisions is referred to as Non-ASME (NASME) Design Basis. The following attachments provide details on the application of NASME to pressure systems, including requirements for their use.

- Attachment REQ-5, *ASME B31.3 Non-Metallic Equivalent Safety Evaluation*
- Attachment REQ-6, *ASME B31.3 Metallic Equivalent Safety Evaluation*
- Attachment REQ-7, *ASME B31.9 Equivalent Safety Evaluation*

Guidance: If NASME is part of the Design Basis, the Designer is not required to follow every provided equivalency, e.g., they may choose to utilize the provisions for unlisted components but follow the rest of the ASME B31 code.

7.4 APPLICATION OF 10 CFR 851 EQUIVALENCY EVALUATIONS

10 CFR 851 Appendix A 4(c) provides allowance for equivalent safety measures when national consensus codes are not applicable:

> "*(c) When national consensus codes are not applicable (because of pressure range, vessel geometry, use of special materials, etc.), contractors must implement measures to provide equivalent protection and ensure a level of safety greater than or equal to the level of protection afforded by the ASME or applicable state or local code. Measures must include the following:*

(1) Design drawings, sketches, and calculations must be reviewed and approved by a qualified independent design professional (i.e., professional engineer). Documented organizational peer review is acceptable.

(2) Qualified personnel must be used to perform examinations and inspections of materials, in-process fabrications, non-destructive tests, and acceptance test.

(3) Documentation, traceability, and accountability must be maintained for each unique pressure vessel or system, including descriptions of design, pressure conditions, testing, inspection, operation, repair, and maintenance."

10 CFR 851 Appendix A 4(c) equivalency evaluations are most commonly applied to programmatic pressure systems that utilize vessels, components, and materials that cannot meet national consensus codes due to the unique nature of design/operating conditions or system components.

1. Pressure systems and/or components of pressure systems that cannot under any circumstances be designed to safely contain or relieve pressure shall be placed behind blast containment (i.e., a barrier or shielding) as a last resort means to protect workers from overpressure hazards. Blast containment is a method by which Designers can comply with 10 CFR851 Appendix A 4(c). This safety measure should only be considered when all other design options have been considered and deemed unsuitable for the pressure system design.
   a. These items shall be shielded behind blast containment (a.k.a. a barrier or shielding) designed to withstand the explosive forces and potential release of shrapnel in the event of over pressurization. OSH-ISH-FSD-009, *Programmatic Work with Explosives (Laboratory and Other High Explosive Operations)* contains pre-approved minimum shielding designs.
   b. Only after sufficiently designed shielding has been installed to protect the worker may the pressure system or components be considered excluded from ESM Chapter 17 design requirements.
2. Pressure systems that do not pose a risk to personnel (e.g., system is pressurized remotely), and where the risk of damage or system loss is acceptable to the ESM Ch. 17 POC and the pressure system Associate Laboratory Director (ALD) (or appointed designee), do not have to comply with the pressure system design requirements of ESM Chapter 17. The following three items must be satisfied:
   a. The adequacy of the methodology to isolate personnel from the potential failure of the pressure system must be verified.
   b. Adequate documented administrative controls (e.g., in an IWD or WCD) must be in place to prevent inadvertent pressurization when personnel are not isolated from the pressure system, for example:
      1) Disconnection of all pressure sources
      2) Double block-and-bleed of all pressurization sources
   c. Completion of the required documentation and Acceptance for Use process described in P101-34.

7.5 APPLICATION OF OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) REQUIREMENTS

(Requirement 17-0220)

A. Pressure systems shall meet the requirements of Title 29 CFR 1910 as follows:

1. A table that summarizes the applicable code and/or standard requirements of the CFR is in Attachment REQ-8, *OSHA Requirements for Pressure Systems*; see CFR for the complete text and all requirements.

   Guidance: Following the document(s) in the "LANL Applied Code" column satisfies the OSHA requirement for the systems listed.

2. The requirements of these paragraphs shall be integrated into the design when applicable. When the requirements are outside of the jurisdiction of pressure safety, OSH-ISH and/or Fire Protection Office (or successor orgs.) shall be involved in ensuring compliance.

7.6 DESIGN RESTRICTIONS FOR CREDITED PRESSURE SYSTEMS

(Requirement 17-0221)

A. Pressure systems that are credited in an approved safety basis (e.g., nuclear) may have design requirements that influence the Design Basis. These requirements must be incorporated into design for these systems and may go above and beyond national code requirements.

7.7 APPLICATION OF CODES, STANDARDS, OR DOCUMENTS NOT INVOKED BY 10 CFR 851

(Requirement 17-0222)

A. Requirements from other countries or international organizations that are not compliant with 10 CFR 851 pressure safety requirements are not allowed at LANL or to be used by LANL personnel unless reviewed and approved using the Alternate Method process described in Section PS-GENERAL - *General Information, Alternate Method/Variance or Clarification/Interpretation.*

   Two examples of requirements from entities not recognized by 10 CFR 851 are below.

1. The Canadian Registration Number (CRN) system.
2. The European Union (EU) Pressure Equipment Directive (PED).

B. Standards that do not affect compliance with 10 CFR 851 pressure safety requirements are permitted as part of the pressure system design. This includes, for example:

1. Process Industry Practices (PIP)
   a. PIP INEG1000, *Insulation Design and Type Codes*
   b. PIP PCCIP001, *Instrument Piping and Tubing Systems Criteria*
   c. PIP PCSIP001, *Instrument Piping and Tubing Systems Specifications*
   d. PIP PIC001, *Piping and Instrumentation Diagram Documentation Criteria*

e. PIP PNCM0001, *Piping Material Specification Designator System*

2. Compressed Gas Association (CGA) (see 29CFR1910)

   a. CGA 341, *Specification for Insulated Cargo Tank for Nonflammable Cryogenic Liquids*

   b. CGA E-4, *Standard for Gas Pressure Regulators*

   c. CGA G1.2, Acetylene Metering and Piping

   d. CGA G-4.1, *Cleaning Equipment for Oxygen Service*

   e. CGA G-4.4 *Oxygen Pipeline and Piping Systems*

   f. CGA H-3, *Cryogenic Hydrogen Storage*

   g. CGA P-18, *Standard for Bulk Gas Storage Systems*

   h. CGA P-23, *Standard for Categorizing Gas Mixtures Containing Flammable and Nonflammable Components*

3. National Fire Protection Association

   a. NFPA 30, *Flammable and Combustible Liquids Code*

   b. NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*

   c. NFPA 55, *Compressed Gases and Cryogenic Fluids Code (e.g., Dewar vacuum jacket)*

4. UL enterprise – UL Research Institutes, UL Standards & Engagement, UL Solutions (formerly Underwriters Laboratories)

   a. UL 404, *Standard for Gauges, Indicating Pressure, for Compressed Gas Service*

   b. UL 207, *Refrigerant-Containing Components and Accessories, Nonelectrical*

   c. UL 1963, *Refrigerant Recovery/Recycling Equipment*

5. ASTM International (ASTM), formerly American Society for Testing and Materials

   a. ASTM G93, *Standard Practice for Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen-Enriched Environments*

   b. ASTM G128, *Standard Guide for Control of Hazards and Risks in Oxygen Enriched Systems*

   c. ASTM A380, *Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems*

   d. ASTM E681, *Standard Test Method for Concentration Limits of Flammability of Chemicals*

6. American Petroleum Institute (API), where they do not conflict with 10 CFR 851

   a. API 520 Part I and Part II, *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries*

   b. API 521, *Pressure-Relieving and Depressurizing Systems*

c. API 570, *Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems*

d. API RP 574, *Inspection Practices for Piping System Components*

e. API RP 575, *Inspection Practices for Atmospheric and Low-Pressure Storage Tanks*

f. API 579/ASME FFS-1, *Fitness for Service*

g. API RP 580, *Risked-based Inspection*

h. API RP 581, *Risked-based Inspection Methodology*

i. API 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*

j. API 650, *Welded Tanks for Oil Storage*

k. API 653, *Tank Inspection, Repair, Alteration, and Reconstruction*

8.0 DESIGN REQUIREMENTS

8.1 ASME LISTED PIPING COMPONENTS AND MATERIALS

(Requirement 17-0223)

Pressure system components or materials that conform to a standard listed in the COR, are defined as listed components and listed materials, respectively. Designers shall make every effort to utilize listed components and materials when available.

Example: B31.3 Tables 326.1 and A326.1 contain listed components; B31.3 Appendix A and Appendix B contain mostly listed materials but also contain components (pipe).

8.2 ASME UNLISTED, SPECIALTY, OR UNIQUE COMPONENTS

(Requirement 17-0224)

Pressure system components or materials used in systems built to ASME COR that are not listed in the code must be evaluated using the LANL unlisted component evaluation process.

NOTE: Alternately, if the conditions for its use as a Design Basis are met, the NASME process may be used to evaluate unlisted components (see NASME Pressure System Design section below).

A. Previously Approved Materials and Components

1. The master list of Approved Unlisted Materials and Components allowed for use is maintained by the chief pressure safety officer / deputy chief pressure safety officer (CPSO/DCPSO) and available for both internal and external web access.

2. When designing with these items, the Designer shall ensure that they are being used within allowable pressure, temperature, and other parameters. Additionally, the Designer shall make mention that the unlisted items being utilized are on the master list.

B. Approving a New Unlisted Item

1. Forms and instructions to assist in evaluating and gaining approval of unlisted components and materials are available here).

2. The Designer shall request approval of additional materials and components using the provided forms and forward to the CPSO/DCPSO for review and approval. When new items are approved for use, the Designer shall make mention that the unlisted items being utilized are on the master list.

3. The PSC will resolve disputes over unlisted component evaluations.

8.3 COMMERCIALLY AVAILABLE, OFF-THE-SHELF (COTS) EQUIPMENT

A. P101-34 Attachment D, *Procurement of Pressure Safety Goods or Services*, Section 3.2.1, provides a detailed definition of what is considered COTS equipment within the scope of the pressure safety program.

B. COTS containing equipment within the scope of ASME for quality marking (e.g., B31.1, Section I, IV, VIII, X, XII, or XIII) shall be quality marked. *Exception: COTS containing equipment within the scope of ASME Section VIII but with non-ASME quality marked vessels may be permitted upon design review acceptance.*

C. COTS equipment that has pre-installed relief devices utilize the manufacturer as the Designer to satisfy overpressure protection requirements for the equipment. Overpressure protection outside the confines of the COTS equipment remains the responsibility of the ESM Ch. 17 Designer.

8.4 NASME PRESSURE SYSTEM DESIGN

(Requirement 17-0225)

This section is only applicable if NASME equivalency can be applied; see Application of Non-ASME (NASME) Code Equivalency Evaluations section above.

1. Piping that is not part of a "supporting piping system" but is within the scope of B31.3 or B31.9 may apply the applicable, approved equivalency evaluations in the Attachments of this chapter. The pressure system must meet the approved equivalency restrictions defined in each NASME section.

2. The equivalency evaluations are not applicable to boilers, pressure vessels, air receivers, or supporting piping associated with the ASME quality marked item. The equivalencies can apply to all other piping within a system that has a vessel.

From Attachment GEN-1 Definitions and Acronyms:

Supporting piping systems – term shall be considered any and or all the piping necessary for the function of the pressure vessels or air receivers. Piping that is attached in excess of that required for the function of the pressure vessel or air receiver is not "supporting piping." This is analogous to the application of Boiler External Piping under ASME B31.1 and B31.9. See Figure 2 below.

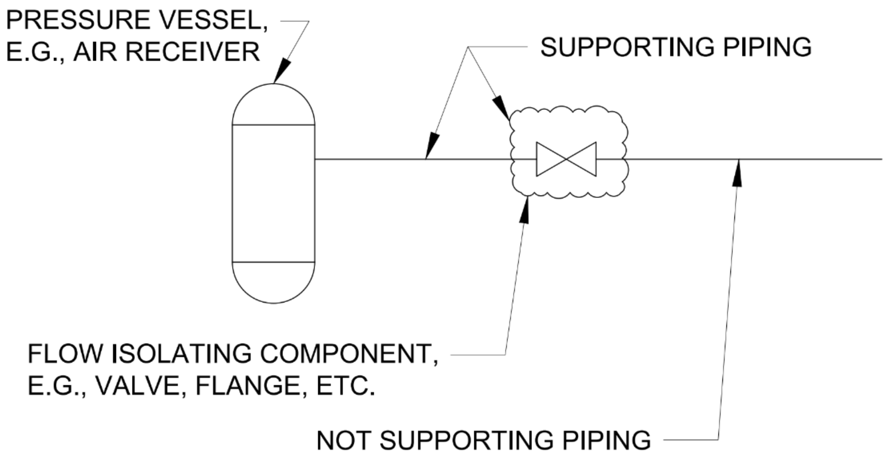


Figure 2

3. Previously approved components and materials on the Reputable Manufacturers List (RML) of approved NASME piping components allowed for use is maintained by the CPSO/DCPSO and available for both internal and external web access here.

4. The RML includes the equivalency evaluations (Att. REQ-5, -6, or -7) for which the approved components can be applied. If using the components on an unapproved NASME attachments, the Designer shall seek approval for use.

5. NASME materials and piping components are selected by the Designer based on the applicable equivalent safety evaluation. The design is reviewed using the Design Review process outlined in this chapter.

6. Items submitted to reputable manufacturers listing must be evaluated and accepted by the LANL CPSO/DCPSO prior to use. To submit a request for Reputable Manufacturers List (RML) additions, add desired components to the latest RML in empty rows at the bottom of the list. Format previous revision entries in black text and desired entries in red text. Submit revised RML to the LANL CPSO/DCPSO for review and acceptance. If accepted, reviewer will have the information included into the RML on the ESM website and notify requestor.

8.5 OVERPRESSURE PROTECTION REQUIREMENTS

(Requirement 17-0226)

A. General

1. Every pressure system shall have an overpressure protection evaluation. Overpressure protection (e.g., pressure relief devices) protects a system from over-pressurization during beyond-design-basis abnormal conditions. Requirements for overpressure protection evaluations is provided in the Overpressure Protection Evaluation section, below. *Guidance: Attachment GUIDE-1, Overpressure Protection Evaluation Guide, provides examples of overpressure protection evaluations for a common variety of pressure systems.*

   Guidance: The pressure system owning organization is responsible for implementing the necessary preventing maintenance for overpressure protection as required by P101-34.

2. It is the Designer's responsibility (defined as the "user" in ASME Section VIII) to size the relief device if one is required. ASME BPVC Section VIII uses the terms "user" or "designated agent" as shown in Nonmandatory Appendix NN, Guidance To The Responsibilities Of The User And Designated Agent*. Exception: COTS air compressor packages that have pre-installed relief devices utilize the manufacture as the "designated agent" to satisfy the ASME Section VIII requirements.*

3. Generally, pressure relief devices shall have a relief pressure setting not higher than the component with the lowest pressure rating in the portion of the system being protected. This requirement may vary depending on the Design Basis, particularly if ASME codes are involved.

4. Backflow preventer regulators shall not be used as pressure relief devices.

5. Pressure regulators are not considered pressure relief devices, however there are cases where there are alternative methods to relief devices that may be considered (e.g., the use of multiple regulators in series with appropriate administrative controls to detect a single regulator failure).

6. An oversized pressure relief valve (PRV) can chatter, which can damage the PRVs and/or the pressure system. This is especially true in the case of piping systems where the pressure system volume available for accumulation is small. *Guidance: Pressure Protection Design Guide WSRC-M-DP-G-0006, Rev. 5, contains information on PRV chatter.* For the protection of piping systems and their PRVs, the PRV capacity should not exceed the failure flow rate of the pressure system by more than a factor of two. For PRVs less than 1½" Nominal Pipe Size (NPS), greater ratios may be acceptable.

7. Relief devices that are ASME stamped (e.g., V, UV, UD, HV, etc.) are accepted as listed items for B31 design basis. Any non-stamped relief device with a set pressure of 15 psi or above that is used on a B31 design basis pressure system must be evaluated if required by the code of record as an unlisted component. Relief devices

8. A set pressure less than 15 psi are not within the scope of code stamping (i.e., non-stamped). *Guidance: Swagelok relief devices are accepted as listed components, but because they are non-stamped proportional relief devices, they must be used with great care and their use is discouraged.*

9. The nominal pipe size of piping, valves and fittings, and vessel components between a pressure system and its pressure relief device must be at least as large as the nominal size of the device inlet. *Example: A ½" inlet pressure relief device **cannot be** connected to a ¼" nominal pipe via reducing fittings. Conversely, a ¼" pressure relief device **can be** connected to a ½" nominal pipe systems using reducers.*

10. Power Boiler relief devices shall meet the requirements of ASME BPVC Section I and Section XIII.

11. Heating Boiler relief devices shall meet the requirements of ASME BPVC Section IV and Section XIII.

12. Pressure Vessel relief devices shall meet the requirements of ASME BPVC Section VIII and Section XIII.

13. ASME Fiber-Reinforced Plastic Pressure Vessel relief devices shall meet ASME BPVC Section X and Section XIII.

14. ASME Transport Tank relief devices shall meet ASME BPVC Section XII, Section XIII, and Title 49 CFR.

15. Other non-reclosing relief devices (e.g., rupture pin/buckling pin and spring-loaded) may also be used.
Guidance: See ASME Section XIII Parts 5 and 6 for more information on the use of these devices.

16. Pressure relief of DOT shipping containers (other than ASME Section XII) is governed solely by the Title 49 CFR and not within the scope of the ESM Chapter 17.

17. Liquid Service: Relief devices for vessels that operate with liquid must use relief protection designed for liquid service. *Example: If a relief device is installed at the bottom of a liquid-filled pressure vessel that has a gas space at the top, it would require a liquid-service relief device.*

18. Gas Service: Relief devices for vessels or piping that operate with compressed gases must use relief devices for gas service. *Example: If a relief device is installed at the top of a liquid filled pressure vessel in the gas space at the top it would require a gas service relief device.*

    NOTE: Pressure systems designed to be capable of withstanding the max fill pressure of a gas cylinder are not required to have overpressure protection (Requirement 17-0227).

19. Steam Service: Relief devices for steam service must use relief devices rated for steam service.

20. Cryogenic Service: Relief protection for cryogenic systems must be suitable for the design temperatures and pressures.

21. New or recertified pressure relief valves must be independently tested with a factory-locked set pressure. *Guidance: ASME-stamped relief devices and recertified ASME-stamped relief devices (e.g., "VR" stamped) are by default required to have locked setpoints with independent testing.*

22. Relief devices are required to vent to a safe location, in some cases the vent valve and relief device vents maybe required to be routed outside or to a fume hood or vent system. Designers should consult with OSH, Radiation Protection and/or Fire Protection to aid in this determination.

23. Relief device stop valves (a valve before or after the relief protection) are forbidden by ASME BPVC for steam boiler (Section I) or heating boiler (Section IV) applications. *(Requirement 17-0228)*

24. Relief device stop valves are discouraged for other applications but may be used when all the requirements of the ASME COR are met (e.g., locked open during normal operations). *Example: See ASME B31.3 para. 322.6.1, F322.6, and ASME BPVC Section VIII, Division 1, UG-156. (Requirement 17-0229)*

25. Operations where stop valves are closed must institute the practice defined in ASME B31.3 F322.6 or ASME Section XIII Nonmandatory Appendix B for control of the relief devices while closed and to ensure emergency venting as necessary.

B. Overpressure Protection for Fire *(Requirement 17-0230)*

1. Designers shall determine the need for overpressure protection for pressure systems due to exposure to fire or other unexpected sources of external heat.

   Example: ASME BPVC Section VIII, Division 1, Nonmandatory Appendix M, Part M-13 provides information and references and recommendations for sizing of relief devices for fire conditions. When a pressure vessel can be exposed to fire or other unexpected sources of external heat, the pressure relief device(s) shall meet ASME BPVC Section VIII, UG-153(a)(2) and/or UG-153(a)(3) as applicable.

Guidance: A vessel in a room with a rated fire suppression is not required to have a fire rated relief because the fire suppression system is a credited control.

C. Liquid Lock Overpressure Protection *(Requirement 17-0231)*

1. Liquid lock can be common in cryogenic pressure systems where cryogenic liquid is flowing through the system. Designers should avoid piping installations that could trap cryogenic fluid and, if this cannot be avoided, shall provide overpressure protection as described below. Liquid lock may occur in other types of pressure systems as well, such as systems with incompressible fluids that experience large temperature fluctuations without properly designed liquid expansion vessels.
2. An overpressure protection evaluation is required to determine if liquid lock relief valves are required.
3. If the analysis indicates the pressure increase of the trapped liquid will not exceed the design pressure temperature rating of the piping components, then liquid lock relief protection is not required.
4. If the analysis indicates the pressure increase caused by heating or cooling of the liquid filled piping can exceed the design temperature pressure rating of the piping components, then liquid lock relief protection is required.
5. When liquid lock relief protection is required relief devices must be installed between within the potential liquid lock boundary to prevent over pressurization of the pressure system.
6. Liquid thermal expansion relief valves shall not have a set point greater than leak test pressure or 120% of the design pressure, whichever is lower.
7. Systems do not require provisions for liquid lock relief when the pressure system fluid does not cause pressures in excess of design pressure at single fault conditions.

8.6 OVERPRESSURE PROTECTION EVALUATIONS

A. General

1. Every pressure system shall have an overpressure protection evaluation to determine the pressure relief device needs of the system. The format of the evaluation is not critical; however, the evaluation shall have an independent verification. The evaluation can be developed using AP-341-605, *Calculations*, or by using one of the calculation tools offered by the Pressure Safety Program. Available calculation tools may be found via the ESM Ch. 17 Reference Data SharePoint.
2. If a single-fault condition (not including failure of a relief device) would cause the design pressure of a piping system or the maximum allowable working pressure

(MAWP) of an ASME-stamped item to be exceeded, or cause backfill pressurization beyond the design basis of a vacuum system, overpressure protection is required to protect against over-pressurization.

a. Consideration must also be given to the possibility of latent failure that need to be addressed as single-fault conditions. See Attachment GEN-1, *Definitions and Acronyms*, for more information on latent failure.

3. ASME BPVC Section VIII Division 1 UG-154(e) *Overpressure Protection by System Design* or ASME BPVC Section XIII Part 13 *Rules for Overpressure Protection by System Design* may be used to substantiate the safety of the pressure system without the need for a pressure relief device.

4. Pressure system designs must include a calculation report that includes at least, but not limited to the following:

a. Determination of the maximum pressure that can occur (see A.2 above).

1) If this maximum pressure DOES NOT exceed piping system design pressure or pressure vessel MAWP, a pressure relief device is NOT required, and the calculation is complete.

NOTE: This does not apply to boilers, which are required by code to always be equipped with relief devices.

2) If the pressure CAN exceed the system design pressure or pressure vessel MAWP the calculation determines that a pressure relief device IS required and b. through f. below shall be included in the calculation.

b. Determination of the required relieving flow at single-fault condition (not including failure of a relief device) or latent failure (maximum pressure source flow rate).

c. Determination of the required pressure relief device set pressure (shall be set no higher than pressure system design pressure or vessel MAWP unless allowed by the COR).

d. Determination of the allowable overpressure permitted by the Design Basis.

e. Determination of the pressure relief device capacity at allowable overpressure as required by the COR for the application.

f. Determination of inlet/outlet pressure drop at relieving conditions; this plays a significant role and needs to be included in the relief calculations.

Guidance: The following documents may be used to help evaluate the pressure systems for relief protection.

- Attachment GUIDE-1*, Overpressure Protection Evaluation Guide*
- API Standard 520 *Sizing, Selection, and Installation of Pressure-relieving Devices, Part I, Sizing and Selection*
- API Standard 520 *Sizing, Selection, and Installation of Pressure-relieving Devices, Part I, Sizing and Selection Part II, Installation*
- API Standard 521 *Pressure-relieving and Depressuring Systems*

- API Recommended Practice, Guide for Pressure-Relieving and Depressuring Systems

B. Overpressure protection evaluations for pressure systems using gas cylinders

1. An accurate gas cylinder supply pressure shall be used when performing the evaluation:

   a. Currently, LANL Gas Facility (LOG-PT) can supply four different standard gas cylinders. The gas cylinders are DOT specification packaging 3A2015, 3A2000, 3A2260, and 3AA2265. The maximum supplied pressure is 2265 psig at 21°C (70°F).

   b. However, gas cylinder supply pressure can vary greatly among gas cylinders even for a single gas. For example, nitrogen gas cylinders of varying sizes can provide 225 psig to 2640 psig with CGA 580, 3500 psig with CGA 680, and 6000 psig with CGA 677.

   c. In addition, DOT regulations also allow that some gas cylinders (DOT 49 CFR § 173.302a(b) DOT 3A, 3AX, 3AA, 3AAX, and 3T) may have an internal pressure 10% greater than the marked service pressure at 21 °C (70 °F) if the gas cylinders are stamped with a "+".

2. The replacement of a gas cylinder with a fill pressure that differs from the fill pressure defined in the original overpressure protection is considered a pressure system modification that requires a new overpressure protection evaluation.

3. A flow reducing orifice, also known as a Restrictive Flow Orifice (RFO), may be used on a gas cylinder to reduce the maximum flow below the capacity of the relief device selected for the system.

   Guidance: Use of orifices is not required provided the pressure relief device(s) have a capacity that meets or exceeds the maximum flow rate through the regulator.

C. Overpressure protection evaluations for pressure systems not using gas cylinder supply pressure

1. For a pumping system, the dead head pressure of the pump would need to be evaluated and if a relief device is required; the necessary relief device capacity would be based flow rate/differential pressure on the pump curve. Additionally, if a closed-loop pumping system connects to a makeup water system, full unregulated makeup water pressure (single-fault failure of makeup water pressure regulator) during normal pumping system operations may need to be considered.

2. For a compressor, the flow rate of the compressor at the delivery pressure, or the failure of the high limit switch needs to be evaluated.

3. Internal generation of pressure due to temperature change or a chemical reaction must also be considered when applicable.

4. Other non-reclosing relief devices (e.g., rupture pin/buckling pin and spring-loaded) may also be used. *Guidance: See ASME Section XIII Parts 5 and 6 for more information on the use of these devices.*

8.7 GAS CYLINDER PRESSURE SYSTEMS

A. Pressure systems that connect to gas cylinder pressure sources shall be connected using the correct CGA for the cylinder.

B. Designs including gas cylinders shall use compatible regulators (e.g., don't put an oxygen CGA on a nitrogen regulator). Regulators that are incompatible for the media are prohibited.

C. Piping components used between the gas cylinder valve and the regulator shall be rated for the full as-delivered pressure of the cylinder.

D. Designs without a pressure regulator in the system may be used if the entire system or sub-system are designed to withstand at least the maximum gas cylinder pressure (e.g., a manifold of multiple gas cylinders that connect to a downstream pressure system).

Guidance: Entire pressure systems are generally not designed without regulators because the change in pressure/flow rates as the gas cylinder contents deplete presents operational difficulties.

E. Gas cylinders pressure systems with regulators shall have a regulator manifold incorporated into the design as shown in Figure 3 below.

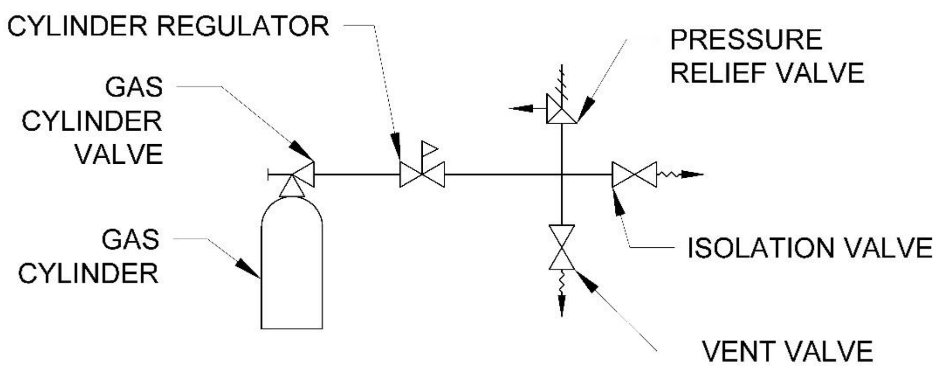


Figure 3

F. The following illustration Figure 4 shows the placement of a flow reducing orifice also known as a Restrictive Flow Orifice (RFO) on a gas cylinder.

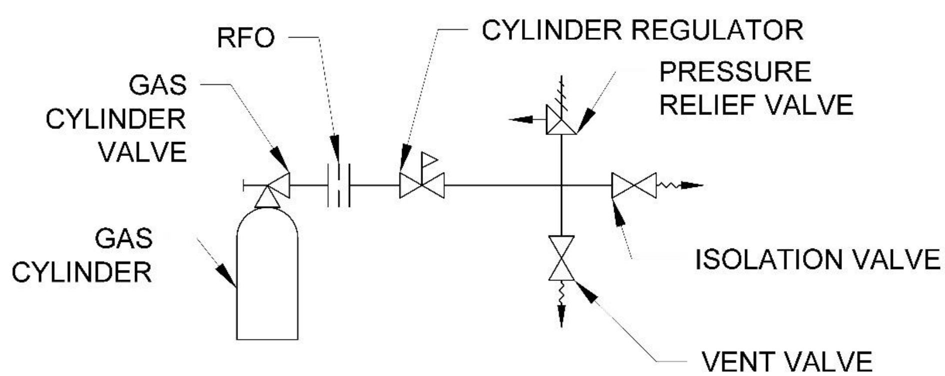


Figure 4

G. The same RFO may be placed after the regulator but may present operational issues since the orifice restriction may decrease operational flowrates. In addition, all items between the regulator and the orifice must be rated for maximum upstream bottle pressure (in the event a regulator fails open). This would include the gauges in the illustration above. It is recommended that RFOs be placed upstream of the regulator.

H. Pressure systems that have flow paths or vents that open directly or indirectly to the atmosphere do not require pressure relief devices (i.e., overpressure protection by system design). *Reference: ASME B&PVC Section XIII Part 11.*

I. Piping components used between the gas cylinder valve and the regulator shall be rated for the full as-delivered pressure of the cylinder.

8.8 GENERAL PRESSURE SYSTEM DESIGN

A. Flexibility Analysis

1. Flexibility analysis of a piping system shall be performed on all new pressure systems with a design temperature greater than 350°F or less than -238°F. Flexibility analysis should be considered for piping systems between -238°F and 350°F when supported beyond deadweight-only pipe support (e.g., lateral seismic supports) because free thermal displacement will be restricted. *(Requirement 17-0232)*

   a. Isometric drawings are required for flexibility analysis and are to be submitted as part of the design.

   b. Software may be used to perform flexibility analyses but must meet ESM Chapter 21, *Software*, requirements (e.g., when ML-1, 2, or 3); see Pressure System Design Software section below.

B. Piping, Tubing, and Flanges

1. Wall-thinning caused by bending of piping or tubing must be accounted for when performing design pressure calculations. This may also be achieved by utilizing an approved vendor tubing or pipe bender or providing a wall thickness 1.5 times the minimum required by the COR for the intrados or extrados of a curved pipe segment. *(Requirement 17-0233)*

2. Design of pressure systems that form and/or bend pipe or tube shall be specified by the Designer and if applicable meet COR requirements. *(Requirement 17-0234)*

   a. Flattening, corrugation, stretching, thinning, wrinkling, and ovaling of piping or tubing shall not exceed the design allowable.

   b. Designs shall address cold or hot formed pipe bends.

   c. Pipe bending shall follow a mandrel or guided bending process. Sand, beads, or other abrasive materials shall not be used to accomplish uniform bends for pressure system tubing or piping.

3. For systems that vent or discharge pressure to ambient surroundings (e.g., manual valves, nozzles, relief devices, solenoid valves), reaction thrust resulting from device discharge shall be evaluated. Systems shall be sufficiently braced to

withstand the maximum and sustained thrust potential. Thrust evaluations shall be documented and receive an independent verification (e.g., AP-341-605 meets this but most evaluations are simple enough that AP-341-605 is not necessary). If evaluations determine that the resultant thrust could impart significant loading onto the system, the anchor and any required piping support shall be defined. *(Requirement 17-0235).*

a. For compressed gas systems, thrust force is usually negligible but justification must still be provided. However, thrust force evaluation is not required when utilizing a compressed gas relief device not larger than ¼" NPS inlet and less than or equal to 150 psig setpoint.

4. Flange bolts and gaskets referenced in ASME PCC-1 *Pressure Boundary Bolted Flange Joint Assembly*, are defined by LANL as listed items if the COR recognizes the referenced code as listed.

C. Pressure System Design Software

1. Use of computer software (e.g., Cosmos®, NASTRAN®, COMPRESS, CAESAR®, Pro/Mechanica®, Ansys®, Algor®) to perform analysis of pressure systems and components is acceptable in performing engineering calculation. However, when the pressure system is ML-1, 2, 3 the software shall meet ESM Chapter 21, *Software* or P1040, *Software Quality Management*. *(Requirement 17-0236)*

D. Piping Supports

1. Follow the COR for piping supports. *(Requirement 17-0237)*

2. When a structural support design is presented by a qualified Designer and is determined to meet ESM Chapter 5, *Structural*, the design meets the ASME B31 piping support element fixtures requirements. Pre-engineered fixtures (e.g., off-the-shelf built to specifications such as Manufacturers Standardization Society (MSS) SP-58) shall meet the applicable ASME B31 COR. *(Requirement 17-0238)*

3. Comply with LANL Master Spec Section 22 0529 *Hangers and Supports for Plumbing Piping and Equipment* for general installations of piping systems.

E. Welding/Brazing Design *(Requirement 17-0239)*

1. Welding/brazing qualifications, welding/brazing procedure specifications (WPS/BPS), and welding/brazing performance qualification shall meet ESM Chapter 13.

2. The Designer shall provide the weld calculation and dimensions.

3. The Designer shall identify the weld process and WPS/BPS.

F. Soldering Design *(Requirement 17-0240)*

1. Soldering is only applicable when permitted by the COR.

2. The Designer shall specify the solder, the flux, and the joints and any pass/fail examination requirements.

3. The Designer is responsible for the pressure rating of the solder joint for the application.

4. The Designer shall specify the soldering process specification as required by the COR. For example, ASME B31.3 and B31.9 requires ASTM B828, *Standard*

Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings.

8.9 PRESSURE SYSTEM MATERIALS

A. It is the Designer's responsibility to select materials suitable for the fluid service. Materials are to be selected that resist deterioration in service and meet the service life defined in the PSIP.

1. The Designer shall define the corrosion rate of the piping system based on system fluid and material selection. If necessary, the Designer shall implement corrosion control for the pressure system. See PS-GUIDE for guidance regarding corrosion.

2. Buried steel pipe shall be protected from corrosion by either cathodic protection or a coating.

a. For cathodic protection design requirements, refer to ESM Ch. 7, *Electrical*, Section G4090, *Other Site Electrical Systems*, 1.0 Cathodic Protection.

b. If a coating system is used it shall be holiday tested in accordance with ASTM G62, *Standard Test Method for Holiday Detection in Pipeline Coatings*. Method A or B shall be used for determining pinholes, voids, or metal particles protruding through the coating. Method B shall be used to verify the thin spots in the coating.

Guidance: Master Specification Section 23 2113, Hydronic Piping, Part 3.6 Corrosion Control, contains detailed information for pipe coatings for black steel pipe. This information can be applied to any buried black steel pressure system; it is not exclusive to hydronic piping.

3. Pressure systems that require periodic inspection because of potential corrosion or required corrosion control shall be identified in the design. The expected corrosion rate shall be specified by the Designer. The pressure system owning organization is responsible for implementing necessary preventative maintenance governed by P101-34.

NOTE: The pressure system owning organization is responsible for implementing any necessary preventing maintenance for corrosion control as required by P101-34.

B. When specifying nonmetallic materials, the Designer will select materials that are compatible with the fluid service in the piping system and be capable of withstanding the Design Pressures and Design Temperatures. See PS-GUIDE for guidance regarding selecting nonmetallic materials.

C. The Designer shall select materials that will not contaminate the service fluid.

8.10 SYSTEM INTERACTIONS

(Requirement 17-0241)

A. Pressure systems that are interconnected shall be evaluated to eliminate or control the potential for adverse interactions. Some common examples of interconnected pressure systems include the following:

1. Multiple pressure sources containing the same or different fluids connecting to a common pressure system.
2. One pressure source connecting to multiple pressure subsystems that have incompatible fluids.

B. The following strategies are suitable to eliminate or control the hazards presented by adverse pressure system interactions:

1. Utilizing P101-3, *Lockout/Tagout for Hazardous Energy Control*
2. Utilizing administrative controls via work procedures/processes (e.g., integrated work document (IWD), WPD, etc.)
3. Designing systems that could interact with non-interchangeable fittings
4. Providing overpressure protection for each subsystem suitable to each of their design pressures
5. Designing the system with a double block and bleed configuration
6. Designing the system with double check valves in series where two or more incompatible fluid systems are pressurized by a common pressure source. See example in Figure 5 below.

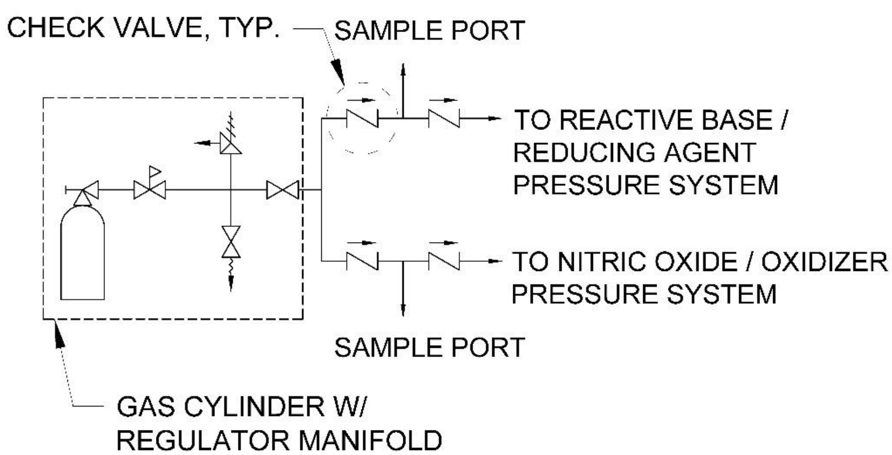


Figure 5

8.11 FLEXIBLE HOSES

(Requirement 17-0242)

A. Flexible hose assemblies without manufacturer's design pressure rating indicated on the hose/flexible tubing shall not be used.

B. Non-metallic hoses may be restricted from flammable service based on the COR.

C. Flexible hoses shall be installed and used in such a manner as to prevent kinking and to minimize torsion, axial loads, twisting, and abrasion.

D. Pre-approved flexible hoses accepted as Listed Components for ASME B31 and NASME Design Basis, respectively, are listed in the ASME Accepted Unlisted Items and NASME Reputable Manufacturers List.

E. All flexible hoses shall be procured in accordance with P101-34, *Pressure Safety*, Attachment D, *Procurement of Pressure Safety Goods or Services*, Section 3.2.4.

8.12 FLEXIBLE HOSE RESTRAINTS

(Requirement 17-0243)

A. General

1. When flexible hoses fail, they can pose a whipping hazard to the worker. Flexible hoses shall be evaluated for reaction thrust load in the event of a failure of the hose.
2. Flex tubing/hoses located inside glove boxes, equipment, or test setups where whipping poses no nuclear safety or personnel danger are excluded from requirements for flexible hose external restraints.

B. External Restraints

1. Flexible tubing and hoses over 12 in. and in service pressure greater than 150 psig must be constrained at both ends or shielded in case of end-connector failure. The maximum separation distance between flexible hose restraints must not exceed 6-ft. intervals. (e.g., an 8-ft. flex hose must use 3 restraints see REQ-9 attachment). Specifically prohibited are free-rotating/translating systems whose designs prohibit securing at 6-ft. intervals.
2. Attachment REQ-9, *Approved Flexible Hose Restraints and Thrust Load Evaluations,* contains information on pre-approved hose restraints and methods for calculating the force from a line failure. This attachment also includes information on other brands that are common and accepted when used within manufacturer guidelines.
3. Approved alternatives or restraining devices approved by a Designer may be used if the restraining device is demonstrated via evaluation to withstand the thrust loads posed by both the initial surge thrust and the sustained surge thrust.
4. Connection of the hose whip restraint to an anchor must be capable of restraining the hose in the event of joint separation.

C. Internal Restraints

1. Flexible hoses that are self-arresting with an internal valve enclosed within each hose end do not require hose restraint because these hoses do not whip. Examples include but are not limited to Global Passive Safety Systems Lifeguard Hose and U.S. Hose Corporation 402X with Spring Guard. Attachment REQ-9, *Approved Flexible Hose Restraints and Thrust Load Evaluations* contains information on pre-approved internal hose restraints and methods for calculating the force from a line failure.

8.13 VENTING OR DISCHARGE OF PRESSURE SYSTEMS

(Requirement 17-0244)

A. All pressure systems shall be designed with a means to manually vent pressure from the system. Loosening fittings to vent pressure is prohibited.

B. Vents and discharges (including relief devices) for hazardous pressure system fluids, e.g., steam condensate, radioactive, flammable, lethal, toxic, reactive, hazardous, or inert asphyxiant gases, must be evaluated for acceptable discharge locations by a Fire Protection, OSH-ISH, or other appropriate SME.

C. Some codes require vent screens, e.g., ASME CSD-1 and NFPA 54. Relief devices and vents that are in an environment which could cause the exhaust ports to be plugged (e.g., insect nests, water, or ice) shall be fitted with a screen or other device to keep them from becoming plugged. Screens/covers shall not inhibit the flow capacity of the relief device.

8.14 INSTRUMENTS

(Requirement 17-0245)

A. Instruments are generally defined as items that are NOT considered "inline portions of instruments" as defined by ASME B31.3 para. 300.2. Common instruments in pressure systems are temperature- or pressure-responsive devices such as pressure gages, pressure transmitters, and transducers.

B. When a manufacturer's published operating range is equal to, or greater than, the design pressure of the system, the instrument shall be considered as meeting the requirements of 10 CFR 851.

   1. For pressure gauges, the maximum pressure and temperature rating is typically greater than the dial indicator range. If necessary, contact the manufacturer for these values.

C. When manufacturer's published operating range does not bound the design pressure, then safeguarding shall be applied to instruments to provide an equal level of protection in accordance with 10 CFR 851. These safeguards shall be in order of precedence: 1) engineering controls, 2) administrative controls, 3) personnel protective equipment.

D. When no pressure rating is available, the manufacturer shall be contacted to request this information. If the manufacturer is unwilling or unresponsive to provide a pressure rating, an evaluation of the instrument shall be performed to conservatively assign a pressure rating as follows:

   1. Verify all pressure boundary components are sealed with in the instrument case to mitigate material impacting workers in the event of over-pressurization. This could include multiple layers of containment within the case itself.

   2. The construction of the instrument shall be conservatively evaluated to estimate the MAWP of the instrument. Estimate a pressure rating for individual components within the instrument case, e.g., stainless steel tubing, plastic tubing, and valves. Use the lowest individually estimated pressure rating as the estimated pressure rating for the instrument.

E. Bourdon-tube pressure and compound pressure vacuum dial-indicating gauges that operate at pressures greater than 15 psig shall be fabricated to protect workers. Two methods that satisfy this requirement include the following:

1. Pressure gauges approved by Underwriters Laboratories (UL) in accordance with UL-404, Standard for Gauges, Indicating Pressure, for Compressed Gas Service – Standard for Safety.

2. Gauge design that incorporates the following

   a. Tempered safety glass, plastic face, or gauge shield; AND

   b. A blowout back or plug.

8.15 SPECIFIC REQUIREMENTS BY SYSTEM TYPE

A. Cryogenic and Pseudo-Cryogenic Pressure Systems *(Requirement 17-0246)*

1. Refer to P101-5, *Cryogens and Compressed Gases: Health and Safety Requirements*, for hazards, design, transportation, filling, storage, use, and specific commodity hazards related to cryogenic and pseudo-cryogenic pressure systems.

2. For systems using ball valves, the ball must have a pressure relief hole designed into the ball to prevent over pressurization inside the ball cavity due to thermal expansion when the valve is in the closed position. The closed position of the ball valve must be installed toward a path with a vent or relief system.

3. All valves and components must be suitable for cryogenic service.

4. Hoses used for cryogenic service must be convoluted stainless steel or specifically designed for cryogenic service.

5. Polymer-lined flexhoses shall not be used.

6. Nonmetallic materials must be compatible with the fluid and be suitable for both the temperature and pressure.

7. The system must be designed for safe cryogenic service for example double-walled pipe with integrated expansion joints.

8. Some pseudo-cryogenic liquefied gases have relatively low vapor pressures at low ambient temperatures and may require the use of check valves to prevent back flow into the container.

9. Design of cryogenic and pseudo-cryogenic liquefied gas pressure systems must take into consideration the effects that change of state of the fluid will have on the piping components (e.g., carbon dioxide "snow" particle impact will erode brass materials).

10. Depending on the fluid used for leak testing and the piping system design temperature it may be necessary to remove the gas or liquid to prevent "ice" formation in the cryogen system.

11. Attachment GUIDE-2, *Oxygen System Design Guide* has additional information on cryogenic oxygen.

12. Carbon dioxide cryogenic systems shall not be repurposed for oxygen because of the potential contamination from combustible materials.

13. Cryogenic Vessels *(Requirement 17-0247)*

    a. The internal portion of a stationary cryogenic vessel shall meet ASME Boiler and Pressure Vessel Code Section VIII.

    b. The vacuum jacket may either meet ASME BPVC Section VIII or other suitable commercial standard such as

        1) CGA 341, *Specification for Insulated Cargo Tank for Nonflammable Cryogenic Liquids*

        2) CGA H-3, *Cryogenic Hydrogen Storage*

        3) NFPA 55, *Compressed Gases and Cryogenic Fluids Code*

14. Relief valves shall be installed whenever cryogenic liquids can be trapped between closures (liquid lock), and on the exterior of the double wall piping to prevent over pressurization.

B. Gas Cylinder Systems

1. Pressure relief devices incorporated integrally into the design of CGA pressure regulators do not perform a pressure protection function for downstream components and shall not be considered as sufficient overpressure protection (ref. CGA Publication E-4).

2. Gas cylinder regulators must meet CGA requirements and use CGA-approved fittings. *(Requirement 17-0248)*

3. Restrictive flow orifices (RFOs) used before a regulator on a gas cylinder (i.e., on the inlet side of the gas regulator) must be rated for full bottle pressure. *(Requirement 17-0249)*

4. Pressure systems designed to be capable of withstanding the full gas cylinder pressure are not required to have overpressure protection *(repeat of Requirement 17-0227).*

    a. Design of pressure systems with gas cylinders shall include the allowable cylinder overpressures in accordance with 49 CFR 173.302a(b), *Special filling limits for DOT 3A, 3AX, 3AA, 3AAX, and 3T cylinders*, if the cylinder ordered or received includes a plus sign (+) after the test date marking on the cylinder.

    b. Pressure systems using hazardous gas cylinders must be designed and evaluated against the requirements of ESM Chapter 10, Hazardous Processes, and its Attachment A: *Hazardous Gas Design*.

    NOTE: ESM Chapter 10 defines Hazardous Gas as toxic, flammable, oxidizing, pyrophoric, or asphyxiating.

    Guidance: Attachment GUIDE-2 – Oxygen System Design Guide, provides guidance for determining risk level of oxygen systems and design recommendations for mitigating risk.

C. Vacuum Systems

1. Vacuum systems that contain a radiological, flammable, toxic, or fluid damaging to human tissues as defined by ASME B31.3 para. 300.2, OR with a design temperature of less than -20°F or greater than 366°F shall meet the requirements of this chapter. *(Requirement 17-0250)*

2. Vacuum systems must be designed for the highest internal pressure from back-fill pressurization, chemical reaction, or thermal effects (including single-fault condition) or equipped with relief device(s) to prevent over-pressurization. *(Requirement 17-0251)*

3. Vacuum systems that **do not** contain fluids or design conditions noted above are excluded from the requirements of this chapter. *NOTE: If connected to a pressurized gas for backfill purposes, the gas source **is** a pressure system and shall meet the requirements of this chapter.*

4. A vacuum vessel that is subject to **less than** 15 psig internal or external ambient pressure shall be designed in accordance with ASME BPVC Section VIII Division 1 for external pressure or the design shall be reviewed to ensure that equivalent safety is provided. *(Requirement 17-0252)*

5. A vacuum vessel subject to internal or external pressure of 15 psig **or greater** shall be designed in accordance with ASME Section VIII Division 1 for both internal and external pressure. *(Requirement 17-0253) NOTE: a design rating of full vacuum may be applied where applicable as defined in ASME Sec VIII-1.*

D. Oxygen and Other Strong Oxidizing Media Systems *(Requirement 17-0254)*

1. Oxygen Systems

a. Oxygen-Fuel Gas pressure systems (e.g., oxy-acetylene) shall meet NFPA 51, *Systems for Welding, Cutting, and Allied Processes*. *(Requirement 17-0255)*

b. Oxygen piping systems shall meet ASME B31.3. *(Requirement 17-0256)*

c. Oxygen systems shall be designed, fabricated, cleaned, and tested to control ignition hazards at the design temperature, pressure, and oxygen concentration of the system. *(Requirement 17-0257)*

d. High pressure oxygen systems above 350 psig require an Oxygen Hazards Analysis and Failure Modes and Effects Analysis (FMEA). This requirement may be applied by the CPSO on oxygen or other strong oxidizing media systems less than 350 psig depending on the application.

Guidance: PS-GUIDE provides guidance for determining risk level of oxygen systems and design recommendations for mitigating risk.

2. General

a. Regulators for oxidizing media must be oil free, cleaned for oxygen service, and contain materials suitable for the pressure and temperature of the system.

b. Quick opening valves are not recommended, for example fast acting solenoid valves or quarter turn ball valves. Rapid changes in pressure due to quick opening components increase the risk of oxygen fire.

c. The Designer shall specify items to stop the kindling chain reaction if a fire were to ignite.

d. The Designer shall specify that cutting wheels on tubing cutters shall be free from grease, oil, or other lubricants not suitable for oxygen service.

e. The Designer shall specify joints to be brazed, welded, compression fittings, butt welded, or flanged. Particulate generating fittings are not allowed (e.g., NPT threads are an interference thread and generate particles). Purge gases may be required when brazing or welding to prevent the formation of oxides on the interior of the joint.

f. Oxygen or Oxidizing Service Cleaning

1) The Designer shall specify the cleanliness level (particulate and non-volatile residue) as determined by evaluation of the system temperature, pressure, and concentration of oxygen. Specifications for cleanliness of O_2 service pressure systems include:

a) ASTM G93 Standard Practice for Cleanliness Levels and Cleaning Methods for Material and Equipment Used in Oxygen-Enriched Environments

b) CGA G-4.1 Cleaning Equipment for Oxygen Service

c) EIGA/IGC 33 Cleaning of Equipment for Oxygen Service Guideline

2) Components, piping, and tubing specified for oxygen or oxidizer service must be cleaned as specified in this document, before assembly, and must be assembled in a manner that maintains cleanliness.

3) Additional information is contained in Attachment GUIDE-2, *Oxygen System Design Guide*, which may aid in meeting requirements stated here and below.

g. Material Requirements

1) Materials used for cleaning and leak-checking oxygen systems shall be compatible for use with oxygen. Hydrocarbon-containing soap solutions shall not be used for leak-checking these systems.

2) Oxygen systems with a design pressure greater than 350 psig shall contain no interconnecting hoses using polymeric materials.

3) Non-metallic materials used in oxygen service shall be evaluated for the oxygen concentration, design pressure, and design temperature.

h. Oxygen System Design

1) The oxygen system shall be designed to control ignition mechanisms. These mechanisms include but are not limited to adiabatic heating (heat of compression), particle impact, frictional heating, and mechanical impact. Example references include the following documents:

- ASTM G128, Standard Guide for Control of Hazards and Risks in Oxygen Enriched Systems
- ASTM MTG 36, Safe Use of Oxygen and Oxygen Systems, Second Edition 2007
- NSS 1740.15, JANUARY 1996, SAFETY STANDARD FOR OXYGEN AND OXYGEN SYSTEMS, Guidelines for Oxygen

System Design, Materials Selection, Operations, Storage, and Transportation

- NASA/TM-2007-213740, Guide for Oxygen Compatibility Assessments on Oxygen Components and Systems
- GLP-QS-8715.1.5 Revision C, Glenn Research Center, Glenn Safety Manual Chapter 5 Title: Oxygen

2) Only pressure regulators intended for oxygen service must be used. Oxygen regulators must not be used with other gases and must be maintained clean for oxygen service when not in use (see American Society for Testing and Materials (ASTM) G93, Standard Practice for Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen-Enriched Environments).

i. Oxygen System Lubricants

1) The Designer shall specify any oxygen system lubricants for the pressure system.

a) The Designer shall specify cutting lubricants for fabrication.

b) The Designer shall specify thread lubricants for assembly.

c) The Designer shall specify component assembly greases or packing materials.

2) Hydrocarbon-based lubricants shall not be used in gaseous oxygen or liquid oxygen (LOX) systems because they can easily ignite; the incorrect use of hydrocarbon-based lubricants is a common cause of oxygen system fires.

Guidance: The best lubricants for compatibility with high-pressure oxygen are highly fluorinated materials.

3) In addition to the above references, the following documents specifically address lubricants:

- MIL-PRF-27617 *Performance Specification, Grease, Aircraft and Instrument, Fuel and Oxidizer Resistant*
- DOD-PRF-24574 (SH) *Performance Specification, Lubricating Fluid for Low and High Pressure Oxidizing Gas Mixtures*
- ASTM G63, *Guide for Evaluating Nonmetallic Materials for Oxygen Service*

E. Hydrogen and Flammable Fluid Pressure Systems *(Requirement 17-0258)*

1. Hydrogen, Deuterium, and Tritium Pressure Systems

a. For hydrogen, deuterium, and tritium pressure systems, the requirements of ASME B31.3 shall be applied for items that fit within the scope of the code. Application of ASME B31.12 to these systems is optional. *(Requirement 17-0259)*

b. Systems containing hydrogen, deuterium, or tritium shall be evaluated for hydrogen embrittlement.

c. Tritium system design basis shall include DOE-HDBK-1129, Tritium Handling and Storage.

d. Flame arrestors, when used, must be rated for hydrogen.

2. Flammable Fluid Pressure Systems

a. Electrical components (solenoid valves, power strips, electrical control cabinets) must be intrinsically safe when required by the National Electric Code (NEC).

b. Flammability of binary gas mixtures shall be determined in accordance with the CGA P-23.

c. The Lower Explosive Limit (LEL), Upper Explosive Limit (UEL) of the fluid shall be in accordance with the Safety Data Sheet (SDS) of the material.

d. If the LEL or UEL limits must be determined see ASTM E681, Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases), or other equivalent methods.

e. Bonding and grounding must be evaluated for storage vessels and nonmetallic hoses, storage vessels, and systems by Fire Protection, OSH-ISH, or other appropriate SMEs.

f. An Emergency Isolation Valve (EIV) is required outside the building for a flammable gas distribution system inside a facility.

F. Facility Natural Gas and Liquefied Petroleum Gas *(Requirement 17-0260)*

1. LANL natural gas from the outlet of the natural gas distribution low-pressure regulator or meter to the appliance must comply with NFPA 54, National Fuel Gas Code.

a. Other codes may apply for safety features of the gas supply, e.g., ASME CSD-1 or NFPA 85 for boilers.

2. Comply with LANL Master Spec Section 23 1123, *Facility Natural-Gas Piping,* for general installations of NFPA 54 systems. Update 23 1123 for boilers installations with specific gas train requirements like ASME CSD-1 or NFPA 85.

3. Facility piping systems that supply liquefied petroleum gas shall comply with NFPA 58, *Liquefied Petroleum Gas Code* or ASME B31.3, *Process Piping*.

NOTE: The LANL master specifications do not currently cover NFPA 58 design.

G. Natural Gas Distribution (LANL Natural Gas Distribution System to Outlet of Low-Pressure Regulator or Meter) *(Requirement 17-0261)*

NOTE: This article contains supplemental information to ESM Chapter 3 Civil Section G30, paragraph G3060 Natural Gas and the two documents should be used concurrently. If/when G3060 indicates that it supersedes this material, then follow it preferentially.

1. Introduction, Purpose, and Scope

a. The 49 CFR 192, Transportation of Natural and Other Gas by Pipelines; Minimum Federal Safety Standards; and ASME B31.8, Gas Transmission and Distribution Piping Systems apply to the LANL natural gas distribution system until the outlet of the low-pressure regulator to the building or appliance. Both the ASME and the CFR must be satisfied (the most stringent code or CFR requirement shall apply).

b. While ASME Codes are issued at discrete intervals, the CFR may change at any time. The design should check the official website for the most current requirements.

2. Definitions

a. Specified Minimum Yield Strength (SMYS):

1) For steel pipe manufactured in accordance with a listed specification, the yield strength specified as a minimum in that specification; or

2) For steel pipe manufactured in accordance with an unknown or unlisted specification, the yield strength determined in accordance with §192.107(b).

b. Hydrostatic Design Basis (HDB) for plastic pipe is in accordance with PPI TR-4/2.

c. Class Location Unit is an onshore area that extends 220 yards (200 meters) on either side of the centerline of any continuous 1- mile (1.6 kilometers) length of pipeline.

3. Mandated Codes and Standards

a. 49 CFR 192, Transportation of Natural and Other Gas by Pipelines; Minimum Federal Safety Standards

b. ASME B31.8, Gas Transmission and Distribution Piping Systems

c. ASME B31.8S, Managing System Integrity of Gas Pipelines

4. Design Basis

a. Design pressure is 100 psig for wall thickness and testing.

b. Design temperature for buried pipe (most commonly HDPE) is 60°F.

c. Design temperatures for above ground pipe (most commonly steel) are:

i. Winter: 5°F dry bulb.

ii. Summer: 89°F dry bulb, 60°F wet bulb.

d. Pipe shall be limited in design to less than 20% of SMYS.

e. Maximum normal operating pressure is 60 psig.

f. Piping shall be designed for a Class Location Unit 4.

g. Piping components shall be as listed in 49 CFR 192.7 or Appendix B, and items that conform to standards or specifications referenced in ASME B31.8.

h. Cast iron and ductile iron pipe is prohibited from use.

i. Each pipeline must be designed with enough flexibility to prevent thermal expansion or contraction from causing excessive stresses in the pipe or components, excessive bending or unusual loads at joints, or undesirable forces or moments at points of connection to equipment, or at anchorage or guide points.

j. A service regulator shall have a relief device included in the design.

k. A low-pressure regulator shall have a relief device included in the design.

l. Branch connections less than 4:1 run: branch ratio may use ASME B16.11 fittings (weld-o-lets).

m. Metallic welding shall comply with ESM Chapter 13 - *Welding, Joining & NDE*.

n. Plastic Pipe: Comply with ESM, Chapter 13 – *Welding, Joining & NDE* and 49 CFR 192.283 and 192.285. Do not use electrofusion fittings without contacting a LANL U&I Group gas system representative.

o. The requirements of 49CFR192.629 Purging of pipelines, B31.8 841.2.7 Precautions to Avoid Explosions of Gas–Air Mixtures or Uncontrolled Fires During Construction Operations, and B31.8 831.4.2 Special Requirements (j) shall be met.

p. LANL Utilities and Infrastructure (UI) shall provide the labor to perform connection at distribution tie-in and all hot-tap operations.

q. The thickness of the base metal must be specified (t); the minimum leg dimension of the fillet weld (0.7t throat dimension), and the maximum leg dimension of the end fillet weld (1.0t throat dimension).

r. Any special joint preparation shall be identified and engineered.

s. If an approved welding procedure specification (WPS) does not exist for the required weld, a new WPS shall be generated.

t. Calculations shall be provided when performing horizontal directional drilling (HDD) or other pipe pulling operations to ensure the piping will handle all stresses experienced during and after construction.

u. All piping systems shall be tested after construction to the requirements of the B31.8 and Title 49 CFR 192 except for pre-tested fabricated assemblies and welded tie-in connections where post construction tie-in testing is not practical.

v. The circumferential welds associated with connecting pretested assemblies, pretested repair pipe lengths or sections, and welded tie-in connections not pressure tested after construction shall be inspected by radiographic or other accepted nondestructive methods in accordance with para. B31.8 826.2.

w. Nonwelded tie-in connections not pressure tested after construction shall be leak tested at not less than the pressure available when the tie-in is placed into service.

x. Butt weld ends shall be in accordance with ASME B31.8 Mandatory Appendix I, End Preparations for Butt Welding.

5. Special Interpretations

   a. Minimum plastic pipe SDR is SDR11 for HDD.

b. Design shall provide the total connected natural gas load in BTUs per hour, input requirement for each connected device in BTUs per hour with device room location, and pressure requirement at building wall.

c. Meters: Provide a gas meter for any building with a heating unit with an input BTU requirement of 5,000,000 BTU/hr or greater. The meter shall

1) be installed downstream of the low-pressure natural gas regulator.

2) be electronic and connected to the building automation system for monitoring.

3) incorporate pressure and temperature compensation.

d. Comply with the following LANL master specification and drawing details:

1) Master Specification 33 5100, *Natural-Gas Distribution*

2) Civil Detail ST-G3010-1, Valve Box

3) Civil Detail ST-G3060-1, *Site Gas Piping Tie-in*

4) Civil Detail ST-G3060-2, *Gas Regulator Station*

6. LANL Special Requirements

a. Provide 1 inch, 1-1/4-inch, 2-inch, or 3-inch Polyethylene service line and 2-inch minimum polyethylene (PE) main line as required for the delivery and to integrate with the existing piping.

b. When pneumatically testing piping, the test area shall be cleared of unauthorized personnel. ASME PCC-2, Repair of Pressure Equipment and Piping, Part 5, Article 5.1, paragraph 6.2 Pneumatic Pressure Test of Pressure Vessels or Piping, (page 202) may be used for the test clearance area determination.

c. Plastic piping shall be polyethylene, high density ASTM D2513, PPI-PE4710, SDR 11 iron pipe size, ASTM D3350 cell classification number 445574C, Driscopipe 8100 or Yellowstripe 8300), no substitution.

d. Steel pipe shall be protected from the burial corrosion by either cathodic protection or a coating.

e. For cathodic protection design requirements, refer to the ESM Electrical Chapter 7, Electrical, Section G4090, Other Site Electrical Utilities, 1.0 cathodic protection.

f. A factory applied fused coating system consisting of; an adhesive primer layer, with minimum 10 mil thermoplastic elastomer layer and minimum 40 mil polyolefin top layer containing UV protection; or alternatively an epoxy primer layer with minimum 50-mil high-density polyethylene top layer.

g. If a coating system is used it shall be holiday tested in accordance with ASTM G62, Standard Test Method for Holiday Detection in Pipeline Coatings. Method A or B shall be used for determining pinholes, voids, or metal particles protruding through the coating. Method B shall be used to verify the thin spots in the coating.

h. Use steel pipe if gas line is installed less than 20 feet from steam and condensate lines.

H. Steam/Condensate Pressure System Design *(Requirement 17-0262)*

NOTE: This article contains supplemental information to ESM Chapter 3 Civil Section G30, paragraph G3040 Steam/Condensate. The two standards should be used in conjunction during design.

1. Special requirements exist for boiler external piping. Reference the B31 COR and the figures to determine applicability and requirements:

   a. B31.1 Power Piping

      1) Figure 100.1.2-1, *Code Jurisdictional Limits for Piping — An Example of Forced-Flow Steam Generators with No Fixed Steam and Waterline*

      2) Figure 100.1.2-2, *Code Jurisdictional Limits for Piping — An Example of Steam Separator Type Forced-Flow Steam Generators with No Fixed Steam and Waterline*

      3) Figure 100.1.2-3, *Code Jurisdictional Limits for Piping — Drum-Type Boilers*

      4) Figure 100.1.2-4, *Code Jurisdictional Limits for Piping — Isolable Economizers Located in Feedwater Piping and Isolable Superheaters in Main Steam Piping (Boiler Pressure Relief Valves, Blowoff, and Miscellaneous Piping for Boiler Proper Not Shown for Clarity)*

   b. B31.9 Building Services Piping

      1) Figure 900.1.2, *Code Jurisdictional Limits for Piping — Drum-Type Boilers*

2. Steam/condensate pressure systems not exceeding 150 psig design pressure nor outside the 0-366°F design temperature range, ASME B31.9, *Building Services Piping*, is the most applicable design code, or other design codes such as ASME B31.1, *Power Piping*.

3. For steam/condensate outside the B31.9 scope limits, comply with ASME B31.1, *Power Piping*.

   a. Condensate piping outside of the building that returns to a central steam plant shall comply with ASME B31.1, *Power Piping*.

4. For new buildings in Technical Area 3 (TA-03) using the site steam distribution system (TA03-0022), design for incoming temperature/pressure of 500°F and 125 psig; operating pressure/temperature of 85 psig/366°F. For the condensate return system design for 250°F and 125 psig; operating pressure/temperature of 85 psig/200°F.

5. The use of cast iron is not permitted.

6. Refer to the following for additional information that may aid in the design of steam/condensate pressure systems:

   a. Master Specification 23 2215, *Steam and Condensate Heating Piping and Specialties (Note: B31.9 COR)*

b. Master Specification 33 6300, *Steam Energy Distribution (Note: B31.1 COR)*

c. Civil Standard Detail ST-G3040-1, *Site Steam/Condensate Tie-in (Note: B31.1 COR)*

d. Civil Standard Detail ST-G3040-2, *Site Steam Drip Leg (Note: B31.1 COR)*

e. Mechanical Detail ST-D3020-2, *Steam Pressure Reducing Valve (PRV) Station (Note: B31.9 COR)*

f. Mechanical Detail ST-D3020-3, *Steam Drip Leg (Note: B31.9 COR)*

g. Mechanical Detail ST-D3020-4, *Steam Drip Pan Elbow (Note: B31.9 COR)*

9.0 FABRICATION/ASSEMBLY REQUIREMENTS

(Requirement 17-0263)

A. Piping and Tubing

1. Cold spring (twisting or distortion of piping or components for alignment) that introduces strain in equipment or piping components shall be accounted for in the design so as not to be detrimental to pipe supports, or equipment (nozzle loads).

2. If misalignment occurs during fabrication and cold spring is not included or allowed in the design piping must be reworked to remove cold spring.

3. ASTM B88 and B280 tubing that meets UL 207 and UL 1963 wall thickness standards are acceptable for use.

Guidance: Check the ASME Allowed Unlisted Components List for the allowable pressure ratings.

B. Tubing Joint Assembly

1. Swagelok compression tubing fittings are approved for use as listed components. Any other manufacturer's flareless or compression tubing fittings are not considered listed and shall be evaluated prior to use.

2. Intermixing of manufactures proprietary piping components is not allowed (e.g., Swagelok compression tube fitting bodies with Parker ferrules).

3. Flareless and compression tubing joints shall be assembled per the manufacturer's instructions.

4. Swagelok compression fittings shall be assembled and reassembled as required by the Swagelok manufacturer documents.

   a. Reference MS-13-151, *An Installer's Pocket Guide for Swagelok Tube Fittings*

   b. Swagelok Tube Fitter's Manual, 2016 or latest edition.

5. If the design uses flared tubing joints (e.g., Society of Automotive Engineers Standards 513 and 514), it shall specify the acceptance criteria of the flare and the flare imperfections.

6. Personnel fabricating system using compression tubing joints must be trained in accordance with UTrain Course 30831, *Compression Fittings Assembly* or approved equivalent.

C. Threaded Joint Assembly

1. NPT joint assembly shall be in accordance with ASME B1.20.1 3.1.9 Wrench-Tight Engagement between External and Internal Taper Threads.
2. Intermixing of different thread types is not allowed (e.g., straight thread and pipe thread).
3. The design shall specify if threaded fittings must be lubricated and the type of lubricant that is compatible with the system fluid (e.g., halocarbon, hydrocarbon, fluorocarbon, etc.).
4. Unless otherwise specified by the Designer, NPT pipe fittings shall use polytetrafluoroethylene (PTFE) tape.
5. Other types of threaded fittings shall be assembled per the manufacturer's directions.

D. Flanged Piping Joint Connection Assembly

1. The fastener assembly load (torque) design must follow the most applicable of the following:
   a. Manufacturer standards, joint design, and the materials of construction,
   b. A published specification or controlled standard based on the COR,
   c. ASME PCC-1, *Pressure Boundary Bolted Flange Joint Assembly*, as allowed by the COR,
   d. ASME BPVC Section VIII, Division 1, Mandatory Appendix 2, *Rules for Bolted Flange Connections with Ring Type Gaskets*, as allowed by the COR,
   e. Applicable B31 piping COR calculations, or
   f. Special calculations by the Designer accepted by the Owner.
2. Assembly torque of flange bolts must include directions on the use of lubricant or directions not to use lubricant. If lubricant is required, the type of lubricant and how it will be applied must be specified.
3. Flanges must be repaired or replaced whenever any damage has been caused to the sealing surface that prevents the gasket from sealing. Excessive torque beyond torque specifications to achieve a leak-free seal is strictly prohibited.
4. Nuts must have full thread engagement on the bolts or studs. One to two exposed threads are the preferable amount that defines full thread engagement. The minimum acceptable engagement is the outer edge of the nut being not less than flush with the end of the bolt or stud.
5. The faces and bolt holes of flanges must be concentrically aligned, with the flange faces parallel as required by the COR.
6. Bolted flanges shall be retorqued approximately 24 hours after initial torque following assembly, and prior to any leak or pressure tests.
7. New flange gaskets may be required when flanges are loosened.

8. The Designer shall specify the fasteners required to assemble flanges.

    a. The internal and external thread class of the fasteners per ASME B1.1, *Unified Inch Screw Threads (UN, UNR, and UNJ Thread Forms)*

    b. Bolt or stud in accordance with ASME B18.2.1, *Square, Hex, Heavy Hex, and Askew Head Bolts and Hex, Heavy Hex, Hex Flange, Lobed Head, and Lag Screws (Inch Series)*

    c. Nut in accordance with ASME B18.2.2, *Nuts for General Applications: Machine Screw Nuts; and Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)*

    d. Washers in accordance with ASME B18.21.1, *Washers: Helical Spring-Lock, Tooth Lock, and Plain Washers (Inch Series)*

NOTE: Flange bolts and gaskets referenced in ASME PCC-1 Pressure Boundary Bolted Flange Joint Assembly, are defined by LANL as listed items if the COR recognizes the referenced code as listed.

E. Welded and Brazed Joint Assembly

1. The Designer shall specify welding or brazing requirements necessary to meet any applicable code(s) of record and ESM Chapter 13.

2. Welding procedures and personnel shall be certified for the application that they are performing through the LANL welding program, as defined by ESM Chapter 13. See also LANL Master Specification Sections 01 4444, *Offsite Welding and Joining Requirements;* 01 4455, *Onsite Welding and Joining Requirements*; and 01 4631, *Welding of B31 Piping*.

3. Onsite welding must be performed by welders that are currently certified, having completed testing and qualification in accordance with ESM Chapter 13, GWS 1-05, *Welder Performance Qualification/Certification*.

4. Welding on pressure systems must be inspected by a certified welding inspector, AWS CWI, when mandated by applicable ASME BPVC or B31 codes as defined in ESM Chapter 13.

5. Dissimilar material connections involving welding or brazing of piping components or attachments to those piping components shall be specified in the engineering design.

F. Adhesive Joint Assembly

1. Solvent welding is governed by ESM Chapter 13.

2. Adhesives, cements, and sealers used to join piping components shall be compatible with the materials being joined and shall conform to applicable ASTM specifications when required by the Design Basis.

G. Soldered Joint Assembly

1. Soldering is permitted if allowed by the applicable COR or Design Basis.

2. Personnel performing soldering shall meet the process defined by the Designer. For example, ASME B31.3 and B31.9 requires ASTM B828, *Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings*.

10.0 EXAMINATION/INSPECTION/TESTING REQUIREMENTS

10.1 EXAMINATION

(Requirement 17-0265)

A. Nondestructive Examination (NDE) shall be done in accordance with the Design Basis.

B. Piping codes, if part of the Design Basis, defines the minimum required examinations and pass/fail criteria that are required.

C. Examination personnel must have the knowledge, skills, and abilities to perform the required test process adequately and safely. In some cases, specific training, qualification, or certification requirements will apply. Examination personnel shall be trained and qualified to the requirements of the COR when applicable. ESM Chapter 13, *Welding, Joining & NDE*, provides a database of qualified examiners and the specific examination methods for which they are qualified.

NOTE: Additional examination and inspection outside of ESM Chapter 17 and the Design Basis may be required by ESM Chapter 16, Building Code Program.

10.2 INSPECTION

(Requirement 17-0266)

A. Pressure system inspection activities that occur within the scope of ESM Ch. 17 and their requirements are detailed here. *NOTE: inspection activities for existing pressure systems are detailed in P101-34 Attachment A, Acceptance for Use (AFU) of Pressure Systems.*

B. Inspection shall be done in accordance with the Design Basis or the COR.

C. For inspections to ASME code Design Basis pressure systems, LANL will appoint the Owner’s Inspector, Owner's Inspector delegate, and/or Authorized Inspector as applicable.

D. Inspection activities shall be performed by an Inspector with an appropriate level of qualification as defined by Table 2, *Approved Inspector for Design Basis Activities*.

Table 2. Approved Inspector for Design Basis Activities

	Design Basis			
PSP Inspector	**ASME BPVC Section I through XIII, and B31.1 Boiler External Piping**	**Supporting Piping & ASME B31 or NFPA 54/58 Piping Codes**	**Non-Supporting Piping & NASME B31 Code Equivalencies**	**10 CFR 851 Compliant Evaluation**
Authorized Inspector	**R**	**√**	**√**	**√**
Owners Inspector or Designee	**-**	**R**	**R**	**√**
Inspector	**-**	**-**	**-**	**R**
R Minimum required level of applicable Inspector **√** May serve as applicable Inspector - May NOT serve as applicable Inspector				

NOTE: Table 2 does not include all ESM inspection activities for example ESM Chapter 16, *Building Code Program*.

10.3 PRESSURE AND LEAK TESTING

(Requirement 17-0267)

A. General Requirements

1. Testing requirements will be specified in the design and performed according to the COR. *For 10 CFR 851 Design Basis, it is recommended to follow the most applicable ASME B31 code's testing requirements for the sake of simplicity in providing an equivalent level of protection.*

2. There are several ASME Code Cases and/or Interpretations that provide additional clarification of testing requirements. See Common Applicable ASME Code Codes and Interpretations, below, for a non-exhaustive list of common applicable Code Cases and/or Interpretations. Details on the interpretations can be found by accessing the ASME Interpretations Database and entering the Record #, Interpretation #, or keyword information.

3. A written test plan must be created to define the testing and requirements and to record testing results. The test plan will contain the following (at a minimum) and the results of the test recorded and documented:

   a. Test system description

   b. Design basis including the COR, if applicable

   c. Date of the test

   d. Design pressure

e. Acceptable test pressure range

f. Test duration

g. Test instrumentation used

h. Instrument calibration records

i. Test pressurization system (means of achieving test pressure and media used for testing)

j. Test pressurization system relief device (if required)

k. Necessary data required for any NDE

 1) NDE method used, including NDE procedure if applicable

 2) Examiner qualification

l. Exclusion zone required during testing

m. Required personal protective equipment (PPE)

n. Result of the test, pass/fail

o. The examiner and inspector employee or Z number and signature

NOTE: Form 2304, Pressure and Leak Test Plan, may be used for this section.

4. Pressure or leak tests must be conducted from a safe distance with positive control of personnel access.

5. All uninvolved persons will be removed from the test area and barricades installed.

6. Personnel exclusion zones for pneumatic leak testing are based on the contained energy of the system in accordance with ASME PCC-2, Article 5.1 Mandatory Appendix II and III or equivalent.

 NOTE: Pneumatic tests above 1000 lb.-ft. stored energy requires CPSO/DCPSO review and approval of exclusion zone. Pneumatic tests below 1000 lb.-ft. stored energy do not require additional approval.

 NOTE: For piping systems the volume of the stored energy calculation is based on a length of 8 (confirm value in AMSE PCC-2, Article 5.1) pipe diameter.

7. Personnel, including personnel performing the test, are not allowed in the exclusion area while the pressure test or leak test is pressurizing or while the test pressure is being held. Entry into the exclusion zone for examination is only allowed after the hold period, and the pressure must be reduced to the design pressure when allowed by the COR.

8. Pressure or leak testing shall not be performed when metal temperatures are near the ductile-brittle transition temperature, as that may lead to brittle fracture.

9. Hydrostatic or pneumatic testing media may not contain radioactive nuclide materials to prevent inadvertent release.

10. Pressure or leak testing may not be performed with cryogenic, flammable, Category M (toxic), corrosive, pyrophoric, oxygen or strong oxidizers, steam, radioactive, or radioactive liquid waste fluids.

11. Hydrostatic tests shall be performed with water. If water is not suitable (could freeze, or cause adverse effects to piping or process), another suitable non-toxic liquid may be used. Considerations shall be made for the disposal of any testing fluid.

12. Pneumatic tests shall be performed with air or other inert gases except when permitted otherwise by design.

13. Initial service leak tests are permitted for ASME B31.3, ASME B31.9, and B31.3/B31.9 NASME equivalency design basis pressure systems when they meet the prerequisites for this testing method (e.g., must be Category D fluid to qualify for B31.3 initial service leak test).

14. Test instrumentation used to meet the pressure and leak testing requirements of this document must be calibrated as required by P330-2, *Control and Calibration of Measuring and Test Equipment (M&TE)*.

    Calibration is the process of verifying the capability (accuracy, range, and tolerance) and performance of M&TE either by direct or comparative methods to a National Institute of Standards and Technology (NIST) traceable measurement standard.

    Organization-specific procedures may also be necessary. The AP-341-801, *Post Modification/Post Maintenance Testing*, defines required post modification testing / post maintenance testing (PMT) of active structures, systems, and components (SSCs) performed after completion of modifications and maintenance activities but before returning the SSC to service.

    NOTE: If the designer is using equipment that requires calibration, the equipment must be enrolled in the LANL Calibration Program. The Metrology Program and Calibration Laboratory (MPCL) will ensure that requirements for acceptability have been properly met. The MPCL may be able to accept factory calibrations, so long as the factory calibration fulfills DOE/NNSA requirements for vendor provided calibrations.

15. Test plans shall provide a means for a controlled release of pressure (e.g., vent or drain valves). Loosening of fittings, caps, plugs, or flanges to release pressure is not permitted.

16. All leak testing methods require examining for leaks. If leakage is below the acceptance criteria, the system passes. If leakage is above the acceptance criteria, the system shall be depressurized, the leak location repaired, and the system re-tested.

17. Preliminary leak testing is allowed in accordance with the COR and shall be defined in the test plan.

18. Relief devices and other protective measures shall be utilized to protect against over pressurization during the testing in accordance with code of record requirements. This requirement is applicable to pneumatic, hydrostatic, and hydro-pneumatic testing.

    a. Relief devices shall have a set pressure and capacity calculation to verify and prevent the system from exceeding the test pressure constraints of the code of record.

    b. The relief device shall not be adjustable and shall be sealed at the required set pressure.

c. A vacuum breaker valve may be required to prevent a system from being exposed to external pressure.

19. Temporary pressure systems utilized for pressure or leak testing (e.g., portable testing rigs) must also meet the requirements of this chapter.

Guidance: A test and inspection plan in accordance with ESM Chapter 16, Building Code Program, may also be required.

B. Modifications to Existing Systems

1. For existing pressure systems that require system modifications, or any other action which requires the system to be opened and modified by installing a new joint (or removal and replacement of components for maintenance purposes), the affected section of piping must be tested and examined as follows in Figure 6:

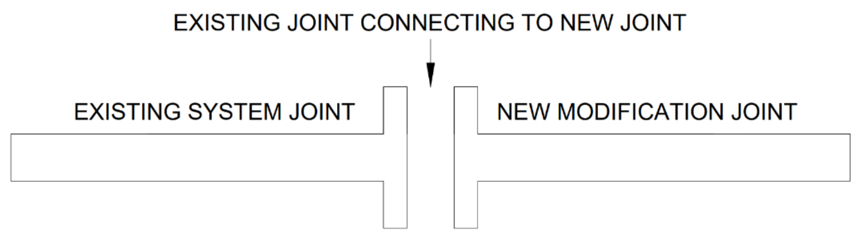


Figure 6

a. For welded connections on FS1 and FS2 systems (N/A for FS3 and FS3-ULH) where elevated pressure leak test is not possible (e.g., unknown if existing system can withstand full COR test pressure):

1) Full penetration weld: perform volumetric examination.

2) Partial penetration weld: perform surface examination.

3) Perform in-service leak test as follows:

a) Verify the joint is leak free with internal pressure. If possible, gradually increase pressure until the line pressure is reached, holding the pressure at each step long enough to equalize piping strains. Systems under 1000 lb.-ft. stored energy can be brought up in one step.

NOTE: The procedure for executing the in-service testing defined does not require any instrumentation (e.g., calibrated pressure indicator, reference indicator on system, etc.).

b) Between each pressure step, examine the affected joints for indications of leaks.

b. For welded connections that can be leak tested at elevated pressure (e.g., tested at full design basis/COR test pressure):

1) Test plan must be approved by pressure safety SME as part of the pressure system design review or subsequent submittal reviews.

c. For mechanical (e.g., threaded, flanged) connections:

1) FS1 systems: CPSO/DCPSO must approve test method.

2) All other fluid category systems: perform in-service leak test as described in 1.a.3) above.

d. For leak testing pressure system modifications that only consist of ASME B31 piping code or LANL CPSO-approved components, with mechanical connections and/or code tested sub-assemblies, where mechanical connections are assembled in accordance with manufacturer's instruction or the applicable code or standard:

1) Perform an in-service leak test described by 1.a.3) above, or may also be performed by either or both tests as follows:

a) *Vacuum rate-of-rise method:* To execute a vacuum rate-of-rise leak test, the relevant sections of the system are evacuated to a predetermined absolute pressure level. The evacuation is stopped, and the system pressure (absolute) monitored for at least five minutes. The acceptance criteria shall be specified by the Designer and shall be determined independently for each unique leak test situation based on system parameters such as volume, number of joints, and system function. Acceptance criteria shall be specified as an acceptable rate of absolute pressure rise. PSO approval is required for specified acceptance criteria greater than 10^{-3} standard cc/sec.

b) *Pressure Decay Method:* Trial run of substitute referee inert gas at same operating conditions as will exist with process gas: Conduct a trial run at the same pressure, temperature, and other salient operating conditions as process gas with substitute inert gas prior to introduction of the process gas. The pressure system shall be examined for evidence of leakage at the joints during the referee inert gas test. The acceptance criteria shall be specified by the Designer and shall be determined independently for each unique leak test situation based on system parameters such as volume, number of joints, and system function. PSO approval is required for specified acceptance criteria greater than 10^{-3} standard cc/sec.

2. Pressure systems that that are modified as stated above but include new joints connecting to new joints (not existing construction) must undergo a Designer-specified pressure and or leak test per the Design Basis. Example illustration shown below.

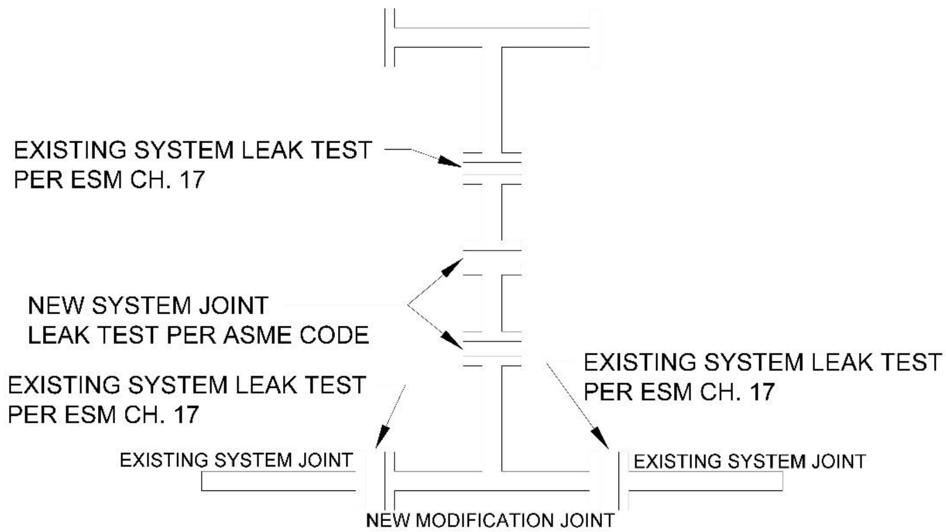


Figure 7

C. Modifications to Radiological Contaminated Existing Systems

1. Perform in-service leak test as follows: Gradually increase pressure in steps until the operating pressure (pressure during normal system operating conditions) is reached, holding the pressure at each step long enough to equalize piping strains. For systems under 25 psig and under 1000 lb.-ft. stored energy, pressure can be brought up in one step. Follow with an in-process examination:

   a. In-process examination of tie-in to existing contaminated piping: The in-service leak test will be performed first by a return to service and then by a subsequent check for gross leaks which might be indicated by contamination release. The assembly and testing are performed inside a bag or within a leak-tight enclosure such as an in-service glovebox and evaluated in accordance with proven radiation monitoring/sampling.

   b. In-process examination of tie-in to existing contaminated wet vac piping: The in-service leak test will be performed by a return to service and subsequent check for gross leaks which might be indicated by contamination release. The assembly and testing are performed inside an in-service glovebox providing confinement for leakage and protection for personnel. Alternatively, assembly and testing are performed inside a bag and evaluated in accordance with proven radiation monitoring/sampling prior to removal of the bagging.

NOTE: The procedure for executing the in-service leak testing does not require any instrumentation (e.g., calibrated pressure indicator, reference indicator on system, etc.).

Guidance: The bag methods described above may also be used for non-radiological contaminated existing systems (e.g., ASME B31.9).

NOTE: The methods described above are qualitative determinations. If a quantitative measurement is required a quantified "bag" method may be created based on pressure and volume of the bag or container over time.

D. ASME B31.5 Refrigerant Piping

1. A pressure test for system integrity in accordance with ASME B31.5 paragraph 538.4.2 *Pressure Test* is required prior to leak testing.

2. The application of the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) 15-2019 Addendum e paragraph 9.13.6.1 *Leak Testing Protocol* provides the same or greater level of leak detection as ASME B31.5 paragraph 538.4.3 *Leak Test*. As such, any of the three methods of leak testing below may be used to satisfy the leak testing requirement:

   a. Bubble leak testing per B31.5 paragraph 538.4.3

   b. Pressure testing per ASHRAE 15 Addendum e 9.13.6.1

   c. Vacuum testing per ASHRAE 15 Addendum e 9.13.6.1

E. Common Applicable ASME Code Codes and Interpretations

1. The following official ASME B31 piping committee Code Cases and Interpretations that provide helpful clarification regarding code requirements for leak testing. Copies of these documents are maintained on the ESM Ch. 17 SharePoint.

2. ASME B31.1

   a. Interpretation # B31.1-23-02, ASME B31.1-2016/2018/2020, Para. 126.1, Listed Components (Record # 21-849)

3. ASME B31.3

   a. B31 Case 180 Leak Testing of Subassemblies of Jacketed Piping for use in ASME B31.3 Piping Systems

   b. Interpretation 25-04, B31.3-2012, Interpretation of Para. 345.5.5 Pneumatic Leak Test Procedure (Record # 14-0269)

   c. Interpretation, B31.3-1996 through 2010, Interpretation of Para. 345.2.2 Leak Test Acceptance Criteria (Record #s 12-56 and 12-666)

   d. Interpretation 24-16, B31.3-2012, Interpretation of Para. 322.6.3 Relief Devices (Record # 13-0266)

   e. Interpretation # B31.3-18-04, B31.3-2016, Interpretation of Para. 302.3 Allowable Stresses and Other Stress Limits (Record # 17-3163)

   f. Interpretation # B31.3-19-06, B31.3-2016, Interpretation of Paras. 302.2.5 and 301.2.2, Relief Device (Record # 19-495)

   g. Interpretation # B31.3-20-05, B31.3-2018, Interpretation of Para. 345.5.2 Leak Test Relief Device Requirement (Record # 20-1159)

   h. Interpretation B31.3-20-07, B31.3-2018, Interpretation of Para. 345.8.2 Leak Tests (Record # B31.3-20-07)

   i. Interpretation 8-31, B31.3 1987 Edition with Addenda through B31.3c 1989, Paragraphs 345 and 345.2.2; Leak Test as Nondestructive Examination (Record # N/A)

4. ASME B31.9
   a. Interpretation # B31.9-18-02, ASME B31.9-2017, Para. 937.4.4 – Pneumatic Test Pressure (Record # 18-2184)
   b. Interpretation # B31.9-18-01, ASME B31.9-2017, Para. 937.4.4 – Pneumatic Test Pressure (Record #18-1857)
   c. Interpretation # B31.9-22-04, B31.9=2020, Paragraph 904.7, Successful Service (Record #21-612)
   d. Interpretation # B31.9-22-05, B31.9-2020, Paragraph 923.1.2, Unlisted (Record #21-611)

11.0 PROCUREMENT

A. Purchases of pressure safety restricted goods (e.g., boilers, pressure vessels, pressure regulators, relief devices) by LANL personnel shall be in accordance with P101-34, Attachment D, *Procurement of Pressure Safety Goods or Services*.
   1. Form 2309, *Regulator and Relief Device Procurement Pre-Approval*
   2. Form 2310, *ASME Vessel Procurement Pre-Approval*

B. Specification for procurement of a relief valve shall include at minimum the information stated below. This information is required by Form 2309.
   1. Metadata: PSID, TA-Building
   2. System design pressure or MAWP
   3. Regulator and relief device identification number
   4. RFO (if required)
   5. Service fluid
   6. Nominal size of piping system to which the relief device is connected
   7. Pressure source maximum failure flow rate

      Guidance: Specification sheets from manufacturers usually include the information below on relief devices.
   8. Relief device
      a. Manufacturer
      b. Model number
      c. Materials of construction (spring, seat, body, etc.)
      d. Relief device inlet size and end connection type
      e. Relief device outlet size and end connection type (if applicable)
      f. Relief device set pressure (psig or psid)
      g. Relief device flow capacity at defined overpressure beyond set pressure
      h. Orifice trim (if applicable)
      i. ASME BPVC section (if applicable)
      j. Temperature range

C. Specification for purchase of a rupture disk (burst disk) shall include at minimum the information stated below. *This information is required by Form 2309.*

1. Metadata: PSID, TA-Building
2. System design pressure or MAWP
3. Regulator and relief device identification number
4. RFO (if required)
5. Service fluid
6. Nominal size of piping system to which the relief device is connected
7. Pressure source maximum failure flow rate

Guidance: Specification sheets from manufacturers usually include the information below on rupture disks and holders.

8. Disk Holder
   a. Manufacturer
   b. Model number
   c. Materials of construction
   d. Nominal inlet size and end connection type
   e. Nominal outlet size and end connection type (if applicable)
   f. Flow capacity at defined overpressure beyond set pressure
   g. Temperature range
9. Disk specification
   a. ASME BPVC section (if applicable)
   b. Disk size and materials
   c. Rated burst pressure
   d. Burst pressure tolerance (standard or close)
   e. Temperature rating at rated burst pressure
   f. Vacuum rating and support (if applicable)
   g. Coating or lamination (if applicable)
   h. Reverse ratio (recommended to be < 1)
   i. Damage ratio (recommended to be < 1)
   j. Maximum recommended operating ratio

   Guidance: Rupture disk life is affected by the stress history (pressure and temperature) applied to the disk. Relatively low operating pressures and static conditions will generally result in very long disk life, while cyclic conditions approaching the burst pressure will result in shorter disk life.
10. Disk type examples
    a. Conventional tension-loaded rupture disk

b. Pre-scored tension-loaded rupture disk

c. Composite rupture disk

d. Reverse buckling rupture disk with knife blades

e. Pre-scored reverse buckling rupture disk

NOTE: See ASME Section XIII Part 4 for derating values and K values of rupture disks. If a rupture disk is placed directly upstream of a pressure relief valve, requirements of ASME Section XIII Part 8, 8.2, shall be met.

D. Specification for procurement of an ASME quality marked (stamped) item will contain the minimum information stated below. This information is required by Form 2310.

Guidance: Specification sheets from manufacturers usually include the information below on ASME quality marked (stamped) items.

1. Metadata: PSID, TA-Building
2. System design pressure or MAWP
3. Vessel type ASME BPVC section
4. Corrosion allowance
5. Manufacturer model/part number, or design drawings for a custom-designed item
6. Heat input/output rating (for boilers) or pressure vessel size (for others)
7. MAWP
8. Minimum/maximum design temperatures
9. ASME relief required (yes or no)
10. Boiler fuel gas system safety requirements (N/A if not boiler)
11. Relief device provider (fabricator, vendor, designer, or N/A)

12.0 DRAWINGS AND SKETCHES

(Requirement 17-0268)

Pressure systems must have, at minimum, an accurate system sketch.

A. Pressure systems must have as a minimum an accurate system sketch. The system sketch documents the fluid flow path and the relationship of all wetted/pressurized components in the fluid system; this includes the piping, system components, process equipment, and any instrumentation and controls. The sketch is a functional representation of the pressure system and is not an isometric representation of the system.

B. Sketches shall contain standard LANL symbols and acronyms to aid in the interpretation of the sketches. For piping components, LANL CAD Standards Manual Section 300, App. G3, G4, and J provide standard symbols and acronyms.

C. System sketches may be hand drawn or drawn using a program like PowerPoint or Visio. Computer-Aided Drafted (CAD) drawings are also acceptable but not required by ESM Chapter 17.

Guidance: ESM Ch. 17 Reference Data SharePoint provides a simple PowerPoint template for creating system sketches.

NOTE: Other LANL requirements may require formal CAD drawings not required by ESM Chapter 17.

D. Pressure systems that require a flexibility analysis require isometric diagrams and dimensions included in the design.

E. Process Industry Practices (PIP) line classes, insulation, piping, and tubing may be used if they do not conflict with the LANL drafting requirements when the LANL drafting standards are required.

13.0 LABELING AND TAGGING OF COMPONENTS

(Requirement 17-0269)

A. Equipment that has preventive maintenance requirements (e.g., boilers, pressure vessels, relief devices, etc.) must be uniquely identified for the pressure system component. This is best achieved by physically labeling or tagging components in the field and including the same identification in any preventative maintenance procedures. Physical labeling or tagging of components must match the system drawing, sketch, or schematic.

B. For small-scale pressure systems, labeling or tagging may not be necessary if the components are easily identified in the field with the sketch or drawing.

C. Components in a pressure system other than piping, tubing, flanges, and fittings are to be identified in accordance with the system drawing, sketch, or schematic, and ESM Chapter 1 Section 200, *Item Numbering and Labeling*.

D. Piping or tubing lines are not readily traceable back to the pressure source (e.g., piping or tubing that goes underground or passes between walls or structures) must be permanently marked with the contents. Suitable marking methods shall be used to prevent damage to the piping system (e.g., some marking methods containing chlorides or halides that can induce stress corrosion cracking of austenitic stainless steels cannot be used).

NOTE: Detailed labeling requirements exist in LANL Master Specification 22 0554, Identification for Plumbing, HVAC, and Fire Piping and Equipment

14.0 RECORDS

(Requirement 17-0270)

A. Pressure system documents generated by the ESM Chapter 17 design process are considered records, and shall be managed per LANL P1020, P1020-1, P1020-2, and P1020-3. Section 2.0 of this document, *Pressure Safety Implementation Plan*, references pressure system documentation required by this chapter, as applicable.

B. Only records required for AFU (P101-34 Attachment A) are required to be uploaded to the PSD. However, the PSD can be used for all records generated during design as well as other records required by additional policies, procedures, facility requirements or organizational requirements.

Guidance: It is recommended that all documents related to the PSID be archived in the PSD for easy retrieval and change management.

NOTE: Other records may be required by other policies, procedures, facility requirements or organizational requirements. These records are not in the scope of this chapter and are not required to be uploaded into the PSD.

15.0 ATTACHMENTS

Attachment REQ-1, Category M Fluid Service and Lethal Service

Attachment REQ-2, New or Modified System Design Document Requirements

Attachment REQ-3, ASME Boiler and Pressure Vessel Code Application

Attachment REQ-4, Piping Code and Regulation Application

Attachment REQ-5, ASME B31.3 Non-Metallic Equivalent Safety Evaluation

Attachment REQ-6, ASME B31.3 Metallic Equivalent Safety Evaluation

Attachment REQ-7, ASME B31.9 Equivalent Safety Evaluation

Attachment REQ-8, OSHA Requirements for Pressure Systems

Attachment REQ-9, Approved Flexible Hose Restraints and Thrust Load Evaluations

RECORD OF REVISIONS

Rev.	Date	Description	POC	RM
0	9/17/2014	Initial issue as section ASME-3.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
1	9/22/2023	Redesignation of attachment numbers and titles (formerly known as Section ASME - New ASME System Requirements, Attachment ASME-3 Category M Fluids). Added "No" where appropriate in table instead of (blank), some changes made to the introductory list.	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards point of contact (POC) for upkeep, interpretation, and variance issues.

Chapter 17	**Pressure Safety POC**

This document is online at https://engstandards.lanl.gov

This attachment defines fluid services designated as Category M at Los Alamos National Laboratory (LANL) per ASME B31.3 Process Piping[1]. It also defines lethal substances for LANL per Boiler and Pressure Vessel (B&PV) Code Section VIII[2].

1. Media that is not listed in the table means that a determination has not yet been made. If using a media missing from this list, written evaluation/determination shall be performed and reviewed by a pressure safety subject matter expert (SME) (with assistance from OSH-ISH if necessary) with concurrence by the owner with notification to the ESM Chapter 17 point of contact (POC) so the media can be added to this document.
2. Media ID shown is not necessarily the operating system or system ID per Engineering Standards Manual (ESM) Chapter 1 Section 200- Item Numbering and Labeling.
3. Some entries are too general to make a definitive determination as to their fluid category (e.g., calibration gas, hydraulic fluid, some acids/bases). The Safety Data Sheet for these types of media shall be reviewed by a pressure safety SME (with assistance from OSH-ISH if necessary) with concurrence by the owner to determine if they meet the Category M/Lethal criteria.
4. Listings are generally sorted alphabetically by media.

   Guidance: See B31.3 Appendix M, Guide to Classifying Fluid Services

[1] See ASME B31.3 paragraph 300.2 Definitions for "Fluid Service"
[2] See ASME B&PV Code Section VIII UW-2 paragraph (a) and footnote 1

Media	Cat M/Lethal?
acetylene	No
acid waste	**Yes** (for concentrated solutions)
argon	No
HCFC – 225g (cleaning fluid)	No
ammonia	No
anhydrous ammonia	**Yes**
air	No
aerozine 50 fuel	**Yes**
aluminum nitrate	No
breathing air	No
biological hazard (deadly)	**Yes**
boiler feed water	No
bromofluorobenzene	No
carbon tetrafluoride	No
calibration gas	Depends on the test gas
chlorobenzene	No
CAM sample air	No
caustic waste	No Yes (for concentrated solutions)
central circulating hot water return	No
central circulating hot water supply	No
central chilled water return	No
central chilled water supply	No
chemical injection (water systems)	No (depends on the chemical)
chlorine	**Yes**
chlorine gas	**Yes**
carbon dioxide	No
carbon monoxide	No
carbon tetrafluoride	No
chilled water	No
compressed air	No
condensate pump discharge	No
diborane (2%), argon bal	**Yes**
diesel	No
deionized water (incl. supply and return)	No
distilled water	No
drain	No
dri-train return	No

Media	Cat M/Lethal?
dri-train supply	No
deuterium	No
house dry vacuum	No
process dry vacuum	No
ethylene glycol	No
fire suppression	No
fixed-head sample air	No
fluorine gas	**Yes**
fluorochlorobenzene	No
HFE – 7100 (cleaning fluid)	No
Freon (r12) dichlorodifluoromethane	No
monomethylhydrazine (MMH) fuel	**Yes**
fire protection water	No
gaseous hydrogen	No
gaseous nitrogen	No
gaseous oxygen	No
gasoline	No
Halon fire suppression	No
hydrogen sulfide	**Yes**
hydroxylamine nitrate	**Yes**
heating water return	No
heating water supply	No
high pressure steam (above 15 psig)	No
hydroxyisobutyric acid	No
hydrochloric acid	**Yes**
hydrocarbon liquid	
hydraulic fluid	Depends on the media reference SDS
gaseous helium	No
hydrogen fluoride	**Yes**
hydrofluoric acid	**Yes**
liquid helium	No
hydrogen chloride gas	**Yes**
hydrogen peroxide (H_2O_2)	No
hydrofluoroether	No
hot water	No
hydrazine fuel	**Yes**
hazardous waste	Depends on the makeup of the waste
isopropyl alcohol	No
industrial waste	No

Media	Cat M/Lethal?
industrial water	No
instrument air	No
kerosene	No
krypton	No
limited-volume circulating chilled water return	No
limited volume circulating chilled water supply	No
liquid air	No
liquid hydrogen	No
liquid nitrogen	No
liquid oxygen	No
propane, butane	No
Lexsol heat transfer fluid	No
low-pressure condensate (15 psig or less)	No
low-pressure natural gas (less than 14 in. w.c.)	No
low-pressure steam (15 psig or less)	No
mercury	**Yes**
methyl alcohol	No
methane	No
Freon MF solvent	No
sodium hydroxide (NaOH)	**Yes** (for concentrated solutions)
natural gas	No
neopentane (2,2-dimethylpropane)	No
negative-pressure circulating chilled water return	No
negative-pressure circulating chilled water supply	No
neon	No
nitric acid	**Yes** (for concentrated solutions)
nitric oxide	No
nitrogen dioxide	**Yes**
nitrous oxide	No
dinitrogen tetroxide (N_2O_4)	**Yes**
oil	No
P-10 (10% methane/90% argon) gas mix	No
phosphine	**Yes**
positive-pressure circulating chilled water return	No
positive-pressure circulating chilled water supply	No
potable water	No
potable hot water return	No
potassium hydroxide	Yes (for concentrated solutions)

Media	Cat M/Lethal?
process compressed air	No
process cooling water return	No
process cooling water supply	No
radioactive liquid waste	No
refrigerant liquid	No
refrigerant suction	No
regeneration gas	No
sodium carbonate	No
sodium citrate	No
sanitary sewer	No
sump pump discharge	No
sulfur hexafluoride (SF6)	No
sulfur dioxide	**Yes**
sulfuric acid	**Yes** (for concentrated solutions)
steam	No
Freon TF solvent	No
test gas (special types, mixes, etc.)	Depends on the test gas
trimethylamine 108 ppm	No
tower water drain	No
tower water return	No
tower water supply	No
treated water	No
tritium	No
unsymmetrical dimethyl hydrazine (UDMH) fuel	**Yes**
vacuum	No
vent header (to TA-55 zone 1 HVAC)	No
wet vacuum	No
water	No
zone 1 (TA-55 HVAC)	No

Attachment REQ-2, New or Modified System Design Document Requirements

RECORD OF REVISIONS

Rev	Date	Description	POC	RM
0	9/17/2014	Initial issue	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
1	9/22/2023	Redesignation of attachment numbers and titles (replaces ADMIN-1-4, New System Document Requirements). Revised to reflect changes to P101-34 and ESM Ch 17.	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards POC for upkeep, interpretation, and variance issues.

Chapter 17	**Pressure Safety POC**

This document is online at https://engstandards.lanl.gov

This attachment summarizes the base set of design documentation required to review and approve pressure system designs. The "Required When" column specifies when any given row applies to a system. The two verification columns can be utilized by the designer and design reviewer as a checklist to acknowledge that all required documentation has been included in the documentation package. Items not applicable to the pressure system design may be marked as "N/A" in the verification columns.

Documentation Package Item	Required When	Designer Verification	Design Reviewer Verification
1. System drawings and schematics	Every Package		
2. Overpressure protection evaluations	Every Package		
3. Applicable Alternate Methods/Variances/Clarifications/Interpretations	The system or any item of the system has an applicable AM/V/C/I to the requirements of ESM Ch 17.		
4. Code Stamped Vessel Fabrication Documentation (i.e., American Society of Mechanical Engineers (ASME) Manufacturer Data Report)	The system contains a code stamped vessel.		
5. Non-ASME code Fabricated Vessel Information (code-equivalent Documentation)	The pressure system contains Non-ASME code stamped boilers and pressure vessels (which includes boilers, pressure vessels, heat exchangers, and accumulators).		

Documentation Package Item		Required When	Designer Verification	Design Reviewer Verification
a.	ASME code equivalent documentation for systems with pressure vessels which includes but is not limited to minimum wall thickness determination, corrosion allowance, weld efficiency rating, support structure loading, nozzle calculations. Calculations will use the material values specified in the ASME code.	A non-code boiler, pressure vessel, heat exchanger, and accumulator are in the pressure system package.		
b.	Pressure/leak test procedures and test reports	Non-code boilers, pressure vessels, heat exchangers, and accumulators are in the pressure system package.		
c.	Modification procedures/instructions	Modifications were made to non-code boilers, pressure vessels, heat exchangers, and accumulators in the pressure system package.		
d.	Nondestructive evaluation (NDE) data reports	NDE was done to non-code boilers, pressure vessels, heat exchangers, and accumulators in the pressure system package		
e.	Weld examination forms as described in ESM Chapter 13	Welding was done to non-code boilers, pressure vessels, heat exchangers, and accumulators in the pressure system package.		
f.	Special calculations such as welding	Special calculations are performed for non-code boilers, pressure vessels, heat exchangers, and accumulators in the pressure system package.		
g.	Vendor drawings	Piece parts are used to fabricate non-code boilers, pressure vessels, heat exchangers, and accumulators in the pressure system package.		
h.	Vessel modification reports	Vessel is modified by other than LANL personnel.		
6.	Pressure relief devices (PRD)	The pressure system contains a pressure relief device.		
a.	Certified test data of relief valves, e.g., steam pressure safety valves are certified by NBIC coded shop	A PRD is modified or tested by an outside facility.		
b.	Documentation of relief valve modification	A relief valve has been modified.		
7.	Piping system documentation	The system contains pipe, tube, or other components not classed as boilers or vessels.		
a.	Fabrication documentation	Fabrication is performed.		
b.	Pressure/leak test procedures and test results	A pressure system package contains piping system components.		
c.	Examiner qualification	Examinations are performed.		
d.	Owner’s Inspector checklist	Owner’s Inspectors are required by ASME code.		
e.	Modification procedures/instructions	Components of a system were modified from original construction.		
f.	Nondestructive evaluation (NDE) data reports	NDE is performed on piping system components.		

Attachment REQ-2, New or Modified System Design Document Requirements

Documentation Package Item	Required When	Designer Verification	Design Reviewer Verification
g. Special calculations such as welds and orifices	A pressure system package contains piping system components that have been welded, modified with "home-made" orifices, or unlisted components.		
h. Corrosion allowance calculations per ASME B31G	Piping is used in corrosive fluid service.		
i. Code required design calculations e.g., flexibility analysis, pipe supports, wind loading, snow loading, and seismic loading. See specific code for additional detail. (e.g., B31.3 paragraph 319 and 321)	System dependent. For example • Flexibility analysis for design temperatures defined in ESM Ch 17 • Pipe support calculations for engineered piping supports • Wind/snow loading for piping outside • Seismic loading when required by safety basis		
j. Weld examination forms in accordance with ESM Chapter 13, and special required examinations defined in the applicable code	Welding of pipe or tube in a pressure system package was performed.		
k. Weld in-process forms in accordance with ESM Chapter 13, and the most applicable code	When in-process examination of welding is used.		
l. Vendor drawings or sketches	A pressure system package contains vendor supplied systems, piping, or components.		
m. Unlisted component evaluation [per piping code of record (COR)] or use of Reputable Manufacturer List (when Non-ASME (NASME) applies)	Using an unlisted component in pressure system.		
8. Oxygen Hazards Analysis and Failure Modes and Effects Analysis (FMEA)	Pressure system is an oxygen system above 350 psig or as required by the chief pressure safety officer.		

RECORD OF REVISIONS

Rev	Date	Description	POC	RM
0	11/09/18	Initial issue.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
1	9/22/23	Updated for 10CFR851 2018 Tech Amendment. Added ASME B&PVC Section XIII, which is newly added in the 2021 edition. Redesignation of attachment numbers and titles (formerly known as Section ASME - New ASME System Requirements Attachment ASME-5 – B&PVC Application).	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards point of contact (POC) for upkeep, interpretation, and variance issues.

Chapter 17	**Pressure Safety POC**

This document is online at https://engstandards.lanl.gov

This attachment contains paraphrased American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PVC) scope summaries with discussion of how these mandates shall be applied at Los Alamos National Laboratory (LANL). It also reflects the latest revision of 10CFR851, which includes a Technical Amendment made effective on January 17, 2018.

Information in the table below reflects the 2021 edition of the ASME B&PVC. Note that 10CFR851 reflects the use of the 2015 edition of the Code. The latest effective edition of the ASME B&PVC is mandated for new construction.

NOTE: Repairs and alterations are governed by PS-GEN-NBIC-RSP, QCSM, Quality Control Systems Manual (R Stamp Program).

ASME Boiler and Pressure Vessel Code (BPVC)

ASME's BPVC document establishes rules of safety relating only to pressure integrity—governing the design, fabrication, and inspection of boilers and pressure vessels, and nuclear power plant components during construction. The objective of the rules is to provide a margin for deterioration in service. The Code Cases clarify the existing requirements or provide, when the need is urgent, rules for materials or constructions not covered by existing BPVC rules.

ASME BPVC.I, Section I—Rules for Construction of Power Boilers

This section provides requirements for all methods of construction of power, electric, and miniature boilers; high temperature water boilers, heat recovery steam generators, and certain fired pressure vessels to be used in stationary service; and power boilers used in locomotive, portable, and traction service. Rules pertaining to use of the V, A, M, PP, S and E ASME Product Certification Marks are also included. The rules are applicable to boilers in which steam or other vapor is generated at a pressure exceeding 15 psig, and high temperature water boilers intended for operation at pressures exceeding 160 psig and/or temperatures exceeding 250°F. Super heaters, economizers, and other pressure parts connected directly to the boiler without intervening valves are considered as part of the scope of Section I.

ASME BPVC.II.A, Section II—Materials, Part A—Ferrous Material Specifications (beginning to SA–450)

This section is a "service section" to the other BPVC sections, providing material specifications for ferrous materials adequate for safety in the field of pressure equipment. These specifications contain requirements for chemical and mechanical properties, heat treatment, manufacture, heat and product analyses, and methods of testing. They are designated by SA numbers and are identical with or similar to those of specifications published by American Society for Testing and Materials (ASTM) International and other recognized national or international organizations.

ASME BPVC.II.A, Section II—Materials, Part A—Ferrous Material Specifications (SA–451 to end)

This section is a "service section" to the other BPVC sections providing material specifications for ferrous materials adequate for safety in the field of pressure equipment. These specifications contain requirements for chemical and mechanical properties, heat treatment, manufacture, heat and product analyses, and methods of testing. They are designated by SA numbers and are identical with or similar to those of specifications published by ASTM and other recognized national or international organizations

ASME BPVC.II.B, Section II—Materials, Part B—Nonferrous Material Specifications

This section is a "service section" to the other BPVC sections, providing material specifications for nonferrous materials adequate for safety in the field of pressure equipment. These specifications contain requirements for chemical and mechanical properties, heat treatment, manufacture, heat and product analyses, and methods of testing. They are designated by SB numbers and are identical with or similar to those of specifications published by ASTM and other recognized national or international organizations.

ASME BPVC.II.C, Section II—Materials, Part C—Specification for Welding Rods, Electrodes, and Filler Metals

This section is a "service section" to the other BPVC sections providing material specifications for the manufacture, acceptability, chemical composition, mechanical usability, surfacing, testing requirements and procedures, operating characteristics, and intended uses for welding rods, electrodes, and filler metals. These specifications are designated by SFA numbers and are derived from American Welding Society (AWS) specifications.

ASME BPVC.II.D.C, Section II—Materials, Part D—Properties (Customary)

This section is a "service section" for reference by the BPVC construction sections providing tables of material properties including allowable, design, tensile and yield stress values, physical properties and external pressure charts and tables. Part D facilitates ready identification of materials to specific Sections of the BPVC. Part D contains appendices which contain criteria for establishing allowable stress, the basis for establishing external pressure charts, and information required for approval of new materials.

ASME BPVC.II.D.M, Section II—Materials, Part —Properties (Metric)

Same as "Customary" above, but in metric units.

ASME BPVC.III, Section III—Rules for the Construction of Nuclear Facility Components (all parts)

This Section applies to nuclear power plants. LANL does not apply Section III because there are no known systems that are within the scope of the code.

ASME BPVC.IV, Section IV—Rules for Construction of Heating Boilers

This section provides requirements for design, fabrication, installation and inspection of steam heating, hot water heating, hot water supply boilers, and potable water heaters intended for low pressure service that are directly fired by oil, gas, electricity, coal or other solid or liquid fuels. It contains appendices which cover approval of new material, methods of checking safety valve and safety relief valve capacity, examples of methods of checking safety valve and safety relief valve capacity, examples of methods of calculation and computation, definitions relating to boiler design and welding, and quality control systems. Rules pertaining to use of the H, HV, and HLW ASME Product Certification Marks are also included.

ASME BPVC.V, Section V—Nondestructive Examination

This section contains requirements and methods for nondestructive examination which are referenced and required by other BPVC sections. It also includes manufacturer's examination responsibilities, duties of authorized inspectors and requirements for qualification of personnel, inspection, and examination. Examination methods are intended to detect surface and internal discontinuities in materials, welds, and fabricated parts and components. A glossary of related terms is included.

ASME BPVC.VI, Section VI—Recommended Rules for the Care and Operation of Heating Boilers

This section covers general descriptions, terminology, and operation guidelines applicable to steel and cast-iron boilers limited to the operating ranges of Section IV Heating Boilers. It includes guidelines for associated controls and automatic fuel burning equipment. Illustrations show typical examples of available equipment. Also included is a glossary of terms commonly associated with boilers, controls, and fuel-burning equipment.

ASME BPVC.VII, Section VII—Recommended Guidelines for the Care of Power Boilers

The purpose of these recommended guidelines is to promote safety in the use of power boilers. The term "power boiler" in this section includes stationary, portable, and traction type boilers, but does not include locomotive and high temperature water boilers, nuclear power plant boilers, heating boilers, pressure vessels, or marine boilers. This section provides such guidelines to assist those directly responsible for operating, maintaining, and inspecting power boilers. Emphasis has been placed on industrial type boilers because of their extensive use. Guidelines are also provided for operation of auxiliary equipment and appliances that affect the safe and reliable operation of power boilers.

ASME BPVC.VIII.1, Section VIII—Rules for Construction of Pressure Vessels, Division 1

This division provides requirements applicable to the design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures exceeding 15 psig. Such pressure vessels may be fired or unfired. Specific requirements apply to several classes of material used in pressure vessel construction, and also to fabrication methods such as welding, forging and brazing. It contains mandatory and non-mandatory appendices detailing supplementary design criteria, nondestructive examination, and inspection acceptance standards. Rules pertaining to the use of the U, UM and UV ASME Product Certification Marks are also included.

ASME BPVC.VIII.2, Section VIII—Rules for Construction of Pressure Vessels, Division 2, Alternative Rules

This division provides requirements applicable to the design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures exceeding 15 psig. Such vessels may be fired or unfired. This pressure may be obtained from an external source or by the application of heat from a direct or indirect source, or any combination thereof. These rules provide an alternative to the minimum requirements for pressure vessels under Division 1 rules. In comparison the Division 1, Division 2 requirements on materials, design, and nondestructive examination are more rigorous; however, higher design stress intensify values are permitted. Division 2 rules cover only vessels to be installed in a fixed location for a specific service where operation and maintenance control is retained during the useful life of the vessel by the user who prepares or causes to be prepared the design specifications. These rules may also apply to human occupancy pressure vessels typically in the diving industry. Rules pertaining to the use of the U2 and UV ASME Product Certification Marks are also included.

ASME BPVC.VIII.3, Section VIII—Rules for Construction of Pressure Vessels, Division 3, Alternative Rules for Construction of High Pressure Vessels

This division provides requirements applicable to the design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures generally above 10,000 psi. Such vessels may be fired or unfired. This pressure may be obtained from an external source, a process reaction, by the application of heat from a direct or indirect source, or any combination thereof. Division 3 rules cover vessels intended for a specific service and installed in a fixed location or relocated from work site to work site between pressurizations. The operation and maintenance control are retained during the useful life of the vessel by the user who prepares or causes to be prepared the design specifications. Division 3 does not establish maximum pressure limits for either Section VIII, Divisions 1 or 2, nor minimum pressure limits for this Division. Rules pertaining to the use of the UV3 ASME Product Certification Marks are also included.

ASME BPVC.IX, Section IX— Welding, Brazing and Fusing Qualifications, Qualification Standard for Welding, Brazing, and Fusing Procedures; Welders; Brazers; and Welding, Brazing, and Fusing Operators

This section contains rules relating to the qualification of welding, brazing, and fusing procedures as required by other BPVC Sections for component manufacture. It also covers rules relating to the qualification and requalification of welders, brazers, and welding, brazing and fusing machine operators in order that they may perform welding, brazing, or plastic fusing as required by other BPVC Sections in the manufacture of components. Welding, brazing, and fusing data cover essential and nonessential variables specific to the joining process used.

ASME BPVC.X, Section X—Fiber-Reinforced Plastic Pressure Vessels

This section provides requirements for construction of a fiber-reinforced plastic pressure vessel in conformance with a manufacturer's design report. It includes production, processing, fabrication, inspection, and testing methods required for the vessel. Section X includes three Classes of vessel design: Class I and Class III—qualification through the destructive test of a prototype and Class II—mandatory design rules and acceptance testing by nondestructive methods. These vessels are not permitted to store, handle or process lethal fluids. Vessel fabrication is limited to the following processes: bag molding, centrifugal casting and filament-winding and contact molding. General specifications for the glass and resin materials and minimum physical properties for the composite materials are given.

ASME BPVC.XI, Section XI—Rules for Inservice Inspection of Nuclear Power Plant Components

LANL does not apply this code because there are no know systems that are within the scope of the code.

ASME BPVC.XII, Section XII—Rules for Construction and Continued Service of Transport Tanks

This section provides requirements for construction and continued service of pressure vessels for the transportation of dangerous goods via highway, rail, air, or water at pressures from full vacuum to 3,000 psig and volumes greater than 120 gallons. "Construction" is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and over-pressure protection. "Continued service" is an all-inclusive term referring to inspection, testing, repair, alteration, and recertification of a transport tank that has been in service. This section contains modal appendices containing requirements for vessels used in specific transport modes and service applications. Rules pertaining to the use of the T ASME Product Certification Marks are included.

ASME BPVC.XIII, Section XIII—Rules for Overpressure Protection

This section provides requirements for the overpressure protection of pressurized equipment such as boilers, pressure vessels, and piping systems. Overpressure protection methods include the following:

(1) Releasing excess pressure by use of pressure relief devices
(2) Applying controls to prevent an increase in pressure (overpressure protection by system design)
(3) A combination of (1) and (2)

This standard provides requirements for topics such as design, material, inspection, assembly, testing, and marking for pressure relief valves, rupture disk devices, pin devices, spring-actuated non-reclosing devices, and temperature and pressure relief valves. This standard also covers devices in combination, capacity and flow resistance certification, authorization to use the ASME Certification Mark, installation, and overpressure protection by system design.

Section XIII was created to combine a large part of the overpressure protection requirements specific to relief devices from ASME B&PVC Sections I, III, IV, VIII, X, and XII. Those Sections generally still contain some requirements regarding acceptable methods and requirements for overpressure protection specific to the Sections.

ASME BPVC.CC.BPV, Code Cases, Boilers and Pressure Vessels

This section provides the approved actions by the BPVC Committee on alternatives intended to allow early and urgent implementation of any revised requirements for boilers and pressure vessels.

ASME BPVC.CC.NC, Code Cases, Nuclear Components

LANL does not apply this code because there are no known systems that are within the scope of the code.

RECORD OF REVISIONS

Rev	Date	Description	POC	RM
0	9/17/14	Initial issue.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
1	9/22/23	Updated for 10CFR851 2018 Tech Amendment. Redesignation of attachment numbers and titles (formerly Section ASME - New ASME System Requirements, Attachment ASME - 1 – Code and Regulation Application).	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards point of contact (POC) for upkeep, interpretation, and variance issues.

Chapter 17	**Pressure Safety POC**

This document is online at https://engstandards.lanl.gov

This attachment contains paraphrased piping code and regulation scope summaries with discussion of how these mandates shall be applied at Los Alamos National Laboratory (LANL). It also reflects the latest revision of 10CFR851, which includes a Technical Amendment made effective on January 17, 2018.

The code editions in the table below reflect the latest edition at the time of issuance of this attachment. The edition of the piping codes required by 10CFR851 Appendix A Part 4, *Pressure Safety*, are older editions. LANL chooses to utilize the latest effective edition of the code for each project.

B31.1 Power Piping (2022)

This Code prescribes minimum requirements for the design, materials, fabrication, erection, test, inspection, operation, and maintenance of piping systems typically found in electric power generating stations, industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems. It also covers boiler-external piping for power boilers and high temperature, high pressure water boilers in which steam or vapor is generated at a pressure of more than 15 psig; and high temperature water is generated at pressures exceeding 160 psig and/or temperatures exceeding 250 degrees Fahrenheit.

American Society of Mechanical Engineers (ASME) B31.1 Paragraph 100.1.3 provides exclusions to the scope of the code.

ASME B31.1 is most commonly applied at LANL for centralized steam distribution piping and for Boiler External Piping of ASME Boiler and Pressure Vessel Code (BPVC) Section I boilers.

B31.2 Fuel Gas Piping

10CFR851 does not require this code. This code has been withdrawn and replaced by NFPA 54, National Fuel Gas Code.

B31.3 Process Piping (2020)

This Code applies to piping for all fluids, including:

(1) Raw, intermediate, and finished chemicals
(2) Petroleum products
(3) Gas, steam, air, and water
(4) Fluidized solids
(5) Refrigerants
(6) Cryogenic fluids

Applies to Design Pressure greater than 15 psig or, regardless of pressure, if the fluid is flammable, toxic, or damaging to human tissues as defined in ASME B31.3 paragraph 300.2 or the design temperature is outside the range of −29°C (−20°F) through 186°C (366°F). Toxic is defined as a Category M fluid.

ASME B31.3 Paragraph 300.1.3 provides exclusions to the scope of the code.

ASME B31.3 is most commonly applied at LANL for process fluids, laboratory fluids, flammable fluids, toxic fluids, and radioactive fluids. Generally, this Code is used for any pressure system in which the other ASME B31 or NFPA piping codes in this document do not apply.

B31.4 Pipeline Transportation Systems for Liquids and Slurries (2022)

LANL does not apply this code because there are no known systems that are within the scope of the code.

B31.5 Refrigeration Piping and Heat Transfer Components (2019)

This Code prescribes requirements for the materials, design, fabrication, assembly, erection, test, and inspection of refrigerant, heat transfer components, and secondary coolant piping for temperatures as low as −320°F (−196°C), whether erected on the premises or factory assembled, except as specifically excluded by ASME B31.5 Paragraph 500.1.1.

ASME B31.5 is most commonly applied at LANL for field-installed refrigerant piping routed between refrigeration equipment for HVAC or other refrigeration processes.

B31.8 Gas Transmission and Distribution Piping Systems (2022)

Note: These systems are also required to meet 49 CFR Part 192 Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards.

This Code covers the design, fabrication, installation, inspection, and testing of pipeline facilities used for the transportation of gas. This Code also covers safety aspects of the operation and maintenance of those facilities. (See B31.8 Mandatory Appendix Q for scope diagrams.)

ASME B31.8 Paragraph 802.1(b) provides exclusions to the scope of this code.

ASME B31.8 is most commonly applied at LANL (in conjunction with 49CFR192, see below) to LANL's Natural Gas Distribution utility system that provides natural gas service to LANL facilities.

B31.8S Managing System Integrity of Gas Pipelines (2022)

This Code applies to onshore pipeline systems constructed with ferrous materials and that transport gas. The principles and processes embodied in integrity management are applicable to all pipeline systems.

This Code is specifically designed to provide the operator (as defined in B31.8S Section 13) with the information necessary to develop and implement an effective integrity management program utilizing proven industry practices and processes. The processes and approaches within this Code are applicable to the entire pipeline system.

ASME B31.8S is considered a supplemental Code to ASME B31.8. It is not a piping design Code.

B31.9 Building Services Piping (2020)

This Code Section has rules for the piping in industrial, institutional, commercial, and public buildings, and multi-unit residences, which does not require the range of sizes, pressures, and temperatures covered in B31.1 or B31.3.

ASME B31.9 Paragraph 900.1.2 provides a detailed description of fluid services, piping material and sizes, pressure limits, and temperature limits within the scope of the Code. Paragraph 300.1.3 provides exclusions to the scope of the code.

ASME B31.9 is most commonly applied at LANL for common building services such as

(1) Facility steam and condensate piping less than 150 psig
(2) Hydronic piping (e.g., heating water, chilled water, tower water)
(3) Compressed air piping less than 150 psig

B31.11 Slurry Transportation Piping Systems

Withdrawn, superseded by B31.4.

B31.12 Hydrogen Piping and Pipelines (2019)

This code is not required by 10CFR851 Appendix A. Use of this code is considered optional at LANL.

IP (industrial piping) Rules for this Part have been developed for hydrogen service included in petroleum refineries, refueling stations, chemical plants, power generation plants, semiconductor plants, cryogenic plants, hydrogen fuel appliances, and related facilities.

B31G Manual for Determining Remaining Strength of Corroded Pipelines (2012)

This document is intended solely for the purpose of providing guidance in the evaluation of metal loss in pressurized pipelines and piping systems. It is applicable to all pipelines and piping systems within the scope of the transportation pipeline codes that are part of ASME B31 Code for Pressure Piping, namely: ASME B31.4, Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids; ASME B31.8, Gas Transmission and Distribution Piping Systems; ASME B31.11, Slurry Transportation Piping Systems; and ASME B31.12, Hydrogen Piping and Pipelines, Part PL. Where the term *pipeline* is used, it may also be read to apply to piping or pipe conforming to the acceptable applications and within the technical limitations discussed below.

ASME B31G is not a piping design Code.

49 CFR Part 192 Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards (check the eCFR website for the latest revision)

NOTE: These systems are also required to meet B31.8

This Part prescribes minimum safety requirements for pipeline facilities and the transportation of gas, including pipeline facilities and the transportation of gas within the limits of the outer continental shelf.

(b) This Part does not apply to offshore gathering of gas in State waters; pipelines on the Outer Continental Shelf (OCS); onshore gathering of gas through a pipeline that operates at less than 0 psig, through a pipeline that is not a regulated onshore gathering line, and within inlets of the Gulf of Mexico; any petroleum gas or petroleum gas/air mixtures only pipeline to fewer than 10 customers, if no portion of the system is located in a public place; or a single customer, if the system is located entirely on the customer's premises (no matter if a portion of the system is located in a public place).

NFPA 54 National Fuel Gas Code (2021)

NOTE: NFPA 54 systems are required to meet ESM Chapter 17 due to New Mexico Administrative Code requiring the use of this code.

NFPA 54 provides requirements for the design, fabrication, installation, testing, operation, and maintenance of piping systems from the point of delivery to the connections with each gas utilization device. NFPA 54 also covers requirements for the installation of gas utilization equipment, related accessories, and their ventilation and venting systems. NFPA 54 covers both gaseous and liquefied forms of fuel gas within specified pressure limitations.

Chapter 1 *Administration* of NFPA 54 details the scope/applicability (including what is *not* in the scope), required references to other standards, rules regarding retroactive application, and rules for the authority having jurisdiction applying code equivalency and enforcement.

NFPA 54 is applied at LANL exclusively to the design of natural gas systems from the exit of the service meter assembly (or, where no meter is provided, the outlet of the service regulator or service shutoff valve). This is commonly referred to as "Facility Natural Gas" service.

Items before and including the low-pressure manifold are in the scope of ASME B31.8/49CFR192.

NFPA 58 Liquefied Petroleum Gas Code (2020)

NOTE: NFPA 58 systems are required to meet ESM Chapter 17 due to New Mexico Administrative Code requiring the use of this code.

NFPA 58 provides requirements for the design, construction, installation, and operation of liquefied petroleum gas (LP-Gas) systems. The scope of this code is broader than the LP-Gas scope of NFPA 54.

NFPA 58 has not historically been applied to piping system designs at LANL; existing LP-Gas systems are likely to have been designed to ASME B31.3. For some LP-Gas pressure systems, applying NFPA 58 (or NFPA 54, within its scope) may simplify the pressure system design. For example, commonly used fuel gas system components may not be constructed to listed standards in ASME B31.3 but are in the NFPA codes.

RECORD OF REVISIONS

Rev	Date	Description	POC	RM
0	9/17/14	Initial issue.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
1	6/30/15	A342 changed to Use B31.3 paragraph as written. A345 change based on ASME interpretation. Updates for B31.3-2014.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
2	8/24/15	Admin change to add missing "for ML-4 only."	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
3	9/22/23	Update to introductory section to clarify application of NASME for B31.3 systems. Combined Normal and Category D evaluations (formerly NASME-1-A and 1-B) into a single document. Updated Section and Attachment name for revised ESM Ch. 17 format.	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards point of contact (POC) for upkeep, interpretation, and variance issues.

Chapter 17	**Pressure Safety POC**

This document is online at https://engstandards.lanl.gov

1.0 PURPOSE

This document provides code equivalencies for ASME B31.3 **Non-Metallic** systems (Fluid Categories D and Normal) for use at Los Alamos National Laboratory (LANL). Any of the equivalencies can be applied to a pressure system to provide an approved equivalency to that specific paragraph of B31.3 without applying all the equivalencies. Code paragraphs can be used as written. Any paragraph not listed in the equivalency table shall be used as written. The equivalencies apply to portions of pressures systems that are not ASME BPVC equipment (e.g., boilers, pressure vessels, and air receivers) or supporting piping. The equivalencies cannot be applied to systems with severe cyclic conditions, Category M fluid service, High Pressure fluid service, High Purity fluid service, or Elevated Temperature fluid service (temperature in the creep range). The equivalencies cannot contradict or invalidate facility specific safety basis requirements for credited pressure systems.

2.0 EQUIVALENCY EVALUATION

The risk-based engineering evaluation process used in this attachment is provided in Section 3.0 at the end of this attachment. The Qualitative Risk of the equivalencies provided is 4 or greater (i.e., low).

B31.3 Paragraph	Equivalency Evaluation
Scope and Definitions	
A300 General Statements (B) Responsibilities	Pressure Safety Officer (PSO) Duty Area B may assist and concur with designer and may serve as a designer. Qualified PSO Duty Area B may perform the role as owner's Inspector delegate if appointed by the Owners Inspector.
A300.1.3 Exclusions	Pressure systems outside the scope of B31.3 as defined in this paragraph are unlikely to have B31.3 as part of the design basis.
A300.2 Definitions	This equivalency is **not** applicable to Category M Fluid Service, Elevated Temperature Fluid Service, High Pressure Fluid Service, or High Purity Fluid Service.

Design	
A301.1 Qualifications of the Designer	See above 300 General Statements (b) Responsibilities
A301.3 Design Temperature	This paragraph does not apply if the pressure system is in a relatively constant temperature environment (+/- 10°F) and the temperature is less than 120°F (50°C)

	NOTE: This is to ensure there is no effect from thermal linear change.
A301.3.1 Design Minimum Temperature	Category Normal: Minimum design temperature is a function of the material and the lower allowable temperatures in Table B-1. Category D: Lowest allowable minimum design temperature is -20°F (-29°C).
A301.4 Ambient Effects	Does not apply if the pressure system is in a relatively constant temperature environment (+/- 10°F) and the ambient temperature is less than 120°F (50°C) (this is to ensure there is no effect from thermal linear change).
A301.5 Dynamic Effects	Impact, wind, earthquake, vibration, discharge reactions are required to be evaluated and discounted or applied.
A301.6 Weight Effects	Live and dead loads are required to be evaluated and discounted or applied.
A301.7 Thermal Expansion and Contraction Effects	Paragraph normally does not apply to pressure system is in a relatively constant temperature environment (+/- 10°F) and the temperature is less than 120°F (50°C) *NOTE: This is to ensure there is no effect from thermal linear change.* This paragraph applies to pressure systems with appreciable thermal expansion or phase change induced volumetric expansion (increases of specific volume).
A301.8 Effects of Support, Anchor, and Terminal Movements	This paragraph does not apply for flex hoses restraints to reduce whip hazard.
A301.9 Reduced Ductility Effects	Not applicable.
A301.10 Cyclic Effects	Not applicable.
A301.11 Air Condensation Effects	Category Normal: Required to be evaluated and discounted or applied. Category D: Not applicable.
A302.2.1 Listed Components Having Established Ratings	Listed components shall be the first design preference. Previously evaluated and approved B31.3 unlisted components are located in the file Allowed Unlisted Components Microsoft Excel file. Unlisted components not on the list described above may be used if they are listed on the ESM Ch. 17 Reputable Manufacturers List. This list will be maintained on the ESM Ch. 17 website.

	NOTE: Institutional Evaluation Suppliers List (IESL) is not necessarily a listing of reputable manufacturers. Commercial Grade Designation (CGD) qualifies ML-3 & 4 equipment from non-IESL suppliers for use in ML-1 & 2 service but does not qualify equipment for ASME B31.3 code equivalency to code concerns.
A302.2.2 Listed Components Not Having Specific Ratings	Use reputable manufacturers' published ratings. A Reputable Manufacturers List of approved unlisted components will be maintained on the ESM Ch. 17 website.
A302.2.3 Unlisted Components	Use reputable manufacturers' published ratings. A Reputable Manufacturers List of approved unlisted components will be maintained on the ESM Ch. 17 website.
A302.2.4 Allowances for Pressure and Temperature Variations	Required to be evaluated and discounted or applied.
A302.3 Allowable Stresses and Other Stress Limits	Per design may consider other protective measures in order of precedence as follows: engineering controls (barriers, interlocks or controls), procedural controls (access control), and/or personal protective equipment (PPE).
A302.4 Allowances	Fluid will be evaluated and determined to be compatible for the service life of the system with the materials of construction and manufacturer's recommendations. or allowances must be added in accordance with the paragraph.
A304 Pressure Design of Components A304.1 Straight Pipe	All LANL component designs or custom component designs for LANL shall comply with paragraph A304.1. The material shall meet A323.1 and must have a 3:1 factor of safety for materials not listed Table B1 (unlisted material). (If using reputable manufacturer's published ratings this Part 2 does not apply.) Otherwise, protect personnel using other controls; engineering, administrative, and/or PPE as approved by the PSO. *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturer's published ratings this paragraph does not apply.*

A304.2 Curved and Mitered Segments of Pipe	All LANL component designs or custom component designs for LANL shall comply with paragraph A304.2. The material shall meet A323.1 and must have a 3:1 factor of safety for materials not listed Table B1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturer's published ratings this paragraph does not apply.*
A304.3 Branch Connections	All LANL component designs or custom component designs for LANL shall comply with paragraph A304.3. The material shall meet A323.1 and must have a 3:1 factor of safety for materials not listed Table B1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturer's published ratings this paragraph does not apply.*
A304.3.1 General	Required to be evaluated and discounted or applied.
A304.3.2 Branch Connections Using Fittings	Required to be evaluated and discounted or applied.
A304.3.3 Additional Design Considerations	Required to be evaluated and discounted or applied.
A304.4 Closures	All LANL component designs or custom component designs for LANL shall comply with paragraph A304.4. The material shall meet A323.1 and must have a 3:1 factor of safety for materials not listed Table B1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturer's published ratings this paragraph does not apply.*
A304.5 Pressure Design of Nonmetallic Flanges and Blanks	All LANL component designs or custom component designs for LANL shall comply with paragraph A304.5. The material shall meet 323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturer's published ratings this paragraph does not apply.*

A304.6 Reducers	All LANL component designs or custom component designs for LANL shall comply with paragraph A304.6. The material shall meet A323.1 and must have a 3:1 factor of safety for materials not listed Table B1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturer's published ratings this paragraph does not apply.*
A304.7 Pressure Design of Other Components	Initial design consistent with the design criteria of ASME B31.3 shall be a hoop stress evaluation at the minimum wall thickness at the maximum part diameter (worst case hoop stress) showing the design meets or exceed the stress. Note use B31.3 allowable stress values with B31.3 equations. Substantiation of the above may be done by one of the four items below: *NOTE: System design pressure may be used to evaluate the component as the design pressure* 1) For a simple part that has no stress intensification factors (notches, threads, pits, cracks, etc.) the minimum calculated hoop stress shall be 4x the design pressure (MAWP). 2) Determine if the piping component was previously used in accordance with paragraph A304.7.2 (a). 3) Pressure test to 4x the design pressure (at maximum design temperature). 4) Perform Engineering Finite Element Analysis (FEA) in accordance with paragraph 304.7.2 (d).
A305 Pipe	Paragraph is required to be evaluated and discounted or applied.
A306 Fittings, Bends, Miters, Laps, and Branch Connections	All LANL component designs or custom component designs for LANL shall comply with paragraph A306. The material shall meet A323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturer's published ratings this paragraph does not apply.*
A307 Valves and Specialty Components	All LANL component designs or custom component designs for LANL shall comply with paragraph A307. The material shall meet A323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturer's published ratings this paragraph does not apply.*

A308 Flanges, Blanks, Flange Facings, and Gaskets	All LANL component designs or custom component designs for LANL shall comply with paragraph A308. The material shall meet A323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturer's published ratings this paragraph does not apply.*
A309 Bolting	If LANL is designing or having a design for a pressure component, the design shall comply with paragraph A309. The material shall meet A323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturer's published ratings this paragraph does not apply.*
A311 Bonded Joints in Plastics	Bonded plastic joints shall be done in accordance with ESM Chapter 13 *Welding, Joining, and NDE*. Follow manufacturer instructions for assembly of PCV solvent welded joints.
A311.2.3 Joints Limited to Category D Fluid Service	Applies only to Category D.
A318 Special Joints	Evaluate in accordance with A304.7 in this equivalency evaluation. *NOTE: The use of "gland" in this paragraph does not mean Swagelok gland fitting.*
A319 Flexibility of Nonmetallic Piping	Follow ESM Ch. 17 PS-REQUIREMENTS "Flexibility Analysis."
A320 Analysis of Sustained Loads	Piping is not to be used to support external equipment that is not part of the piping system. Paragraph is required to be evaluated and discounted or applied. Piping supports may be in accordance with LANL Master Specification 22 0529. If additional support is required see 321.
A321 Piping Supports	Use B31.3 paragraph as written in 321.1.2 "simple calculations and engineering judgment."

<table>
<tr><th colspan="2">Materials</th></tr>
<tr><td>A323 General Requirements</td><td>Use listed materials:
<table><tr><td>Acrylonitrile-butadiene-styrene plastics</td><td>ABS</td></tr><tr><td>Chlorinated poly (vinyl chloride)</td><td>CPVC</td></tr><tr><td>Perfluoro (alkoxyalkane)</td><td>PFA</td></tr><tr><td>Polypropylene
Poly (vinyl chloride)</td><td>PP
PVC</td></tr><tr><td>Poly (vinylidene chloride)</td><td>PVDC</td></tr><tr><td>Poly (vinylidene fluoride)</td><td>PVDF</td></tr><tr><td>Polytetrafluoroethylene</td><td>PTFE</td></tr></table>Additional listed materials are in B31.3 Appendix B.
This evaluation does not apply to Test Articles.</td></tr>
<tr><td>A323.1.2 Unlisted Materials</td><td>Prior to using an unlisted material, the chemistry, physical and mechanical properties, method and process of manufacture, heat treatment, and quality control must be known as required by A323.1.
NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturer’s published ratings this paragraph does not apply. The Designer is cautioned that materials must be suitable for the application and must be evaluated in accordance with A323.1 if necessary to determine the suitability of the material.</td></tr>
<tr><td>A323.1.3 Unknown Materials</td><td>Unknown materials shall not be used.</td></tr>
<tr><td>A323.2 Temperature Limitations</td><td>Category Normal: Use B31.3 paragraph as written.
Category D: The minimum [−29°C (−20°F)] and maximum temperature as shown in the definition of Category D Fluid Service does not necessarily apply and must be verified as required by A323.2.</td></tr>
<tr><td>A323.2.1 Upper Temperature Limits, Listed Materials</td><td>Materials shall have test results or manufacturers supplied data at or above the highest expected service temperature.</td></tr>
</table>

A323.2.2 Lower Temperature Limits, Listed Materials	Materials shall have test results or manufacturers supplied data at or below the lowest expected service temperature. *NOTE: Non-metallic materials exhibit a "glass transition temperature" where the material becomes hard and may be susceptible to brittle fracture.*
A323.2.3 Temperature Limits, Unlisted Materials	Use B31.3 paragraph as written to verify the temperature limits of the unlisted material meet the requirements of the design temperature. *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturer's published ratings this paragraph does not apply. The Designer is cautioned that materials must be suitable for the temperature and must be evaluated in accordance with 323.2.3 if necessary to determine the suitability of the material.*
A323.5 Deterioration of Materials in Service	Designer is required to design the pressure system for the service life of the system and consider material compatibility.
A326 Dimensions and Ratings of Components	Listed components shall be the first design preference. Previously evaluated and approved B31.3 unlisted components are in the Allowed Unlisted Components file. Unlisted components not on the list described above may be used if they are listed on the ESM Ch. 17 Reputable Manufacturers List. This list will be maintained on the ESM Ch 17 website. Listing on a reputable manufacturer's list requires ratings that are acceptable for the design conditions of temperature, pressure, and material compatibility. or Engineering calculations showing a factor of safety of 3:1 (this item would then be entered onto the reputable manufacturer's list as well). Items being placed on this list need final approval by the chief pressure safety officer (CPSO) or Designee. Commercial Grade Dedication (CGD) qualifies ML-3 & 4 equipment from non-IESL suppliers for use in ML-1 & 2 service but does not qualify equipment for ASME B31.9 code equivalency to code concerns.
Fabrication, Assembly, and Erection	
A328 Bonding of Plastics	Not required for low-risk pressure systems (FS3 or FS3-ULH as defined by P101-34, *Pressure Safety*).
A335 Assembly and Erection	Assemble in accordance with the manufacturer's requirements.

A340 Inspection A340.1 General	Qualified PSO Duty Area B may act as the Owner's Inspector. Owner's Inspector shall be knowledgeable with the pressure system of interest.
340.4 Qualifications of the Owner's Inspector	See paragraph 300; Qualified PSO Duty Area B may act as the Owner's Inspector or equivalent.
A345 Testing	Precautions in Appendix F, para. FA323.4 Material Considerations — Nonmetals should be considered. Pneumatic leak testing is approved for all systems with less than 1000 lb-ft stored energy during testing. Pressure systems with additional stored energy must be approved by the CPSO. Materials subject to brittle failure shall not be pneumatically tested. See A345 for other requirements for example test pressures (A345.4.2), test limitations (A345.2.1), and other requirements for pneumatic testing (A345.5.2) *NOTE: Be aware of the ramifications of using high molecular weight gases to test system for lower molecular weight gas. The engineering best practice is to use a lower or equal weight molecular weight gas as the referee test gas except for hydrogen where helium is accepted.* Category Normal: The Owner accepts pneumatic or hydro-pneumatic leak testing with inert gas or air (additional testing may be required by the Designer). Category D: Owner has elected to use Initial Service Leak Test for Category D Fluid Service (additional testing may be required by the Designer).

3.0 RISK-BASED ENGINEERING EVALUATION PROCESS

This Risk-Based Evaluation process is used Section 2.0 above and may be used in other situations (e.g., ASME, NASME) where allowed by those sections or with a variance (Form 2137). This process is based on the methodology described in API Recommended Practice 580, *Risk-Based Inspection*.

Guidance: The risk-based engineering evaluation evaluates the systems and determines if there is a risk to the worker (and equipment). A risk-based engineering evaluation is normally applied to non-hardware issues. A system that has known hardware issues will not likely benefit from this type of analysis.

A. Definitions

1. **Engineering Evaluation** – The Risk-Based Engineering Evaluation is the process of reviewing a pressure system for adequate pressure system integrity

and determining necessary corrective actions to mitigate risk to acceptable level based on best engineering practices.

2. **Consequence** – The potential outcome from an event. There may be more than one consequence from an event.

3. **Probability** – The relative frequency with which an event is likely to occur within the time frame under consideration.

4. **Acceptable Risk** – A Qualitative Risk (QR) number of 4 or higher as shown on Table 1-4, Qualitative Risk, below. Qualitative Risk shall be controlled to QR number of 4 or higher.

B. Baseline Criteria

1. The Risk-Based Engineering Evaluation applies only to systems that have correctly sized relief protection.

C. Engineering Evaluation

1. The Risk-Based Engineering Evaluation is a three-step process. This process applies to evaluation of Risk Level 2 and 3 deficiencies, as defined above; Risk Level 1 deficiencies must be corrected in accordance with the requirements stipulated above.

   a. Using system information generated from the walk down team efforts and other sources, and ESM Chapter 17 requirements, the engineer generates a Qualitative Risk of each deficiency.

   b. The Qualitative Risk is then compared to the Acceptable Risk (i.e., risk number of 4 or higher).

   c. If the Qualitative Risk is greater than the Acceptable Risk (i.e., a risk number lower than 4), then either the consequence or probability must be adjusted to achieve a risk number of 4 or higher.

2. An engineering evaluation of the pressure system shall be performed by personnel meeting the qualification requirements for a pressure system designer and approved by a qualified PSO (*see Section GEN)* with Risk Evaluation training.

3. The engineering evaluation shall be an analysis and examination of the pressure system to determine the system integrity.

4. The Risk-Based Engineering Evaluation analysis shall be included with the pressure system documentation.

5. The Risk-Based Engineering Evaluation shall ensure that hazards and dominant contributors to risk are controlled according to the following:

   a. Eliminate accident scenarios (e.g., eliminate hazards or initiating events by design).

   b. Reduce the likelihood of accident scenarios through design and operational changes (hazard control).

c. Reduce the severity of accident consequences (hazard mitigation).

d. Improve the state-of-knowledge regarding key uncertainties that drive the risk associated with a hazard (uncertainty reduction to support implementation of the above strategies).

6. The control(s) shall be based on the level of risk associated with that hazard. Some risks may require a combination of several different approaches to prevent, mitigate, and/or control the risk.

7. Controls shall be in applied the following order of precedence:

a. Engineered controls,

b. Administrative controls,

c. Personal protective equipment.

D. Qualitative Risk (QR)

1. The Risk-Based Engineering Evaluation shall, as a first step, use a Qualitative Risk based approach to evaluate adequacy of pressure system integrity.

2. The qualitative risk evaluation shall identify:

a. the system(s),

b. the hazard(s) deficiency,

c. the probability assessment,

d. the consequence of failure evaluation, and

e. the subsequent QR number (see Table 1-4).

3. The Qualitative Risk based evaluation shall be based on probability and consequence of a single-point system failure for each deficiency observed.

Table 1-1 Probability factors to be considered

a. corrosion potential (crevice corrosion, general, galvanic, etc.)
b. materials of construction (composite, plastic, steel, brass, etc.)
c. material compatibility (lubricants, seals, and general materials)
d. oxygen systems
e. erosion potential
f. fatigue cycles (cycle life)
   1. low-cycle fatigue (where significant plastic straining occurs)
   2. high-cycle fatigue (where stresses and strains are largely confined to the elastic region)
g. size (contained energy)
h. human error
i. operating history
j. damage mechanisms
k. operation in creep range
l. stress intensification factors; for example, cracks or acute angles in pressure boundaries
m. available documentation
   1. welding
   2. code pressure test
n. documentation of ASME code fabrication
o. MAWP and design pressure as used in code calculations
p. design temperature
q. corrosion allowance determination
r. code required calculations (as applicable)
s. minimum wall thickness
t. nozzle reinforcement
u. thermal load calculations
v. seismic calculations
w. support structure
x. wind loading
y. piping flexibility analysis
z. cyclic loading calculations
aa. other static loadings (static fluid head)
bb. other dynamic loadings
cc. historical operational documentation
   1. corrosion rate (mils/year) (used to determine inspection interval)
   2. locations and dates of thickness measurements
   3. year of construction
   4. date of original installation
   5. date of first use
   6. out of service periods (used to determine inspection interval)
   7. discrepancy conditions
   8. a comprehensive chronological record of maintenance history
   9. history of repair – objective evidence required for ASME code stamped items
   10. history of alterations – objective evidence required for ASME code-stamped items.
   11. historical inspections records of NDE
   12. applicable variances/waivers
   13. fabrication documentation
   14. leak test records
   15. maintenance sheet
   16. daily logs
   17. boiler records – water treatment, maintenance, and boiler appurtenances
   18. engineering evaluations as required by this chapter

4. Consequences of failure to be considered include the following safety and health issues:
    a. Chemical toxicity
    b. Physical hazards (e.g., projectiles)
    c. Flammability
    d. Radioactivity
    e. Asphyxiation hazards
    f. Volume
    g. Failure Mode
        1) Brittle fracture failure mode
        2) Leak before burst failure mode
    h. Inhabited areas
        1) Shielding (glove box, fume hood, test cell)
5. Other issues to consider include:
    a. Mission criticality
    b. Economic impact
    c. Schedule
    d. Environmental impact

E. Hazard Mitigation

1. Based on the results of the probability evaluation, a probability bin is selected as defined in Table 1-2, Failure Probability.
2. Based on the results of the consequence evaluation, a consequence bin is selected as defined in Table 1-3, Consequence of Failure.
3. Enter Table 1-4, Qualitative Risk Evaluation, and locate the QR number that corresponds to the intersection of the probability bin (A through E) and consequence bin (I through V).

    All ASME B31.3 code equivalencies in this document shall have a QR number of 4 or higher.

Table 1-2 Failure Probability

Level	Description	Qualitative
A (Frequent)	Frequent	Likely to occur immediately
B (Probable)	Probable	Probably will occur in time
C (Occasional)	Occasional	May occur in time
D (Remote)	Remote	Unlikely to occur
E (Improbable)	Improbable	Improbable to occur

Table 1-3 Consequence of Failure

Category	Description	Examples
I	Major	Fatalities, and/or major long-term environmental impact
II	Serious	Serious injuries, and/or significant environmental impact
III	Significant	Minor injuries, and/or short-term environmental impact
IV	Minor	First aid injuries only, and/or minimal environmental impact
V	Insignificant	No significant consequence

Table 1-4 Qualitative Risk (QR) Determination

			Probability				
			A	**B**	**C**	**D**	**E**
			Frequent	**Probable**	**Occasional**	**Remote**	**Improbable**
Consequence	**I**	**Major**	**1**	**1**	**1**	**2**	**3**
	II	**Serious**	**1**	**1**	**2**	**3**	4
	III	**Significant**	**1**	**2**	**3**	4	5
	IV	**Minor**	**2**	**3**	4	5	6
	V	**Insignificant**	**3**	4	5	6	7

RECORD OF REVISIONS

Rev	Date	Description	POC	RM
0	9/17/14	Initial issue.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
1	6/30/15	A342 changed to Use B31.3 paragraph as written. A345 change based on ASME interpretation. Updates for B31.3-2014.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
2	11/09/18	A342 changed to use B31.3 paragraph as written; other minor clarifications and corrections.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
3	9/22/23	Update to introductory section to clarify application of NASME for B31.3 systems. Combined Normal and Category D evaluations (formerly NASME-1-C and 1-D) into a single document. Updated Section and Attachment name for revised ESM Ch. 17 format.	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards point of contact (POC) for upkeep, interpretation, and variance issues.

Chapter 17	[Pressure Safety POC](#)

This document is online at https://engstandards.lanl.gov

1.0 PURPOSE

This document provides code equivalencies for ASME B31.3 **Metallic** systems (Fluid Categories D and Normal) for use at Los Alamos National Laboratory (LANL). Any of the equivalencies can be applied to a pressure system to provide an approved equivalency to that specific paragraph of B31.3 without applying all the equivalencies. Code paragraphs can be used as written. Any paragraph not listed in the equivalency table shall be used as written. The equivalencies apply to portions of pressures systems that are not ASME Boiler and Pressure Vessel Code (BPVC) equipment (e.g., boilers, pressure vessels, and air receivers) or supporting piping. The equivalencies cannot be applied to systems with severe cyclic conditions, Category M fluid service, High Pressure fluid service, High Purity fluid service, or Elevated Temperature fluid service (temperature in the creep range). The equivalencies cannot contradict or invalidate facility specific safety basis requirements for credited pressure systems.

2.0 EQUIVALENCY EVALUATION

The risk-based engineering evaluation process used in this attachment is provided in Section 3.0 at the end of this attachment. The Qualitative Risk of the equivalencies provided is 4 or greater (i.e., low).

B31.3 Paragraph	Equivalency Evaluation
Chapter I Scope and Definitions	
300 General Statements (b) Responsibilities	Pressure safety officer (PSO) Duty Area B may assist and concur with designer and may serve as a designer. Qualified PSO Duty Area B may perform the role as Owner's Inspector delegate if appointed by the Owner's Inspector.
300.1.3 Exclusions	Pressure systems outside the scope of B31.3 as defined in this paragraph are unlikely to have B31.3 as part of the design basis.
300.2 Definitions	This table is **not** applicable to Category M Fluid Service, Elevated Temperature Fluid Service, High Pressure Fluid Service, or High Purity Fluid Service.

Chapter II Design	
301.1 Qualifications of the Designer	See above 300 General Statements (b) Responsibilities.
301.3 Design Temperature	This paragraph does not apply if the pressure system is in a relatively constant temperature environment (+/- 10°F) and the temperature is less than 120°F (50°C) (this is to ensure there is no effect from thermal linear change).
301.3.1 Design Minimum Temperature	Category Normal: Minimum design temperature is a function of the material and the lower allowable temperatures in Table A.

	Category D: Lowest allowable minimum design temperature is -20°F (-29°C).
301.4 Ambient Effects	Does not apply if the pressure system is in a relatively constant temperature environment (+/- 10°F) and the ambient temperature is less than 120°F (50°C). *NOTE: This is to ensure there is no effect from thermal linear change.*
301.5 Dynamic Effects	Impact, wind, earthquake, vibration, discharge reactions are required to be evaluated and discounted or applied.
301.6 Weight Effects	Live and dead loads are required to be evaluated and discounted or applied.
301.7 Thermal Expansion and Contraction Effects	Paragraph normally does not apply to pressure system in a relatively constant temperature environment (+/- 10°F) and the temperature is less than 120°F (50°C) (this is to ensure there is no effect from thermal linear change). This paragraph applies to pressure systems with appreciable thermal expansion or phase change induced volumetric expansion (increases of specific volume).
301.8 Effects of Support, Anchor, and Terminal Movements	This paragraph does not apply for flex hose restraints to reduce whip hazard.
301.9 Reduced Ductility Effects	Category Normal: Paragraph is required to be evaluated and discounted or applied. Category D: Not applicable.
302.2.1 Listed Components Having Established Ratings	Listed components shall be the first design preference. Previously evaluated and approved B31.3 unlisted components are located in the Allowed Unlisted Components Microsoft Excel file. Unlisted components not on the list described above may be used if they are listed on the Engineering Standards Manual (ESM) Ch. 17 Reputable Manufacturers List. This list will be maintained on the ESM Ch. 17 website. *NOTE: Institutional Evaluation Suppliers List (IESL) is not necessarily a listing of reputable manufacturers.* Commercial Grade Designation (CGD) qualifies ML-3 & 4 equipment from non-IESL suppliers for use in ML-1 & 2 service but does not qualify equipment for ASME B31.3 code equivalency to code concerns.

302.2.2 Listed Components Not Having Specific Ratings	Use reputable manufacturers' published ratings. A Reputable Manufacturers List of approved unlisted components will be maintained on the ESM Ch. 17 website.
302.2.3 Unlisted Components	Use reputable manufacturers' published ratings. A Reputable Manufacturers List of approved unlisted components will be maintained on the ESM Ch. 17 website.
302.3 Allowable Stresses and Other Stress Limits	The designer may consider other protective measures in order of precedence as follows: engineering controls (barriers, interlocks, or controls), procedural controls (access control), and/or personal protective equipment (PPE).
302.3.5 Limits of Calculated Stresses Due to Sustained Loads and Displacement Strains	The paragraph is required to be evaluated and discounted or applied. If unlisted, use manufacturer's allowable stress ratings for the material. *NOTE: If piping and piping elements (unions, couplings, etc.) are rated above the maximum design pressure and is sufficiently supported (see Paragraph 321 "Piping Supports"), and the other piping components that are in the pressure system are adequately supported this paragraph does not apply.*
302.3.6 Limits of Calculated Stresses Due to Occasional Loads	Applies only when occasional loads are a factor in piping system integrity (e.g., seismic or wind loads apply).
302.4 Allowances	Fluid shall be evaluated and determined to be compatible for the service life of the system with the materials of construction and manufacturer's recommendations. Otherwise, allowances shall be added in accordance with the paragraph.
304 Pressure Design of Components 304.1 Straight Pipe	All LANL component designs or custom component designs for LANL shall comply with paragraph 304.1. The material shall meet 323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturers' published ratings this paragraph does not apply.*
304.2 Curved and Mitered Segments of Pipe	All LANL component designs or custom component designs for LANL shall comply with paragraph 304.2. The material shall meet 323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material).

	NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturers' published ratings this paragraph does not apply. When the wall thickness is 1.5 times the minimum required by equation 3a no additional evaluation of Intrados or Extrados is required. or Use approved vendor tubing or pipe bender with their required pipe/tube to their published standard.
304.3 Branch Connections	All LANL component designs or custom component designs for LANL shall comply with paragraph 304.3. The material shall meet 323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturers' published ratings this paragraph does not apply.*
304.4 Closures	All LANL component designs or custom component designs for LANL shall comply with paragraph 304.4. The material shall meet 323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *Note: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturers' published ratings this paragraph does not apply.*
304.5 Pressure Design of Flanges and Blanks	All LANL component designs or custom component designs for LANL shall comply with paragraph 304.5. The material shall meet 323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturers' published ratings this paragraph does not apply.*
304.6 Reducers	All LANL component designs or custom component designs for LANL shall comply with paragraph 304.6. The material shall meet 323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturers' published ratings this paragraph does not apply.*

304.7 Pressure Design of Other Components	Initial design consistent with the design criteria of ASME B31.3 shall be a hoop stress evaluation at the minimum wall thickness at the maximum part diameter (worst case hoop stress) showing the design meets or exceed the stress. *NOTE: Use 31.3 material allowable stress values with B31.3 equations.* Substantiation of the above may be done by one of the four items below: 1) For a simple part that has no stress intensification factors (notches, threads, pits, cracks, etc.) the minimum calculated hoop stress shall be four times the design pressure (MAWP) maximum allowable working pressure. 2) Determine if the piping component was previously used in accordance with paragraph 304.7.2 (a). 3) Pressure test to four times the design pressure. 4) Perform Engineering Finite Element Analysis (FEA) in accordance with paragraph 304.7.2 (d).
305 Pipe	The paragraph is required to be evaluated and discounted or applied.
306 Fittings, Bends, Miters, Laps, and Branch Connections	All LANL designs or custom designs for LANL shall comply with paragraph 306. The material shall meet 323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturers' published ratings this paragraph does not apply.*
307 Valves and Specialty Components	All LANL designs or custom designs for LANL shall comply with paragraph 307. The material shall meet 323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturers' published ratings this paragraph does not apply.*
308 Flanges, Blanks, Flange Facing, and Gaskets	All LANL designs or custom designs for LANL shall comply with paragraph 308. The material shall meet 323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturers' published ratings this paragraph does not apply.*

309 Bolting	All LANL designs or custom designs for LANL shall comply with paragraph 309. The material shall meet 323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturers' published ratings this paragraph does not apply.*
311 Welded Joints	Welding and brazing shall be done in accordance with ESM Chapter 13 *Welding, Joining, & NDE* [Nondestructive Examination].
311.2 Specific Requirements	Welding and brazing shall be done in accordance with ESM Chapter 13 *Welding, Joining, & NDE* [Nondestructive Examination].
311.2.1 Welds for Category D Fluid Service	Welding and brazing shall be done in accordance with ESM Chapter 13 *Welding, Joining, & NDE* [Nondestructive Examination].
311.2.7 Seal Welds	Welding and brazing shall be done in accordance with ESM Chapter 13 *Welding, Joining, & NDE* [Nondestructive Examination].
312 Flanged Joints	U Vacuum style flanges for example "ConFlat" CF or KF (QF) flanges may be used after qualification in accordance with this document.
314 Threaded Joints	All LANL designs or custom designs for LANL shall comply with paragraph 314. The material shall meet 323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturers' published ratings this paragraph does not apply.*
315 Tubing Joints	All LANL designs or custom designs for LANL shall comply with paragraph 315. The material shall meet 323.1 and must have a 3:1 factor of safety for materials not listed Table A1 (unlisted material). *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturers' published ratings this paragraph does not apply.* Evaluate inter-mixed fittings using paragraph 304.7 above. May consider de-rating the fitting based on the application to define or establish the MAWP.
316 Caulked Joints	Category Normal: Not permitted for Normal Fluid Service. Category D: Permitted for Category D; use paragraph 316 as written.
317 Soldered and Brazed Joints	Soldering shall meet B31.3 para. 317.1 requirements and may only be used in Category D fluid service.

	Brazed joints shall be done in accordance with ESM Chapter 13 *Welding, Joining, & NDE* [Nondestructive Examination].
318 Special Joints	Evaluate in accordance with 304.7.2 in this equivalency evaluation. *NOTE: The use of "gland" in this paragraph does not mean Swagelok gland fitting.*
319 Piping Flexibility	Follow ESM Ch. 17 REQUIREMENTS "Flexibility Analysis."
320 Analysis of Sustained Loads	Piping is not to be used to support external equipment that is not part of the piping system. Paragraph is required to be evaluated and discounted or applied. Piping supports may be in accordance with LANL Master Specification 22 0529. If additional support is required, see 321.
321 Piping Supports	Use B31.3 paragraph as written in 321.1.2 "simple calculations and engineering judgment."

Chapter III Materials	
323 General Requirements	Use listed materials for example: 304, 316, B88, and A108; additional listed materials are in B31.3 Appendix A. This evaluation does not apply to Test Articles.
323.1.2 Unlisted Materials	Prior to using an unlisted material, the chemistry, physical and mechanical properties, method and process of manufacture, heat treatment, and quality control must be known as required by 323.1.2. *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturers' published ratings this paragraph does not apply.* The Designer is cautioned that materials must be suitable for the application and must be evaluated in accordance with 323.1.2 if necessary to determine the suitability of the material.
323.1.3 Unknown Materials	Unknown materials shall not be used.
323.2 Temperature Limitations	Category Normal: Use B31.3 paragraph as written. Category D: Any carbon steel material may be used to a minimum temperature of −29°C (−20°F) for Category D Fluid Service.
323.2.1 Upper Temperature Limits, Listed Materials	Identify the temperature limits of the materials.

323.2.2 Lower Temperature Limits, Listed Materials	Category Normal: Use B31.3 paragraph as written. Category D: Select materials that are ductile (including welds/braze/solder) at -20 F. Normally these materials include 304, 316 (austenitic SS), brass, etc.; additional listed materials are in B31.3 Appendix A.
323.2.3 Temperature Limits, Unlisted Materials	Verify the temperature limits of the unlisted material meet the requirements of the design temperature. *NOTE: This paragraph is for designing pipe and components, not for procurement of items offered for sale. If using reputable manufacturers' published ratings this paragraph does not apply.* The Designer is cautioned that materials must be suitable for the temperature and must be evaluated in accordance with 323.2.3 if necessary to determine the suitability of the material.
323.3 Impact Testing Methods and Acceptance Criteria	Category Normal: Use B31.3 paragraph as written. Category D: Not required for Category D Fluid Service.
323.4 Fluid Service Requirements for Materials (entire)	Category Normal: Use B31.3 paragraph as written. Category D: Not required for Category D Fluid Service.
323.5 Deterioration of Materials in Service	Designer is required to design the pressure system for the service life of the system and consider material compatibility.

Chapter IV Standards for Piping Components	
326 Dimensions and Ratings of Components	Listed components shall be the first design preference. Previously evaluated and approved B31.3 unlisted components are located in the Allowed Unlisted Components Microsoft Excel file. Unlisted components not on the list described above may be used if they are listed on the ESM Ch. 17 Reputable Manufacturers List. This list will be maintained on the ESM Ch. 17 website. Listing on a reputable manufacturers list requires ratings that are acceptable for the design conditions of temperature, pressure, and material compatibility. or Engineering calculations showing a factor of safety of 3:1 (this item would then be entered onto the reputable manufacturers list as well). Items being placed on this list need final approval by the chief pressure safety officer (CPSO) or Designee. Commercial Grade Dedication (CGD) qualifies ML-3 & 4 equipment from non-IESL suppliers for use in ML-1 & 2 service but does not qualify equipment for ASME B31.9 code equivalency to code concerns.

Chapter V Fabrication, Assembly, and Erection	
328 Welding	Welding and brazing shall be done in accordance with ESM Chapter 13 *Welding, Joining, & NDE* [Nondestructive Examination].
330 Preheating	Welding and brazing shall be done in accordance with ESM Chapter 13 *Welding, Joining, & NDE* [Nondestructive Examination].
331 Heat Treatment	Welding and brazing shall be done in accordance with ESM Chapter 13 *Welding, Joining, & NDE* [Nondestructive Examination].
331.2 Specific Requirements	Welding and brazing shall be done in accordance with ESM Chapter 13 *Welding, Joining, & NDE* [Nondestructive Examination].
332 Bending or Forming	Bend or form in accordance with the manufacturer's specification or requirements.
333 Brazing and Soldering	Welding and brazing shall be done in accordance with ESM Chapter 13. Category Normal: Soldering is not permitted for Category Normal. Category D: Soldering is permitted; see para. 317.1. Follow B31.3 paragraph 333 as written.
335 Assembly and Erection	Assemble in accordance with the manufacturer's specification or requirements.

Chapter VI Inspection, Examination, and Testing	
340 Inspection 340.1 General	Qualified PSO Duty Area B may act as the Owner's Inspector. Owner's Inspector shall be knowledgeable with the pressure system of interest.
340.4 Qualifications of the Owner's Inspector	See paragraph 300. Qualified PSO Duty Area B may act as the Owner's Inspector or equivalent.
345 Testing	Pneumatic leak testing is approved for all systems with less than 1000 lb-ft stored energy during testing. Additional stored energy must be approved by the CPSO. Follow B31.3 paragraphs as written. *NOTE: Be aware of the ramifications of using high molecular weight gases to test system for lower molecular weight gas. The engineering best practice is to use a lower or equal weight molecular weight gas as the referee test gas except for hydrogen where helium is accepted.* Category Normal: The Owner accepts pneumatic or hydro-pneumatic leak testing with inert gas or air (additional testing may be required by the Designer).

	Category D: Owner has elected to use Initial Service Leak Test for Category D Fluid Service (additional testing may be required by the Designer).

3.0 RISK-BASED ENGINEERING EVALUATION PROCESS

This Risk-Based Evaluation process is used in Chapter 17 Section 2.0 above and may be used in other situations (e.g., ASME, NASME) where allowed by those sections or with a variance (Form 2137). This process is based on the methodology described in API Recommended Practice 580, *Risk-Based Inspection*.

Guidance: The risk-based engineering evaluation evaluates the systems and determines if there is a risk to the worker (and equipment). A risk-based engineering evaluation is normally applied to non-hardware issues. A system that has known hardware issues will not likely benefit from this type of analysis.

A. Definitions

1. **Engineering Evaluation** – The Risk-Based Engineering Evaluation is the process of reviewing a pressure system for adequate pressure system integrity and determining necessary corrective actions to mitigate risk to acceptable level based on best engineering practices.

2. **Consequence** – The potential outcome from an event. There may be more than one consequence from an event.

3. **Probability** – The relative frequency with which an event is likely to occur within the time frame under consideration.

4. **Acceptable Risk** – A Qualitative Risk (QR) number of 4 or higher as shown on Table 1-4, Qualitative Risk, below. Qualitative Risk shall be controlled to QR number of 4 or higher.

B. Baseline Criteria

1. The Risk-Based Engineering Evaluation applies only to systems that have correctly sized relief protection.

C. Engineering Evaluation

1. The Risk-Based Engineering Evaluation is a three-step process. This process applies to evaluation of Risk Level 2 and 3 deficiencies, as defined above; Risk Level 1 deficiencies must be corrected in accordance with the requirements stipulated above.

   a. Using system information generated from the walk down team efforts and other sources, and ESM Chapter 17 requirements, the engineer generates a Qualitative Risk of each deficiency.

   b. The Qualitative Risk is then compared to the Acceptable Risk (i.e., risk number of 4 or higher).

   c. If the Qualitative Risk is greater than the Acceptable Risk (i.e., a risk number lower than 4), then either the consequence or probability must be adjusted to achieve a risk number of 4 or higher.

2. An engineering evaluation of the pressure system shall be performed by personnel meeting the qualification requirements for a pressure system designer and approved by a qualified PSO (*see Section GEN)* with Risk Evaluation training.

3. The engineering evaluation shall be an analysis and examination of the pressure system to determine the system integrity.

4. The Risk-Based Engineering Evaluation analysis shall be included with the pressure system documentation.

5. The Risk-Based Engineering Evaluation shall ensure that hazards and dominant contributors to risk are controlled according to the following:

   a. Eliminate accident scenarios (e.g., eliminate hazards or initiating events by design).

   b. Reduce the likelihood of accident scenarios through design and operational changes (hazard control).

   c. Reduce the severity of accident consequences (hazard mitigation).

   d. Improve the state-of-knowledge regarding key uncertainties that drive the risk associated with a hazard (uncertainty reduction to support implementation of the above strategies).

6. The control(s) shall be based on the level of risk associated with that hazard. Some risks may require a combination of several different approaches to prevent, mitigate, and/or control the risk.

7. Controls shall be applied in the following order of precedence:

   a. Engineered controls

   b. Administrative controls

   c. Personal protective equipment

D. Qualitative Risk (QR)

1. The Risk-Based Engineering Evaluation shall, as a first step, use a Qualitative Risk based approach to evaluate adequacy of pressure system integrity.

2. The Qualitative Risk evaluation shall identify the following:

   a. the system(s),

   b. the hazard(s) deficiency,

   c. the probability assessment,

   d. the consequence of failure evaluation, and

   e. the subsequent QR number (see Table 1-4).

3. The Qualitative Risk based evaluation shall be based on probability and consequence of a single-point system failure for each deficiency observed.

Table 1-1 Probability factors to be considered

a. corrosion potential (crevice corrosion, general, galvanic, etc.)
b. materials of construction (composite, plastic, steel, brass, etc.)
c. material compatibility (lubricants, seals, and general materials)
d. oxygen systems
e. erosion potential
f. fatigue cycles (cycle life)
   1) low-cycle fatigue (where significant plastic straining occurs)
   2) high-cycle fatigue (where stresses and strains are largely confined to the elastic region)
g. size (contained energy)
h. human error
i. operating history
j. damage mechanisms
k. operation in creep range
l. stress intensification factors; for example, cracks or acute angles in pressure boundaries
m. available documentation
   1) welding
   2) code pressure test
n. documentation of ASME code fabrication
o. MAWP and design pressure as used in code calculations
p. design temperature
q. corrosion allowance determination
r. code required calculations (as applicable)
s. minimum wall thickness
t. nozzle reinforcement
u. thermal load calculations
v. seismic calculations
w. support structure
x. wind loading
y. piping flexibility analysis
z. cyclic loading calculations
aa. other static loadings (static fluid head)
bb. other dynamic loadings
cc. historical operational documentation
   1) corrosion rate (mils/year) (used to determine inspection interval)
   2) locations and dates of thickness measurements
   3) year of construction
   4) date of original installation
   5) date of first use
   6) out of service periods (used to determine inspection interval)
   7) discrepancy conditions
   8) a comprehensive chronological record of maintenance history
   9) history of repair – objective evidence required for ASME code stamped items
   10) history of alterations – objective evidence required for ASME code-stamped items
   11) historical inspections records of NDE
   12) applicable variances/waivers
   13) fabrication documentation
   14) leak test records
   15) maintenance sheet
   16) daily logs
   17) boiler records – water treatment, maintenance, and boiler appurtenances
   18) engineering evaluations as required by this chapter

4. Consequences of failure to be considered include the following safety and health issues:
    a. Chemical toxicity
    b. Physical hazards (e.g., projectiles)
    c. Flammability
    d. Radioactivity
    e. Asphyxiation hazards
    f. Volume
    g. Failure Mode
        1) Brittle fracture failure mode
        2) Leak before burst failure mode
    h. Inhabited areas
    i. Shielding (glove box, fume hood, test cell)
5. Other issues to consider include:
    a. Mission criticality
    b. Economic impact
    c. Schedule
    d. Environmental impact

E. Hazard Mitigation

1. Based on the results of the probability evaluation, a probability bin is selected as defined in Table 1-2, Failure Probability.
2. Based on the results of the consequence evaluation, a consequence bin is selected as defined in Table 1-3, Consequence of Failure.
3. Enter Table 1-4, Qualitative Risk Evaluation, and locate the QR number that corresponds to the intersection of the probability bin (A through E) and consequence bin (I through V).

All ASME B31.3 code equivalencies in this document shall have a QR number of 4 or higher.

Table 1-2 Failure Probability

Level	Description	Qualitative
A (Frequent)	Frequent	Likely to occur immediately
B (Probable)	Probable	Probably will occur in time
C (Occasional)	Occasional	May occur in time
D (Remote)	Remote	Unlikely to occur
E (Improbable)	Improbable	Improbable to occur

Table 1-3 Consequence of Failure

Category	Description	Examples
I	Major	Fatalities, and/or major long-term environmental impact
II	Serious	Serious injuries, and/or significant environmental impact
III	Significant	Minor injuries, and/or short-term environmental impact
IV	Minor	First aid injuries only, and/or minimal environmental impact
V	Insignificant	No significant consequence

Table 1-4 Qualitative Risk (QR) Determination

			Probability				
			A	**B**	**C**	**D**	**E**
			Frequent	**Probable**	**Occasional**	**Remote**	**Improbable**
Consequence	**I**	**Major**	**1**	**1**	**1**	**2**	**3**
	II	**Serious**	**1**	**1**	**2**	**3**	4
	III	**Significant**	**1**	**2**	**3**	4	5
	IV	**Minor**	**2**	**3**	4	5	6
	V	**Insignificant**	**3**	4	5	6	7

RECORD OF REVISIONS

Rev	DATE	Description	POC	RM
0	03/03/2016	Initial issue.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
1	9/22/2023	Update to introductory section to clarify application of NASME for B31.9 systems. Added record of revisions. Updated Section and Attachment name (formerly known as Section NASME - New Non-ASME System Requirements, Attachment NASME-2- B31.9 Equivalent Safety Evaluation) for revised ESM Ch. 17 format.	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards point of contact (POC) for upkeep, interpretation, and variance issues.

Chapter 17	Pressure Safety POC

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1.0 PURPOSE

This document provides code equivalencies for ASME B31.9 design basis pressure systems for use at LANL. Any of the equivalencies can be applied to a pressure system to provide an approved equivalency to that specific paragraph of B31.9 without applying all the equivalencies. Code paragraphs can be used as written. Any paragraph not listed in the equivalency table shall be used as written. The equivalencies apply to portions of pressures systems that are not ASME BPVC equipment (e.g., boilers, pressure vessels, and air receivers) or supporting piping. The equivalencies cannot contradict or invalidate facility specific safety basis requirements for credited pressure systems.

2.0 EQUIVALENCY EVALUATION

The risk-based engineering evaluation process used in this attachment is provided in Section 3.0 at the end of this attachment. The Qualitative Risk of the equivalencies provided is 4 or greater (i.e., low).

B31.9 Paragraph	**Equivalency Safety Evaluation**
Chapter I Scope and Definitions	
900.1 Scope	This equivalency may be used for all fluids within the scope of B31.9 *except steam, steam condensate, and boiler external piping*.
900.2 Terms and Definitions	In addition to 900.2 the following definitions also apply: Fully engaged: A bolt or stud shall at least be flush with exit of the nut or fastener. Listed: For the purposes of this equivalency, describes a material or component that conforms to a specification in at least one of the following: ASME B31.9 Table 926.1, Table I-1, Table I-2, Table I-3, Table I-4, or Table II-1, and ASME B31.1 Table 126.1-1 and Tables A-1 through A-10.
Chapter II Design	
PART 1 CONDITIONS AND CRITERIA	
901 DESIGN CONDITIONS	
901.1 General 901.2 Pressure 901.3 Temperature 901.4 Ambient Influences	Pressure safety officer (PSO) Duty Area C may assist and concur with designer and may serve as a designer. Designer is also known as the Engineer in this code.
901.5 Dynamic Effects	Seismic supports shall accommodate thermal expansion and contraction.
901.6 Thermal Expansion and Contraction Loads	Supports that are not fixed anchors (hangers) shall be used to accommodate thermal expansion or contraction.
902 DESIGN CRITERIA	

902.2.1 Components Having Specific Ratings	Listed components shall be the first design preference. Items listed in ASME B31.1 may also be used. Previously evaluated and approved B31.9 unlisted components are located in the Allowed Unlisted Components Microsoft Excel file. Unlisted components not on the list described above may be used if they are listed on the ESM Ch. 17 Reputable Manufacturers List. This list will be maintained on the ESM Ch. 17 website. *NOTE: Institutional Evaluation Suppliers List (IESL) is not necessarily a listing of reputable manufacturers.* Listing on a reputable manufacturer's list requires ratings that are acceptable for the design conditions of temperature, pressure, and material compatibility. or Engineering calculations showing a factor of safety of 4:1 (this item would then be entered onto the reputable manufacturer's list as well). Items being placed on this list need final approval by the chief pressure safety officer CPSO or designee. Commercial Grade Designation (CGD) qualifies ML-3 & 4 equipment from non-IESL suppliers for use in ML-1 & 2 service but does not qualify equipment for ASME B31.9 code equivalency to code concerns.
902.3 Allowable Stresses and Other Stress Limits	Per design may consider other protective measures in order of precedence as follows: engineering controls (barriers, interlocks or controls), procedural controls (access control), and/or personal protective equipment (PPE) with PSO review and approval.
PART 2 PRESSURE DESIGN OF PIPING COMPONENTS	
904 PRESSURE DESIGN OF COMPONENTS	
904.7.2 Unlisted Components	See 902.2.1.
PART 3 SELECTION AND LIMITATION OF COMPONENTS	
907.1.2 Unlisted Valves.	See 902.2.1.
907.2 Marking	For reputable manufactured item the manufacturer's identification is acceptable.
PART 4 SELECTION AND LIMITATION OF JOINTS	
912 FLANGED JOINTS	U Vacuum style flanges for example "ConFlat" CF or KF (QF) flanges may be used after qualification in accordance with this document.
913 MECHANICAL AND PROPRIETARY JOINTS	See 902.2.1.
917 BRAZED AND SOLDERED JOINTS	Soldering shall be in accordance with B31.9. Brazing shall be in accordance with Engineering Standards Manual (ESM) Chapter 13.

PART 5 EXPANSION, FLEXIBILITY, AND SUPPORT	
919 EXPANSION AND FLEXIBILITY	Follow ESM Ch. 17 PS REQUIREMENTS "Flexibility Analysis."
920 LOADS ON PIPE-SUPPORTING ELEMENTS	Piping is not to be used to support external equipment that is not part of the piping system. Paragraph is required to be evaluated and discounted or applied. Piping supports may be in accordance with edited LANL Master Spec Section 22 0529 for all Normal Fluid Service including pressures above 150 psig. Hangers used at elbows are to be of the supporting guide style not fixed rigid style; the piping supports must allow expansion and contraction of the piping system when required by 919 above. If additional support is required, see 921.
921 DESIGN OF PIPE-SUPPORTING ELEMENTS	Use paragraph and subparagraphs except add the allowance from ASME B31.3 paragraph 321.1.2, "In general, the location and design of pipe supporting elements may be based on simple calculations and engineering judgment."
PART 6 SYSTEMS	
922 DESIGN REQUIREMENTS PERTAINING TO SPECIFIC PIPING SYSTEMS	
922.1 Pressure Reducing Systems 922.1.1	Use as is. *NOTE: Unlike ASME B31.3 there is no allowed accumulation over pressure of 10% above design pressure. For example, compressed gas systems are limited to 150 psig and B31.9 does not permit any overpressure beyond 150 psig. Therefore, if (again for example) using a "UV" stamped pressure relief valve that guarantees full capacity flow at 10% overpressure, the setpoint of the relief valve shall be set no higher than [Design Pressure – 0.10*(Design Pressure)].*
922.1.2 Alternative Systems	Do not apply paragraph 922.1.2, because this equivalency cannot be applied to steam systems (see 900.1 above).
922.3 Fuel Oil Piping	Use most applicable National Fire Protection Association (NFPA) code for combustible or flammable liquids (likely NFPA 58).
Chapter III Materials	
923 MATERIALS — GENERAL REQUIREMENTS	
923.1.2 Materials Not Listed	Use as is and reference Table 902.3.

Chapter IV Component Requirements and Standard Practices	
926 DIMENSIONS AND RATINGS OF COMPONENTS	
926.1 Standard Piping Components	Use Table 926.1 in accordance with 902.2.1 in this equivalency evaluation. Items listed in ASME B31.1 may also be used.
926.2 Standard Practices	Use as is. Other installation practices of approved unlisted components shall follow the manufacturer's instructions, for example Swagelok® or LOKRING™.
Chapter V Fabrication, Assembly, and Erection	
927 WELDED FABRICATION OF METALS	
927.1 General	Welding shall be performed in accordance with the qualification requirements of ESM Chapter 13. Limitations on imperfections and acceptance standards are as stated in B31.9 Chapter VI or in the engineering design.
927.2 Materials	Materials shall be in accordance with ESM Chapter 13.
927.3 Preparation	Preparations shall be in accordance with ESM Chapter 13.
927.4 Rules for Welding	Use as is. Welding and Brazing shall be in accordance with ESM Chapter 13.
927.5 Qualification	Qualification shall be in accordance with ESM Chapter 13.
927.6 Qualification Requirements	Qualification Requirements shall be in accordance with ESM Chapter 13.
928 BRAZING AND SOLDERING OF METALS	
928.1 Brazing	Brazing shall be in accordance with ESM Chapter 13.
929 BENDING	
929.1 General	Pipe may be bent to any radius by any hot or cold method that results in a crack free bend surface free of cracks and free of buckles. Cracks and creases in bends are not allowed. Such bends shall meet the design requirements of para. 904.2.1. This shall not prohibit the use of corrugated bends if specified in the engineering design.
Chapter VI Inspection, Examination, and Testing	
936 INSPECTION AND EXAMINATION	Use as is. Qualified PSO Duty Area C may perform the role as Owner's Inspector delegate if appointed by the Owner's Inspector.

3.0 RISK-BASED ENGINEERING EVALUATION PROCESS

This Risk-Based Evaluation process is used in Section 2.0 above and may be used in other situations (e.g., ASME, NASME) where allowed by those sections or with a variance (Form 2137). This process is based on the methodology described in API Recommended Practice 580, *Risk-Based Inspection*.

Guidance: The risk-based engineering evaluation evaluates the systems and determines if there is a risk to the worker (and equipment). A risk-based engineering evaluation is normally applied to non-hardware issues. A system that has known hardware issues will not likely benefit from this type of analysis.

A. Definitions

1. **Engineering Evaluation** – The Risk-Based Engineering Evaluation is the process of reviewing a pressure system for adequate pressure system integrity and determining necessary corrective actions to mitigate risk to acceptable level based on best engineering practices.
2. **Consequence** – The potential outcome from an event. There may be more than one consequence from an event.
3. **Probability** – The relative frequency with which an event is likely to occur within the time frame under consideration.
4. **Acceptable Risk** – A Qualitative Risk (QR) number of 4 or higher as shown on Table 1-4, Qualitative Risk, below. Qualitative Risk shall be controlled to QR number of 4 or higher.

B. Baseline Criteria

1. The Risk-Based Engineering Evaluation applies only to systems that have correctly sized relief protection.

C. Engineering Evaluation

1. The Risk-Based Engineering Evaluation is a three-step process. This process applies to evaluation of Risk Level 2 and 3 deficiencies, as defined above; Risk Level 1 deficiencies must be corrected in accordance with the requirements stipulated above.
   a. Using system information generated from the walk down team efforts and other sources, and ESM Chapter 17 requirements, the engineer generates a Qualitative Risk of each deficiency.
   b. The Qualitative Risk is then compared to the Acceptable Risk (i.e., risk number of 4 or higher).
   c. If the Qualitative Risk is greater than the Acceptable Risk (i.e., a risk number lower than 4), then either the consequence or probability must be adjusted to achieve a risk number of 4 or higher.
2. An engineering evaluation of the pressure system shall be performed by personnel meeting the qualification requirements for a pressure system designer and approved by a qualified PSO (*see Section GEN)* with Risk Evaluation training.
3. The engineering evaluation shall be an analysis and examination of the pressure system to determine the system integrity.
4. The Risk-Based Engineering Evaluation analysis shall be included with the pressure system documentation.

5. The Risk-Based Engineering Evaluation shall ensure that hazards and dominant contributors to risk are controlled according to the following:
   a. Eliminate accident scenarios (e.g., eliminate hazards or initiating events by design).
   b. Reduce the likelihood of accident scenarios through design and operational changes (hazard control).
   c. Reduce the severity of accident consequences (hazard mitigation).
   d. Improve the state-of-knowledge regarding key uncertainties that drive the risk associated with a hazard (uncertainty reduction to support implementation of the above strategies).
6. The control(s) shall be based on the level of risk associated with that hazard. Some risks may require a combination of several different approaches to prevent, mitigate, and/or control the risk.
7. Controls shall be in applied the following order of precedence:
   a. Engineered controls,
   b. Administrative controls,
   c. Personal protective equipment.

D. Qualitative Risk (QR)
1. The Risk-Based Engineering Evaluation shall, as a first step, use a Qualitative Risk based approach to evaluate adequacy of pressure system integrity.
2. The qualitative risk evaluation shall identify the following:
   a. the system(s),
   b. the hazard(s) deficiency,
   c. the probability assessment,
   d. the consequence of failure evaluation, and
   e. the subsequent QR number (see Table 1-4).
3. The Qualitative Risk based evaluation shall be based on probability and consequence of a single-point system failure for each deficiency observed.

Table 1-1 Probability factors to be considered

a. corrosion potential (crevice corrosion, general, galvanic, etc.) b. materials of construction (composite, plastic, steel, brass, etc.) c. material compatibility (lubricants, seals, and general materials) d. oxygen systems e. erosion potential f. fatigue cycles (cycle life)	1) low-cycle fatigue (where significant plastic straining occurs) 2) high-cycle fatigue (where stresses and strains are largely confined to the elastic region) g. size (contained energy) h. human error i. operating history j. damage mechanisms k. operation in creep range

l. stress intensification factors; for example, cracks or acute angles in pressure boundaries
m. available documentation
  1) welding
  2) code pressure test
n. documentation of ASME code fabrication
o. MAWP and design pressure as used in code calculations
p. design temperature
q. corrosion allowance determination
r. code required calculations (as applicable)
s. minimum wall thickness
t. nozzle reinforcement
u. thermal load calculations
v. seismic calculations
w. support structure
x. wind loading
y. piping flexibility analysis
z. cyclic loading calculations
aa. other static loadings (static fluid head)
bb. other dynamic loadings
cc. historical operational documentation
  1) corrosion rate (mils/year) (used to determine inspection interval)
  2) locations and dates of thickness measurements
  3) year of construction
  4) date of original installation
  5) date of first use
  6) out of service periods (used to determine inspection interval)
  7) discrepancy conditions
  8) a comprehensive chronological record of maintenance history
  9) history of repair – objective evidence required for ASME code stamped items.
  10) history of alterations – objective evidence required for ASME code-stamped items.
  11) historical inspections records of NDE
  12) applicable variances/waivers
  13) fabrication documentation
  14) leak test records
  15) maintenance sheet
  16) daily logs
  17) boiler records – water treatment, maintenance, and boiler appurtenances
  18) engineering evaluations as required by this chapter

4. Consequences of failure to be considered include the following safety and health issues:
    a. Chemical toxicity
    b. Physical hazards (e.g., projectiles)
    c. Flammability
    d. Radioactivity
    e. Asphyxiation hazards
    f. Volume
    g. Failure Mode
        1) Brittle fracture failure mode
        2) Leak before burst failure mode
    h. Inhabited areas
    i. Shielding (glove box, fume hood, test cell)
5. Other issues to consider include:
    a. Mission criticality
    b. Economic impact
    c. Schedule
    d. Environmental impact

E. Hazard Mitigation

1. Based on the results of the probability evaluation, a probability bin is selected as defined in Table 1-2, Failure Probability.
2. Based on the results of the consequence evaluation, a consequence bin is selected as defined in Table 1-3, Consequence of Failure.
3. Enter Table 1-4, Qualitative Risk Evaluation, and locate the QR number that corresponds to the intersection of the probability bin (A through E) and consequence bin (I through V).

All ASME B31.9 code equivalencies in this document shall have a QR number of 4 or higher.

Table 1-2 Failure Probability

Level	Description	Qualitative
A (Frequent)	Frequent	Likely to occur immediately
B (Probable)	Probable	Probably will occur in time
C (Occasional)	Occasional	May occur in time
D (Remote)	Remote	Unlikely to occur
E (Improbable)	Improbable	Improbable to occur

Table 1-3 Consequence of Failure

Category	Description	Examples
I	Major	Fatalities, and/or major long-term environmental impact
II	Serious	Serious injuries, and/or significant environmental impact
III	Significant	Minor injuries, and/or short-term environmental impact
IV	Minor	First aid injuries only, and/or minimal environmental impact
V	Insignificant	No significant consequence

Table 1-4 Qualitative Risk (QR) Determination

			Probability				
			A	**B**	**C**	**D**	**E**
			Frequent	**Probable**	**Occasional**	**Remote**	**Improbable**
Consequence	**I**	**Major**	**1**	**1**	**1**	**2**	**3**
	II	**Serious**	**1**	**1**	**2**	**3**	4
	III	**Significant**	**1**	**2**	**3**	4	5
	IV	**Minor**	**2**	**3**	4	5	6
	V	**Insignificant**	**3**	4	5	6	7

RECORD OF REVISIONS

Rev	Date	Description	POC	RM
0	9/17/2014	Initial issue.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
1	9/22/2023	Revised attachment name for major ESM Ch. 17 revision (formerly Section GEN – General Requirements, Attachment GEN-3, OSHA Requirements for Pressure Systems). Major revisions in the table to provide a better summary of the CFR Citations and update the LANL Applied Code/Standard/etc. as needed.	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

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Chapter 17	**Pressure Safety POC**

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1.0 INTRODUCTION

Pressure system design shall meet the requirements of 29 CFR 1910 when the system fluid or type of pressure system listed in the table below applies.

1. A table that summarizes the applicable code requirements of the CFR is below; see CFR for the complete text and all the requirements. *Note: The 29 CFR 1910 text still contains references to very old editions of codes/standards/etc., and the "Summary" column keeps these references as presented in the CFR.*
2. Following the latest applicable edition of the document(s) in the "LANL Applied Code/Standard/etc." column satisfies the OSHA requirement for the systems listed.

29CFR1910 Section	CFR Citation	CFR Reference	Summary of Citation	LANL Applied Code/Standard/etc.
1910 Subpart H – Hazardous Materials				
1910.101 – Compressed gases (general requirements).	1910.101(a)	CGA C-6 (1968) Standards for Visual Inspection of Compressed Gas Cylinders CGA C-8 (1962) Standard for Requalification of ICC-3HT Cylinders	Each employer shall determine that compressed gas cylinders under his control are in a safe condition to the extent that this can be determined by visual inspection.	CGA C-6 CGA C-8
	1910.101(b)	CGA P-1	Required use of CGA P-1 to ensure safe handling, storage, and use of compressed gases.	CGA P-1
	1910.101(c)	CGA S-1.1 (1963 and 1965 Addenda) Safety Release Device —Standards Part 1-Cylinders for Compressed Gases CGA S-1.2 (1963) Safety Relief Standards Part 2-Cargo and Portable Tanks for Compressed Gases	Compressed has containers shall have pressure relief devices installed and maintained in accordance with CGA S-1.1 and S-1.2.	CGA S-1.1 CGA S-1.2
1910.102 - Acetylene.	1910.102(a)	CGA G-1-2003 Acetylene	Acetylene in cylinders shall comply with the provisions of CGA G-1.	CGA G-1
	1910.102(b)	Chapter 9 ("Acetylene Piping") of NFPA 51A-2006 ("Standard for Acetylene Charging Plants") CGA G-1.2-2006, part 3 ("Acetylene piping")	Requirements for acetylene piping systems	NFPA 51A CGA G-1.2
1910.103 - Hydrogen.	1910.103(b)(1)(iii)	Section 2 – "Industrial Gas and Air Piping" – Code for Pressure Piping, ANSI B31.1-1967	Requirements for piping, tubing, and fittings in hydrogen service	ASME B31.3
	1910.103(c)(1)(i)	ASME Boiler and Pressure Vessel Code, Section VIII - Unfired Pressure Vessels (1968) or applicable provisions of API Standard 620, Recommended Rules for Design and Construction of Large, Welded, Low-Pressure Storage Tanks, Second Edition (June 1963) and appendix R (April 1965), DOT Specifications and Regulations	Requirements for the design, construction, and testing of liquefied hydrogen storage containers.	ASME BPVC Section VIII, Division 1 API 620 49 CFR

29CFR1910 Section	CFR Citation	CFR Reference	Summary of Citation	LANL Applied Code/Standard/etc.
	1910.103(c)(1)(iv)(a)(1)	CGA Pamphlet S-1, Part 3, Safety Relief Device Standards for Compressed Gas Storage Containers	Requirements for safety relief devices for stationary liquefied hydrogen systems.	CGA S-1.3
	1910.103(c)(1)(iv)(a)(2)	CGA Pamphlet S-1, Safety Relief Device Standards, Part 1, Compressed Gas Cylinders and Part 2, Cargo and Portable Tank Containers.	Requirements for safety relief devices for portable liquefied hydrogen systems.	CGA S-1.1 CGA S-1.2
	1910.103(c)(1)(iv)(d)	N/A	Safety relief devices shall be provided for piping wherever liquefied hydrogen could be trapped between closures [i.e., liquid lock].	ASME B31.3 or B31.12
	1910.103(c)(1)(v)(b)	Pressure Piping Section 2 - Industrial Gas and Air Piping, ANSI B31.1-1967 with addenda B31.1-1969; Petroleum Refinery Piping ANSI B31.3-1966; Refrigeration Piping ANSI B31.5-1966	Design code requirements for both gaseous hydrogen piping (above -20°F) and liquid or cold gaseous (below -20°F) hydrogen piping.	ASME B31.3 or B31.12
	1910.103(c)(1)(viii)(b)	N/A	Requirements for safety relief devices for liquefied hydrogen vaporizer and associated piping systems.	ASME B31.3 or B31.12
	1910.103(c)(2)(i)(f)	N/A	If liquefied hydrogen is located anywhere *except* Outdoors (See Table H-3) containers shall have the safety relief devices vented unobstructed to the outdoors at a minimum elevation of 25 feet above grade to a safe location as required in paragraph 103(c)(1)(iv)(b).	ASME B31.3 or B31.12
1910.104 - Oxygen.	1910.104(a) 1910.104(b)(1)	N/A	(READ FIRST) The provisions in 1910.104 apply only to bulk oxygen systems, which are defined as "an assembly of equipment, such as oxygen storage containers, pressure regulators, safety devices, vaporizers, manifolds, and interconnecting piping, which has storage capacity of more than 13,000	N/A

29CFR1910 Section	CFR Citation	CFR Reference	Summary of Citation	LANL Applied Code/Standard/etc.
			cubic feet of oxygen, Normal Temperature and Pressure (NTP), connected in service or ready for service, or more than 25,000 cubic feet of oxygen (NTP) including unconnected reserves on hand at the site. The bulk oxygen system terminates at the point where oxygen at service pressure first enters the supply line. The oxygen containers may be stationary or movable, and the oxygen may be stored as gas or liquid."	
	1910.104(b)(4)(ii)	ASME Boiler and Pressure Vessel Code, § VIII, 1968	Requirements for the design, construction, and testing of liquefied oxygen storage containers.	ASME BPVC Section VIII, Division 1
	1910.104(b)(4)(iii)	ASME Boiler and Pressure Vessel Code, § VIII, 1968 DOT Specifications and Regulations	Requirements for the design, construction, and testing of gaseous oxygen storage containers.	ASME BPVC Section VIII, Division 1 49 CFR
	1910.104(b)(5)(ii)	ANSI B31.1-67 and Addenda B31.1 (1969) Code for Pressure Piping	Requirements for piping, tubing, and fittings in oxygen service.	ASME B31.3
	1910.104(b)(6)	CGA S-1, Part 3, Safety Release Device Standards-Compressed Gas Storage Containers ASME Boiler and Pressure Vessel Code, § VIII, 1968 DOT Specifications and Regulations	Requirements for safety relief devices for bulk oxygen storage containers, whether governed by ASME BPVC or DOT.	CGA S-1.3 ASME BPVC Section VIII, Division 1 49 CFR
1910.105 - Nitrous oxide.	1910.105	CGA G-8.1 (1964)	Requirements for the design, installation, maintenance, and operation of nitrous oxide piping systems.	CGA G-8.1
1910.106 - Flammable and combustible liquids.	1910.106(b)(1)(iii)	UL Standards 142, 58, and 80 API 650	Design standard options for atmospheric tanks containing flammable or combustible liquids (atm. is defined as operating pressure between 0 and 0.5 psig).	UL Standards 142, 58, and 80 API 650

29CFR1910 Section	CFR Citation	CFR Reference	Summary of Citation	LANL Applied Code/Standard/etc.
	1910.106(b)(1)(iv)	API 620 ASME Boiler and Pressure Vessel Code, § VIII, 1968	Design standard options for low pressure tanks containing flammable or combustible liquids (low pressure is defined as operating pressure between 0.5 and 15 psig).	API 620 ASME BPVC Section VIII, Division 1
	1910.106(b)(1)(v)	ASME Boiler and Pressure Vessel Code, § VIII, 1968	Design standard requirement for pressure vessels containing flammable or combustible liquids (pressure vessel is defined as operating pressure greater than 15 psig).	ASME BPVC Section VIII, Division 1
	1910.106(c)(1)	ANSI B31 series	Requirements for the design, fabrication, assembly, testing, and inspection of piping systems containing flammable or combustible liquids.	ASME B31.3
1910.107 - Spray finishing using flammable and combustible materials.	1910.107(e)(5)	ASME Boiler and Pressure Vessel Code, § VIII, 1968	Design standard requirements for spraying containers under air pressure for flammable liquids and liquids with a flashpoint greater than 199.4°F (93°C).	ASME BPVC Section VIII, Division 1
1910.110 - Storage and handling of liquefied petroleum gases.	1910.110(b)(10)(iii) (Table H-26), (d)(2) (Table H-31); (e)(3)(i) (Table H-32), (h)(2) (Table H-34)	ASME Boiler and Pressure Vessel Code, § VIII, 1968	Design standard requirements for relief devices (Table H-26), storage containers other than DOT containers (H-31), fuel containers other than DOT containers (H-32), and storage containers for LPG fueling stations (H-34).	ASME BPVC Section VIII, Division 1
	1910.110(b)(11)(i)(b) and (iii)(a)(1)	ASME Boiler and Pressure Vessel Code, § VIII, 1968	Code of record. Indirect fired vaporizers utilizing steam, water, or other heating medium not in the scope of ASME BPVC Section VIII shall have a design pressure not less than 250 psig and need not be permanently marked. Direct gas-fired vaporizers shall be constructed to ASME BPVC.	ASME BPVC

29CFR1910 Section	CFR Citation	CFR Reference	Summary of Citation	LANL Applied Code/Standard/etc.
1910.111 - Storage and handling of anhydrous ammonia.	1910.111(b)(2)(i), (ii), and (iv)	ASME Boiler and Pressure Vessel Code, § VIII, 1968	Requirements for the design, construction, and testing of nonrefrigerated anhydrous ammonia storage containers.	ASME BPVC Section VIII, Division 1
	1910.111(b)(2)(vi)	ASME Boiler and Pressure Vessel Code, § VIII, 1968	Provisions to permit the continued use or reinstallation of nonrefrigerated anhydrous ammonia storage containers constructed prior to 1968.	ASME BPVC Section VIII, Division 1
	1910.111(b)(7)(iii)	ANSI B31.5-66 Addenda B31.5a (1968) Refrigeration Piping,	Requirements for the design, installation, maintenance, and operation of refrigerant piping systems that use anhydrous ammonia as the refrigerant.	ASME B31.5
	1910.111(d)(1)(ii)	API 620, Fourth Ed. [1970] Including Appendix R, Recommended Rules for Design and Construction of Large Welded Low Pressure Storage Tanks	Requirements for the design of containers for the purpose of anhydrous ammonia storage under refrigerated conditions.	API 620
	1910.111(d)(4)(ii)(b)	CGA S-1.3 (1959) Safety Release Device Standards-Compressed Gas Storage Containers	Requirements for safety relief devices for anhydrous ammonia storage under refrigerated conditions when exposed to fire.	CGA S-1.3
1910 Subpart M - Compressed Gas and Compressed Air Equipment				
1910.169 - Air receivers.	1910.169(a)(2)(i) and(ii)	ASME Boiler and Pressure Vessel Code, § VIII, 1968	All air receivers shall be constructed in accordance with ASME BPVC Section VIII. All safety valves used to prevent overpressurization of air receivers shall be constructed, installed, and maintained in accordance with the ASME Boiler and Pressure Vessel Code.	ASME BPVC Section VIII, Division 1
	1910.169(b)(3)(iv)	ASME Boiler and Pressure Vessel Code, § VIII, 1968	All safety valves shall be tested frequently and at regular intervals to	P101-34, Attachment A, Section A-1

29CFR1910 Section	CFR Citation	CFR Reference	Summary of Citation	LANL Applied Code/Standard/etc.
			determine whether they are in good operating condition.	
1910 Subpart O - Machinery and Machine Guarding				
1910.217 - Mechanical power presses.	1910.217(b)(12)	ASME Boiler and Pressure Vessel Code, § VIII, 1968	Design standard requirement for pressure vessels used in conjunction with mechanical power presses.	ASME BPVC Section VIII, Division 1
1910.218 - Forging machines.	1910.218(d)(4) and (e)(1)(iv)	ANSI B31.1-67 and Addenda B31.1 (1969) Code for Pressure Piping,	Requirements for the design, fabrication, assembly, testing, and inspection of piping systems used for power-driven hammers (steam or air) or air-lift gravity hammers (air).	Most applicable ASME B31 code
1910 Subpart Q - Welding, Cutting, and Brazing				
1910.252 - General requirements.	1910.252(d)(1)(v)	API 1104 (1968) Standard for Welding Pipelines and Related Facilities	Construction standards. The welded construction of transmission pipelines shall be conducted in accordance with the Standard for Welding Pipe Lines and Related Facilities, API Std. 1104-1968, which is incorporated by reference as specified in Sec. 1910.6	API 1104
	1910.252(d)(1)(vi)	API 2201 (1963) Welding or Hot Tapping on Equipment Containing Flammables,	The connection, by welding, of branches to pipelines carrying flammable substances shall be performed in accordance with Welding or Hot Tapping on Equipment Containing Flammables, API Std. PSD No. 2201-1963, which is incorporated by reference as specified in Sec. 1910.6.	API 2201
1910.253 - Oxygen-fuel gas	1910.253(d)(1)(i)(A)	ANSI B31.1-67	Requirements for the design, fabrication, assembly, testing, and	ASME B31.3

29CFR1910 Section	CFR Citation	CFR Reference	Summary of Citation	LANL Applied Code/Standard/etc.
welding and cutting.			inspection of oxygen-fuel gas service piping systems.	
	1910.253(d)(4)(ii)	ANSI A13.1-56 Scheme for the Identification of Piping Systems	Requirements for the marking of Oxygen-Fuel Gas piping lines installed above ground.	ASME A13.1
	1910.253(e)(4)(v) and (5)(iii)	CGA 1957 Standard Hose Connection Standard	Requirements for Oxygen-Fuel Gas station outlet termination connections when station outlets are connected directly to a hose.	CGA E-1
	§1910.253(e)(4)(iv) and (6)	CGA 1958 Regulator Connection Standard	Requirements for Oxygen-Fuel Gas station outlet termination connections when station outlets are equipped with a detachable regulator.	CGA V-7
	1910.253(e)(5)(i)	CGA and RMA (Rubber Manufacturer's Association) Specification for Rubber Welding Hose (1958)	Requirements for hoses used for Oxygen-Fuel Gas service.	CGA E-1

RECORD OF REVISIONS

Rev	Date	Description	POC	RM
0	9/17/2014	Initial issue.	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
1	9/22/2023	New document title to match new ESM Ch. 17 formatting (formerly known as Section ASME - New ASME System Requirements, Attachment ASME-4-1, Flexhose and Relief Device Restraint). Moved additional flex hose restraint content from main ESM Ch. 17 Sections to this attachment.	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards point of contact (POC) for upkeep, interpretation, and variance issues.

Chapter 17	**Pressure Safety POC**

This document is online at https://engstandards.lanl.gov

1.0 PURPOSE

This document provides a listing of approved flex hose restraints and one acceptable method/example for designer approval of alternative flex hose restraint by determining thrust load. This same method can be used for thrust load determination of relief devices or their outlet piping to be used as an input to design of their supports.

2.0 APPROVED PARKER FLEX HOSE RESTRAINTS

Parker Hannifin flex hose restraints provide acceptable protection against whipping in the event of flex hose failure (most commonly shear at the fitting) up to the size/pressure values listed in the table below. For all other hoses, the designer is responsible to evaluate the material of construction and the anchor location to ensure the alternative is a safe design based on a thrust load calculation like the one later in this document.

Per the Parker Hose Whip Restraint Bulletin 4480-148 © 2009 Parker Hannifin Corp: "The Whip Restraint System has been tested to the operating pressures of the hoses listed in HPD Catalog 4400."

The HPD Catalog 4400 © 2011 Parker Hannifin Corporation has multiple types of hoses listed. The highest rating for a given size is shown below in Table 1.

Table 1: Highest Hose Ratings listed in Catalog 4400

Hose Size Designation	Hose Size (inch)	Highest Hose Rating	Hose Type
-4	1/4	10,500	Hydraulic JK
-5	5/16	5,000	Hydraulic 302
-6	3/8	10,000	Hydraulic JK
-8	1/2	6,000	Constant Working Pressure 797TC
-10	5/8	6,000	Constant Working Pressure 797TC
-12	3/4	6,000	Constant Working Pressure 797TC
-16	1	6,000	Constant Working Pressure 797TC
-20	1 1/4	6,000	Constant Working Pressure 797TC
-24	2	6,000	Constant Working Pressure 791TC
-32	2 1/2	5,000	Constant Working Pressure P35
-40	3 1/4	350	Transportation 201
-48	4	200	Transportation 201

Thus, the Parker Hose Whip Restraint may be used to the maximum value as shown in HPD Catalog 4400. An example of a Parker hose restraint installation is provided in Figure 1 below.

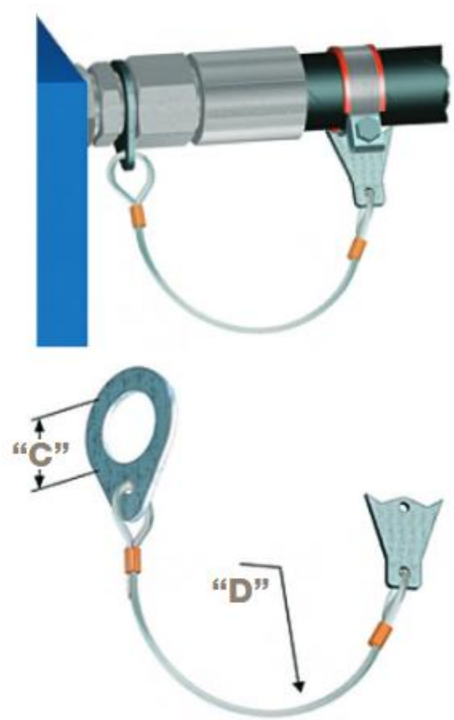

Figure 1. Parker Hose Whip Restraint

3.0 APPROVED ALTERNATIVE FLEX HOSE RESTRAINTS

Self-restraining flex hoses like Air Liquide's LifeGuard Safety Hose Anti-Whip Internal Safety System and Global Passive Safety System's LifeGuard meet the requirements of this chapter for preventing flex hose whip. Figure 2 below provides a visual example of a self-restraining flex hose.

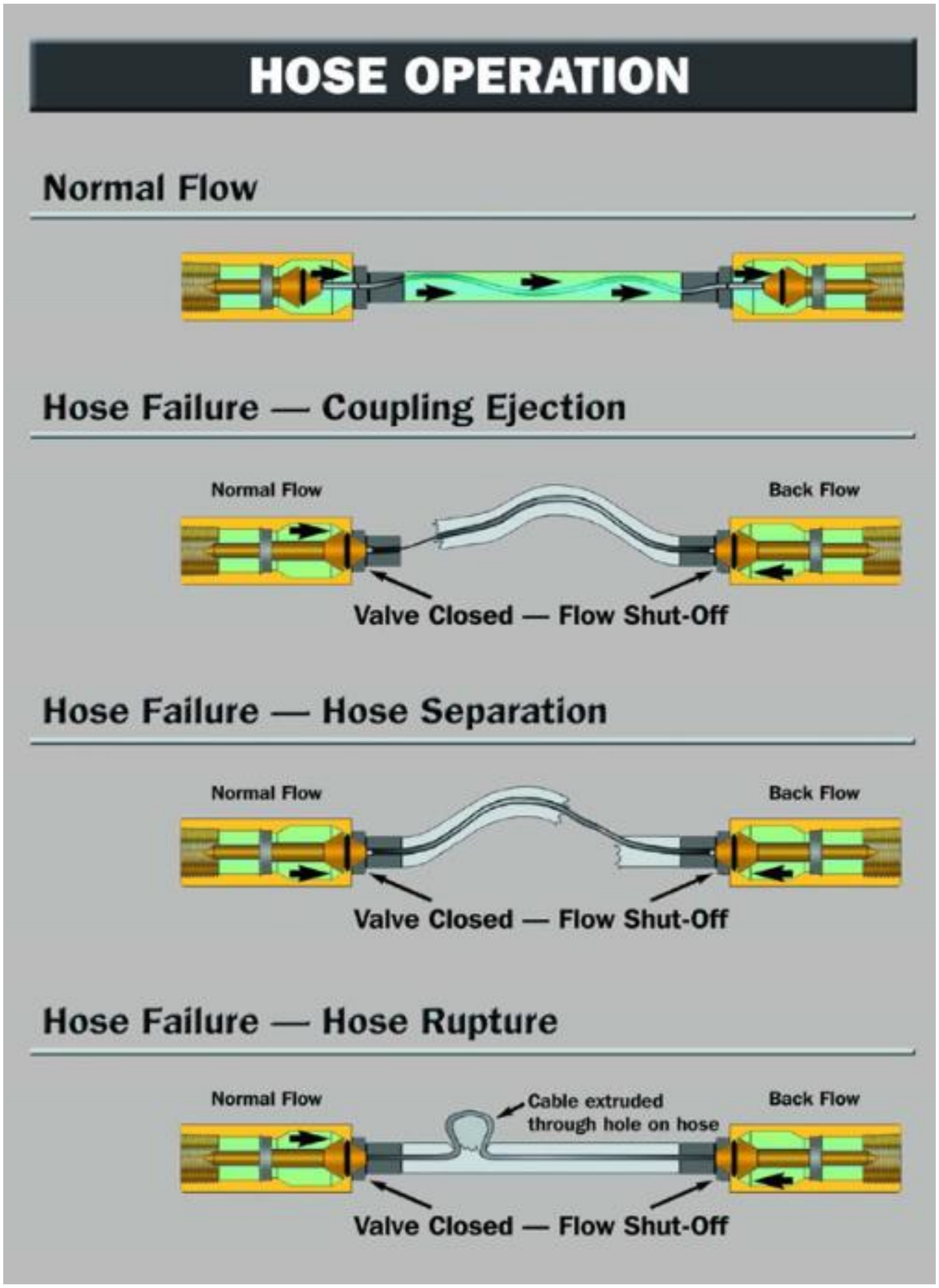

Figure 2. Self-Restraining Flex Hose

Hose sock grips (a.k.a., whip socks) from brands such as Kellems may be used within manufacturer guidelines for pressure and hose size restrictions.

Clamp-on hose restraints from brands such as Adel may be used within manufacturer guidelines for pressure and hose size restrictions.

Examples of hose sock and clamp-on restraint installations are provided in the figures below.

Figure 3a. Example of a Hose Sock (whip sock)

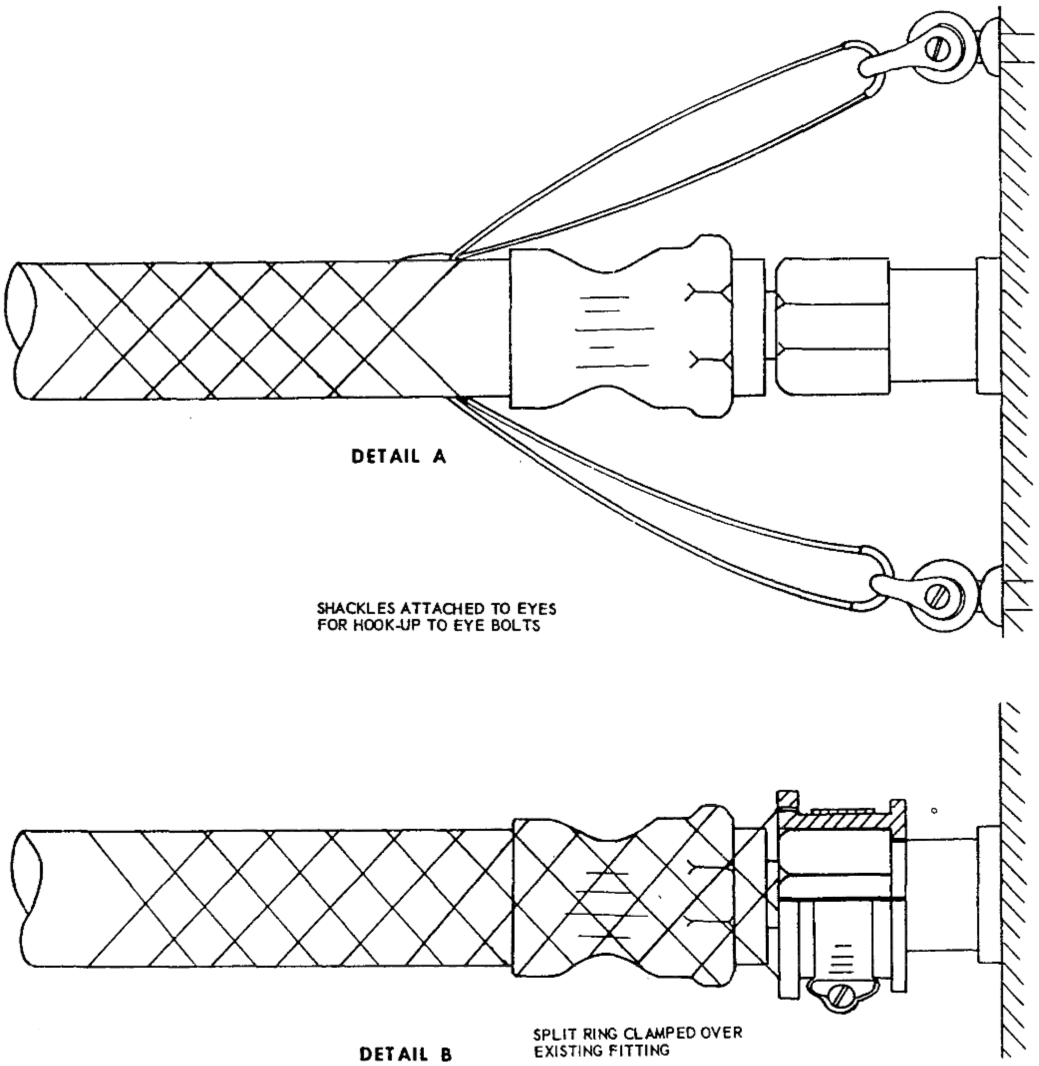

Figure 3b. Example of a Hose Sock (whip sock)

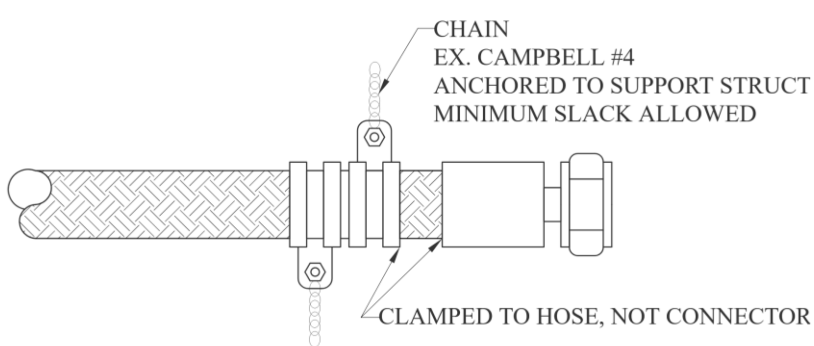

Figure 4. Example of a Clamp-On Restraint

4.0 DESIGNER APPROVAL OF ALTERNATIVE FLEX HOSE RESTRAINTS AND CALCULATING THE CONSERVATIVE CASE THRUST MODEL

The example below is for a full gas cylinder at 2265 psig.

Estimating the initial surge thrust from an open line based on the assumption that the gas is exiting at sonic velocity, the mass flow rate results from the initial (pre-flow) density and sonic velocity, and that the pressures at the outlet of the tube has decrease to the highest pressure that maintains sonic flow (the critical pressure ratio). This is a worst-case condition and would probably only last a very short time duration until line losses resulted in a decrease in the mass flow and outlet pressure. In addition, the gas temperature will decrease due to isentropic expansion.

Reference: *Introductory Gas Dynamics*, Chapman and Walker, 1971 Ed. Page 273 Equation 7.7

Thrust, $T = m' V + P_o A$ where:

m' mass flow rate

V' gas outlet velocity

P_o outlet pressure

A Area of the outlet

$m' = rho/g\ v_s A$ mass flow rate based on upstream density (rho), sonic velocity (v_s), and inside diameter

$V = v_s$ outlet gas velocity is sonic velocity

$rho = P/RT$ density based on ideal gas behavior, where:

P absolute pressure

R Gas Constant

T absolute temperature

$V_s = (k\ g\ R\ T)^{1/2}$ sonic velocity for an ideal gas, where:

k ratio of specific heats

g acceleration due to gravity

$P_o = P/PR_c$ outlet pressure based on upstream pressure and critical pressure ratio

critical pressure ratio, reference *Orifice Meters With Supercritical Compressible Flow*, Cunningham, page 635, formula 20, inverse of formula used for upstream to downstream pressure

$PR_c = [(k + 1)/2]^{(k/(k-1))}$

General Thrust Equation: $F = m_e w - m_i V_o + (P_e – P_o) A_e$, where:

F = Thrust

m_e = Exit Mass Flow Rate

w = Velocity of exit gas

m_i = Inlet mass flow rate

V_o =Velocity of Free-Stream Air (flight speed)

P_e = Absolute Static Pressure in Exit Section of Exhaust Nozzle

P_o = Absolute Static Pressure of Free-Stream Ambient

A_e = Cross-Sectional Area of Exit Section of Exhaust Nozzle

Solving for thrust:

$T_s = [(P/(RTg)) ((k\ g\ R\ T)^{1/2}) A\ ] ((k\ g\ R\ T)^{1/2}) + [P/[((k+1)/2)^{(k/(k-1))}] A$

Simplifying the equation:

$T_s = PA \{k + 1/[((k+1)/2)^{(k/(k-1))}]\}$

Defining the value within the bracket as the Surge Thrust Factor (STF):

T_s = PA STF

Example: Surge thrust forces for various flex hose sizes with argon with a maximum internal pressure of 2265 psig:

k (argon) = 1.67

Rc (Critical Pressure Ratio) = 2.05

STF (argon) = 2.16 (bounding condition)

Result:

Table 2 Calculated Surge Thrust (example, argon @ 2265 psig)

Flex Hose ID (fractional inch)	Flex Hose ID (decimal inch)	Internal Area (Pi*D^2/4), (in^2)	Argon Surge Thrust Factor	Surge Thrust (lbf)
1/8"	0.125	0.0123	2.16	60
1/4"	0.25	0.0491	2.16	240
5/16"	0.3125	0.0767	2.16	375
3/8"	0.375	0.1104	2.16	540
7/16"	0.4375	0.1503	2.16	735
1/2"	0.5	0.1963	2.16	961
9/16"	0.5625	0.2485	2.16	1216
5/8"	0.625	0.3068	2.16	1501
11/16"	0.6875	0.3712	2.16	1816
3/4"	0.75	0.4418	2.16	2161

Attachment REQ-9, Approved Flexible Hose Restraints and Thrust Load Evaluations

Flex Hose ID (fractional inch)	Flex Hose ID (decimal inch)	Internal Area (Pi*D^2/4), (in^2)	Argon Surge Thrust Factor	Surge Thrust (lbf)
7/8"	0.875	0.6013	2.16	2942
1"	1	0.7854	2.16	3842
1 1/4"	1.25	1.2272	2.16	6004
1 1/2"	1.5	1.7671	2.16	8646
1 3/4"	1.75	2.4053	2.16	11768
2"	2	3.1416	2.16	15370
2 1/4"	2.25	3.9761	2.16	19453
2 1/2"	2.5	4.9087	2.16	24016
2 3/4"	2.75	5.9396	2.16	29059
3"	3	7.0686	2.16	34582
3 1/4"	3.25	8.2958	2.16	40586
3 1/2"	3.5	9.6211	2.16	47070
3 3/4	3.75	11.0447	2.16	54035
4"	4	12.5664	2.16	61480

Brackets, supports, hose restraints, or whip restraints must be designed to meet or exceed the surge thrust calculated.

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Rev.	Date	Description	POC	RM
0	9/22/2023	Initial issue as section PS-GUIDE. Some content was in previous sections (ADMIN and others) while other content is new.	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards point of contact (POC) for upkeep, interpretation, and variance issues.

Chapter 17	**Pressure Safety POC**

This document is online at https://engstandards.lanl.gov

1.0 INTRODUCTION

This section provides guidance and precautionary considerations relating to pressure system design. These are not Code or LANL-imposed requirements but should be considered if applicable to the engineering design.

2.0 OVERPRESSURE PROTECTION EVALUATIONS

Guidance for performing overpressure protection evaluations is provided in Attachment GUIDE-1, *Overpressure Protection Evaluation Guide*.

3.0 MATERIAL COMPATIBILITY

A. Corrosion

1. For systems with active corrosion (e.g., carbon steel and water), corrosion inhibitors should be utilized to reduce the corrosion rate.
2. Corrosion rates should be evaluated prior to selecting materials for fluid service at temperature and pressure. The manufacturer's compatibility information may be used or a general guide like the National Association of Corrosion Engineers (NACE) "Corrosion Data Survey" ISBN 0-915567-07-5. *Note: At time of writing, the ES-UI Gas System Engineer was a NACE member and standards committee author. Contact ES-UI if assistance is needed on using this ISBN.*
3. Passive Corrosion
    a. Systems that utilize passive corrosion (passivation) as a means of self-protecting the system from further corrosion (e.g., aluminum oxide, fluorine systems) should not be disturbed. Care should be taken to re-establish the passive corrosion layer if ever removed.
    b. Fluorine systems should be passivated (see Ultrapure Gas Delivery "Preparing a gas delivery system for excimer lasers with fluorine passivation of 316L stainless steel" by Eugene, J. Karwacki Jr., Kerry R. Berger, Ronald M. Pearlstein, and Robert J. Haney Air Products and Chemicals).
4. The Designer should consider the potential for galvanic corrosion when specifying dissimilar metal connections for electrolytic liquid fluid service (e.g., water, deionized water, etc.).
5. The Designer should consider potential corrosion effects for the fluid service and the temperature and pressure of the fluid service, such as the following:
    a. The susceptibility of the piping material to crevice corrosion under backing rings, in threaded joints, in socket welded joints, and in other stagnant, confined areas,
    b. The possibility of adverse electrolytic effects if the metal is subject to contact with a dissimilar metal (i.e., galvanic corrosion),
    c. The effect of stress corrosion,

d. The effect of intergranular corrosion (e.g., austenitic stainless steel carbide precipitation and chromium depletion),

e. The effect of hydrogen embrittlement,

f. The effect of pitting corrosion,

g. The effect of Microbiologically Influenced Corrosion,

h. The possible corrosion under insulation effect,

i. The effect of erosion corrosion and/or flow-accelerated corrosion,

j. The effect of environmental cracking,

k. The effect of selective corrosion attack on structural constituents,

l. The effect of exfoliation corrosion, and

m. The effect of interfacial corrosion.

6. Stress Corrosion Cracking (SCC)

a. Stress corrosion cracking is induced from the combined influence of tensile stress, elevated temperature, and a corrosive environment. The impact of SCC on a material usually falls between dry cracking and the fatigue threshold of that material. The required tensile stresses may be in the form of directly applied stresses or in the form of residual stresses. The problem itself can be quite complex. The situation with buried pipelines is a good example of such complexity.

b. Cold deformation and forming, welding, heat treatment, machining, and grinding can introduce residual stresses. The magnitude and importance of such stresses is often underestimated. The residual stresses set up because of welding operations tend to approach the yield strength. The build-up of corrosion products in confined spaces can also generate significant stresses and should not be overlooked. SCC usually occurs in certain specific alloy-environment-stress combinations.

c. Usually, most of the surface remains unharmed, but with fine cracks penetrating the material. In the microstructure, these cracks can have an intergranular or a transgranular morphology. Macroscopically, SCC fractures have a brittle appearance. SCC is classified as a catastrophic form of corrosion, as the detection of such fine cracks can be very difficult, and the damage not easily predicted. Experimental SCC data is notorious for a wide range of scatter. A disastrous failure may occur unexpectedly, with minimal overall material loss.

7. Chloride Stress Corrosion Cracking (CSCC)

a. CSCC is a localized corrosion mechanism like pitting and crevice corrosion. Chloride stress corrosion is a type of intergranular corrosion that involves selective attack of the metal along grain boundaries. The three conditions that should be present for chloride stress corrosion to occur include the following:

- Chloride ions are present in the environment,
- Dissolved oxygen is present in the environment, and
- Metal is under tensile stress.

b. Austenitic stainless steel is a non-magnetic stainless-steel grade consisting of iron, chromium, and nickel, with a low carbon content. This alloy is highly corrosion resistant and has desirable mechanical properties. Chloride stress corrosion can attack austenitic stainless steel. During stainless steel formation, a chromium-rich carbide precipitates at the grain boundaries leaving these areas low in protective chromium, and thereby, susceptible to attack. It has been found that this is closely associated with certain heat treatments resulting from welding. The potential for CSCC can be minimized considerably by utilizing proper annealing processes.

c. This form of corrosion is controlled by maintaining low chloride ion and oxygen content in the environment and using low carbon steels. Environments containing dissolved oxygen and chloride ions can readily be created in auxiliary water systems. Temperature plays an important role in CSCC, with a maximum effect at around 180°F.

B. Organic Material (Soft Goods) and Flexible Hose Selection

1. Organic materials that are part of the pressure boundary (e.g., O-ring, valve seats, flange gaskets) typically have more stringent compatibility requirements and need to be selected with careful consideration, primarily temperature and chemical compatibility.

2. Manufacturer's compatibility information should be reviewed prior to selection of material for the system's fluid service at the design temperature and pressure. For general use, the Parker Hannifin Corporation O-Ring Division "Parker O-Ring Handbook" ORD 5700 may be used to evaluate the materials.

3. Consider material compatibility per NFPA 30, NFPA 45, or similar when selecting flexible hoses.

C. Radiological Service

1. Review the guidance of ESM Chapter 6, Mechanical, Section D20 Plumbing/Piping/Vessels, D2090 Other Plumbing and Piping Systems (R&D, PROG, & FAC) paragraph 5.0 RADIOACTIVE SERVICE GENERAL GUIDANCE.

   a. DOE-HDBK-1132-99 (reaffirmed 2014), *Design Considerations*

   b. ESM Ch. 6, Section D20, Table D2090-1, *Relative Stability of Plastics*.

2. Tritium system design should consider DOE-HDBK-1129, *Tritium Handling and Safe Storage*, if applicable.

4.0 FLANGE GASKETS

A. Gaskets should be selected so that the required seating load is compatible with the flange rating and facing, the strength of the flange, and its bolting. See ASME B16.20 (metallic) and B16.21 (non-metallic) for information on gaskets. See ASME B16.5 5.3 and 5.4 for guidance on flange bolting and flange gaskets.

B. Gaskets should be made of material which is compatible with the fluid service and should be capable of withstanding the pressures and temperatures to which they will be subjected in service.

5.0 FLEXIBLE ELASTOMERIC SEALED JOINTS (EXPANSION JOINTS)

A. When possible, specify expansion joints that meet Expansion Joint Manufacturers Association (EJMA) Standards.

B. Assembly of flexible elastomeric sealed joints should be in accordance with the manufacturer's recommendations.

C. Any solvents or lubricant used to facilitate joint assembly should be compatible with the joint components and the intended service.

D. Flammable vapors should be purged prior to hot work.

6.0 OXYGEN AND OTHER OXIDIZER SYSTEMS

A. Pressure system design guidance for the use of oxygen or other oxidizer system fluids is provided in Attachment GUIDE-2, *Oxygen System Design Guide*.

B. GUIDE-2 serves as a detailed design guide that will aid the designer in assessing the hazard level of the oxygen/oxidizer system and should generally relax the requirements given in the previous revision of ESM Chapter 17.

7.0 ACETYLENE

A. In all cases, copper, silver, and mercury must be excluded from contact with acetylene in transmission and control systems; copper content of 65% may be used if the designer specifies the specific item.

B. Acetylene can react explosively with fluorine or chlorine when exposed to sunlight and caution should be exercised to avoid this interaction.

C. Aluminum should be avoided, since it may become corroded by exposure to calcium hydroxide formed in the production of acetylene from calcium carbide.

D. The common nonmetallic materials that have been found satisfactory for use with acetylene include polytetrafluoroethylene (PTFE), polychlorotrifuoroethylene (PCTFE), polyamide (PA), natural and synthetic rubbers, and leather.

E. Use of semi-steel that may be exposed to the pressure effects of an acetylene deflagration or detonation is not recommended.

F. For additional guidance, refer to CGA G-1, *Acetylene*, and CGA G1.3, *Acetylene Transmission for Chemical Synthesis (Recommended Minimum Safe Practices for Piping Systems*).

8.0 CLEANING

A. When potential contamination could impact the pressure system, the engineering design should specify cleaning requirements. The purpose of cleaning is to remove harmful deposits from all parts of the system that encounter the fluid during operation. All foreign materials, fatty acids, oils and grease, loose mill scale, rust, paint, and similar materials should be removed. Any solution employed should be a good cleaning agent for these purposes and should be compatible with the materials of construction.

B. Standard Cleaning

1. The need for and degree of cleanliness of pressure systems is dictated by the system requirements, the degree to which the system can be cleaned after installation, and the need for removal of contaminants deposited during fabrication.

2. Unless otherwise specified by the customer, cleaning will consist of removing all non-adhering material such as loose scale, sand, weld spatter particles, rust, cutting chips, grinding residue, etc. from the inside of the piping assembly by suitable means. This level of cleaning will allow the presence of mill scale, surface rust, and tightly adhered weld spatter.

3. Externally the piping should be free of weld slag, flux, and weld spatter.

C. Additional Cleaning

1. Additional cleaning if required will be specified by the customer. These methods include but are not limited to brushing, grinding, blasting, degreasing, and pickling and passivation.

D. Precision cleaning of contamination may be required by the customer. Precision cleaning includes but is not limited to particulate contamination, chemical surface contamination, non-volatile surface residue (greases and oils), and biological clean (sterile).

E. Cleaning should consider different types of contamination as applicable to the system, for example:

1. Particulate contamination

2. Chemical surface contamination

3. Non-volatile surface residue (greases and oils)

4. Biological clean (sterile)

F. Particulate contamination (dirt and fibers) chemical cleaning is conducted with solvent solution primarily for the purpose of removing mill scale and products of corrosion. The solvent solution may be acidic or basic, or successive solutions of differing character may be employed. The effect of the cleaning agent on the substrate should be evaluated.[1]

G. Purging, flushing, or blowing down unwanted dirt, debris, and residual fluid from the inside of a piping system should be performed with caution and control. It is left to the discretion, knowledge, and responsibility of the Owner or Designer as to the degree of caution and control necessary for a safe work environment. The fluid selected for the purpose of purging, flushing, or blowing down should preferably be inert. However, for cases in which the use of a flammable or toxic fluid is unavoidable, e.g., when displacing residual testing or flushing fluid with the service fluid, the implementation of additional precautionary considerations may be necessary. Those precautionary considerations should include the following items:

1. The discharge of liquids to a safe collection point,

2. The discharge of flammable liquids away from ignition sources and personnel,

---

[1] Because of the chemical control required to ensure a successful cleaning, to avoid damage to both ferrous and nonferrous materials through improper use of the solvent and because of the potential dangers involved in dealing with corrosive solutions and possibly explosive and toxic products of the cleaning process.

3. Venting of gases to a safe outdoor location,
4. Venting of flammable gases away from ignition sources and personnel,
5. Further protection of personnel via controlled access of the work area, including perimeter warning signs for personnel not involved in the purging process, and
6. For precautionary requirements and recommendations regarding the displacement of flushing and testing fluids using a flammable gas, refer to ANSI Z223.1/NFPA 54, National Fuel Gas Code.

9.0 INSTALLATION

A. Plastic and nonmetallic tubing is discouraged where the tubing is hidden from sight.

B. Wire brushes used on pipe or tube can cause corrosion if the wire brush material is dissimilar to the pipe or tube material. The use of proper wire brushes should be communicated in the work documents.

10.0 VESSEL INSPECTION DURING INSTALLATION OR SERVICE CHANGES

A. The Designer may require vessel inspection during installation or service changes in accordance with American Petroleum Institute (API) 510, *Pressure Vessel Inspection Code*, Section 6.2.1.

11.0 HOSE ASSEMBLY AND PRESSURE REGULATOR INSPECTION

Maintenance guidance for inspecting flexible hose and pressure regulators is provided in P101-34, Attachment B, *Maintenance Guidance for Hose Assembly Inspections and Pressure Regulators.*

12.0 ATTACHMENTS

GUIDE-1, *Overpressure Protection Evaluation Guide*

GUIDE-2, *Oxygen System Design Guide*

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RECORD OF REVISIONS

Rev	Date	Description	POC	RM
0	9/17/2014	Initial issue. Was Appendix D of Section I, rev. 3	Ari Ben Swartz, *ES-EPD*	Larry Goen, *ES-DO*
1	9/22/2023	Complete revision of Attachment ADMIN-2-1, Relief Device Selection Process for Gas Bottle Systems (Guidance).	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards point of contact (POC) for upkeep, interpretation, and variance issues.

Chapter 17	**Pressure Safety POC**

This document is online at https://engstandards.lanl.gov

1.0 INTRODUCTION AND PURPOSE

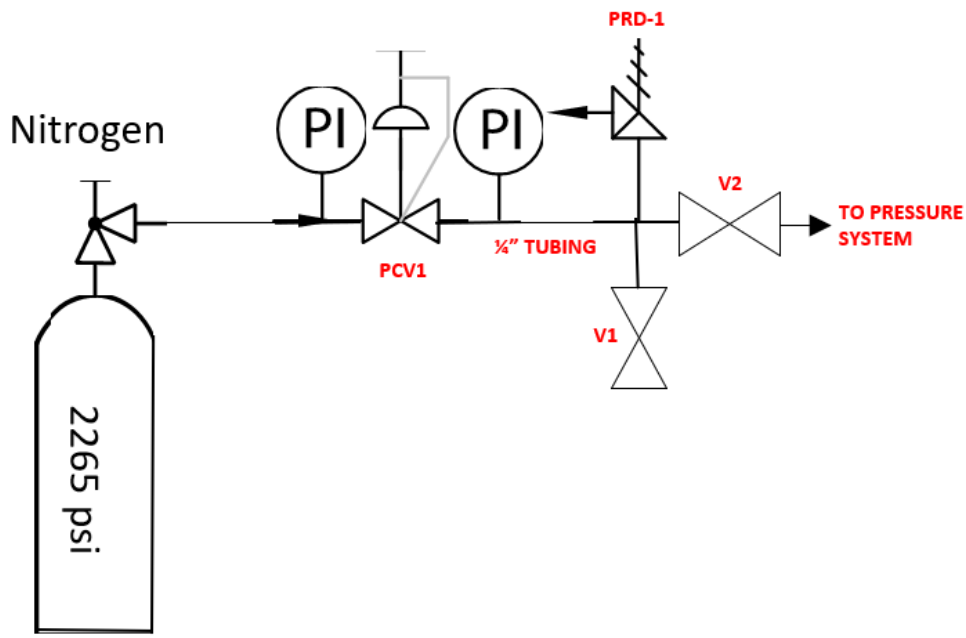
This document provides examples of overpressure scenarios for various types of pressure systems/sources and the evaluations necessary to determine requirements for overpressure protection of those systems. This document provides commonly encountered scenarios and should not be considered exhaustive.

The example evaluations in this guide consider a single fault / single point-of-failure (SPOF) to determine overpressure protection needs, in compliance with the requirements of this Engineering Standards Manual (ESM) chapter. Latent failures (see Attachment GEN-1, *Definitions and Acronyms*) also need to be considered but this guide does not directly address any latent failure scenarios.

Throughout this document, web links are provided to product pages for some components. Copies of the documents contained in the links are also available for reference on the "Reference Data" SharePoint linked on the ESM Chapter 17 website.

2.0 GAS CYLINDER AND PRESSURE REGULATOR

A typical starting configuration for a single gas cylinder and pressure regulator manifold is as follows:



A. Scenario 1 – Failure flow rate of regulator does not exceed pressure relief device (PRD) capacity

The following design parameters are used for this example:

- Gas cylinder: Nitrogen at 2265 psig max fill pressure
- Pressure regulator: Swagelok KCY series two-stage regulator with a flow coefficient (C_V) of 0.02

- Maximum operating pressure: 40 psig
- Downstream system Design Pressure: 50 psig

In this scenario, the pressure system downstream of the regulator, PCV1, must be protected from the single fault / single point-of-failure overpressure scenario of PCV1 failing in the fully open position (i.e., fails to regulate pressure entirely). When PCV1 fails, the downstream pressure system would be exposed to the full gas cylinder pressure of 2265 psig which exceeds the system maximum allowable working pressure (MAWP) of 50 psig.

To protect the pressure system, a pressure relief device (in this case, a pressure relief valve) needs to be installed. To determine the necessary relief capacity of the PRV, LANL's "Determining-regulator-flow" Excel tool (found here) may be utilized. This tool outputs the air-equivalent flow rate in standard cubic feet per minute (SCFM) of several commonly used gases. The air-equivalent flow rate (rather than the flow rate of the source gas itself) is necessary because pressure relief device capacity is measured with air.

DETERMINING REGULATOR FLOW BY Cv

EQUIVALENTS AS AIR

REGULATOR	SOURCE	Nitrogen
	SOURCE PRESSURE (psi)	2265
	C_v	0.02
	FAILURE FLOW RATE AS AIR (SCFM)	27.44

The overpressure protection needs to meet or exceed 27.44 SCFM capacity with a setpoint no higher than the downstream system MAWP of 50 psig. The overpressure protection also cannot exceed ¼" inlet size to match the size of the connecting system.

A ¼" inlet Control Devices ST25 relief valve is specified for this system. At a 50 psig setpoint, this relief valve provides ~53 SCFM flow capacity which exceeds the 27.44 SCFM failure flow rate. This relief valve will protect the system from overpressure.

NOTES
1. SET PRESSURE RANGE IS 25 PSI TO 350 PSI.
2. RELIEF CAPACITY IS GIVEN BY THE EQUATION
   Q = .759(1.1P + 14.7), WHERE
   Q = RELIEF CAPACITY IN SCFM, AND
   P = SET PRESSURE IN PSI
3. MATERIALS OF CONSTRUCTION
   BODY, ROD, CUP, SCREW--BRASS
   SPRING--MUSIC WIRE
   PAD--SILICONE OR FLUOROCARBON
   PULL RING--STAINLESS STEEL
4. MAX TEMPERATURE 250° F
5. MAX INSTALLATION TORQUE 20 FT-LBS
6. ORIFICE DIA. = .250 IN.

TOLERANC
(EXCEPT AS NC
DECIMAL ±
FRACTIONAL ±
ANGULAR ±

B. Scenario 2 – Failure flow rate of regulator exceeds PRD capacity

The following design parameters are used for this example:

- Gas cylinder: Nitrogen at 2265 psig max fill pressure
- Pressure regulator: Swagelok KCY series two-stage regulator with a flow coefficient (C_V) of 0.06
- Maximum operating pressure: 40 psig
- Downstream system Design Pressure: 50 psig

Scenario 2 has the same single fault / single point-of-failure situation as Scenario 1. However, in this scenario the pressure regulator has a flow coefficient (C_V) of 0.06, which results in a higher failure flow rate.

DETERMINING REGULATOR FLOW BY Cv

EQUIVALENTS AS AIR

REGULATOR	SOURCE	Nitrogen
	SOURCE PRESSURE (psi)	2265
	C_v	0.06
	FAILURE FLOW RATE AS AIR (SCFM)	82.32

The overpressure protection needs to meet or exceed 82.32 SCFM capacity with a setpoint no higher than the downstream system design pressure of 50 psig. The overpressure protection also cannot exceed ¼" inlet size to match the size of the connecting system.

A ¼" inlet Conrader SRV250 relief valve is specified for this system. At a 50 psig setpoint, this relief valve provides only ~53 SCFM flow capacity (see data sheet page 8) which is less than the 82.32 SCFM failure flow rate. This PRV alone will not sufficiently protect the system from overpressure. This issue can be corrected in at least two different ways:

- Install two SRV250 relief valves. The total combined capacity of the two PRVs is 102 SCFM, which exceeds 82.32 SCFM.
- Install a Restrictive Flow Orifice (RFO) upstream of the pressure regulator to limit the maximum flow. A 0.035” orifice diameter would reduce the maximum flow rate to 38.42 SCFM, which is less than the ~53 SCFM capacity of a single SRV250 relief valve.

DETERMINING REGULATOR FLOW BY ORIFICE

EQUIVALENTS AS AIR			
	Diameter (in)	C_v	
Diameter to Cv	0.035	0.028	(This diameter and
REGULATOR	SOURCE		Nitrogen
	SOURCE PRESSURE (psi)		2265
	Equivalent C_v (if not listed)		0.028
	FAILURE FLOW RATE AS AIR (SCFM)		38.42

C. Scenario 3 – Downstream system MAWP exceeds pressure source

The following design parameters are used for this example:

- Gas cylinder: Nitrogen at 2265 psig max fill pressure
- Pressure regulator: Swagelok KCY series two-stage regulator with a flow coefficient (C_V) of 0.20
- Maximum operating pressure: 500 psig
- Downstream system Design Pressure: 2500 psig

Scenario 3 has the same single fault / single point-of-failure situation as Scenarios 1 and 2. When the pressure regulator fails, the system downstream of the regulator would be exposed to the full gas cylinder pressure of 2265 psig. However, the downstream system has an MAWP of 2500 psig, meaning all downstream components meet or exceed a 2500 psig pressure rating.

The pressure source is considered self-limiting (i.e., the gas cylinder pressure source is finite). This pressure system cannot be over pressurized in the worst-case failure scenario. Therefore, the pressure system is protected from overpressure by system design. For more information on overpressure protection by system design, see American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) Section XIII, Part 13 and ASME B31.3 para. 301.2.2.

3.0 AIR COMPRESSOR

The following design parameters are used for this example:

- Pressure source: Quincy GQV-40 variable speed rotary screw air compressor

- Maximum operating pressure: 125 psig
- Downstream system Design Pressure: 150 psig
- Piping design basis: ASME B31.9, *Building Services Piping*
- Piping system size: 1-1/2″
- System includes ASME BPVC Section VIII, Division 1 air receiver and air dryer, each with an MAWP of 200 psig
- Operating at ambient indoor temperatures

The single fault / SPOF overpressure scenario for air compressors assumes that the air compressor controls fail, which would permit the compressor to run continuously. While all air compressors have a pressure at which zero flow will occur, this point is generally not known, and it is assumed that this value would exceed the downstream system MAWP.

Rotary Screw Air Compressors 8

QGV Variable Speed Technical Data

Model No.	HP	KW	PSI	ACFM	Length	Width	Height	Lbs	DBA
QGV-40	40	30	100	209.8	67	37.7	65.8	2277	67
QGV-40	40	30	125	183.0	67	37.7	65.8	2277	67
QGV-40	40	30	150	173.9	67	37.7	65.8	2277	67

Per the technical data available from Quincy, at 125 psig delivery pressure the compressor provides 183 actual cubic feet per minute (ACFM) Free Air Delivery (FAD). Conservatively, this ACFM value may be used to size the overpressure protection. A more accurate SCFM value can be determined by correcting for altitude – atmospheric pressure at LANL altitude (7500 ft) results in a performance reduction of the air compressor. The performance reduction is a ratio of (Pressure at 7500 ft)/(Pressure at sea level), (11.13 psi/14.7 psi) = 0.757.
NOTE: It is the responsibility of the designer to ensure that the relief device capacity is not significantly oversized if using the ACFM output instead of the altitude-corrected output.

For this compressor, the anticipated altitude corrected output would be 183*0.757=139 SCFM. A ¼″ inlet Kingston 118CSS relief valve is specified for this system. This relief valve is ASME 'UV' code stamped, which is required for PRVs that protect ASME Section VIII pressure vessels.

Accepted interpretation of ASME B31.9 overpressure protection requirements concludes that the working pressure scope of the code is not permitted to be exceeded. For compressed air, the working pressure cannot exceed 150 psig. 'UV' stamped relief valves are designed to permit 10% pressure accumulation above its set pressure, so the relief valve set pressure should be about 10% below 150 psig (approx. 135 psig). At a 135 psig setpoint, this relief valve provides 175 SCFM capacity, which exceeds the maximum output of the compressor at 150 psig delivery pressure.

A ¼″ inlet relief valve is sufficient for this system, which has 1-1/2″ piping. A relief valve with an inlet smaller than the connecting piping system is acceptable and often necessary. Specifying a larger inlet relief valve to closer match the connecting piping system is a common mistake that can lead to oversized relief devices. For example, the 1″ inlet Kingston 118CSS has a flow capacity of 659 SCFM at 150 psig setpoint which is 5 times the 139 SCFM altitude-corrected maximum flow.

The PRV needs to be installed near the outlet of the compressor, without any intervening stop valves between the compressor outlet and PRV (except when permitted by ASME code and ESM Ch 17). This PRV will protect the entire downstream compressed air system from the compressor SPOF scenario.
NOTE: The Section VIII pressure vessels may need their own overpressure protection if the risk of exposure to fire is a credible scenario, which is not covered by this example.

4.0 WATER PUMP

A. Scenario 1 – Process water system without make-up water

The following design parameters are used for this example:

- Pressure source: four (4) Grundfos CME 1-7 A-S-I-E-AQQE U-A-A-N, installed in parallel, operating at 100% [no variable frequency drive (VFD) present]
    - Pump curve
- System fill pressure: atmospheric (0 psig), with some residual system head pressure (5 psig)
- Piping system size: 1-1/2"
- Normal operating pressure: 75 psig
- System MAWP: 100 psig (ASME BPVC Section VIII Division 1 pressure vessel)

In this scenario, a process water system (e.g., deionized, distilled, reverse osmosis water) is supplied pressure by a water pump. The system does not connect to a make-up water system such as potable municipal water due to unprocessed potable water having the potential to disturb the balance of the process water. If the system ever needs to be refilled, it is done via atmospheric filling with process water during a shutdown. Due to system geometry, the maximum fill pressure is the lowest point of the system due to head pressure of water, 5 psig.

The system normally operates with flowing water at 75 psig (70 psig pump differential + 5 psig residual head pressure). The primary failure scenario is that valve(s) on the discharge piping are closed such that water flow is entirely blocked, creating a pump dead-head condition. In this zero-flow condition, the pump differential pressure reaches a maximum, potentially overpressurizing the piping system.

Per the pump curve linked above, the pump in this design is capable of approximately 300 ft. of total head in a zero-flow dead-head condition. One foot of head converts to 0.4334 psig, therefore the pump dead-head condition can produce 300*0.4334=130 psig. To determine the maximum system pressure on the discharge side of the pump, add the pump dead-head pressure to the residual system head pressure, which results in a maximum possible system pressure of 135 psig.

The system MAWP is 100 psig which is less than 135 psig. A pressure relief device is needed to protect the pressure system. Because an ASME BPVC Section VIII Division 1 pressure vessel needs to be protected, the pressure relief device needs to meet the requirements of Section VIII Division 1 and Section XIII (i.e., needs to be UV or UD stamped).

To determine the required flow capacity in gallons per minute (GPM) of the relief valve, the pump curve can be utilized to determine the flow rate of water at the point at which system pressure reaches 100 psig. This point is 95 psig pump differential, or 219 feet of head. Per the pump curve, the flow rate is about 8 GPM at 219 feet of head. Because the four pumps are operating in parallel, the total flow of the system at 219 feet of head is (8 GPM)*(4 pumps) = 32 GPM.

One relief valve that is deemed to be sufficient for this system is an Aquatrol series 740 with a "D" size orifice. Its Section VIII liquid flow capacity at 100 psig setpoint is 40 GPM (see data sheet page 8), which exceeds the maximum failure flow of 32 GPM. This relief valve is available from 1/2" to 1" inlet, which are all less than the 1-1/2" piping system size.

NOTE: This example assuming 100% operating speed without VFDs is very simplified. Pumps operating at less than 100% capacity with VFDs adds complexity to the evaluation due to the presence of VFD controls that may reduce maximum pressure output. VFDs are more common in new system installations or pump replacements and may aid in reducing or eliminating the need for overpressure protection.

NOTE: An alternative approach to installing a relief device in this scenario would be to replace the component(s) with an MAWP/pressure rating/etc. less than 135 psig, with items rated for 135 psig or higher. Assuming all other components are rated to 135 psig except for the pressure vessel, replacing the pressure vessel for one rated for at least 135 psig would eliminate the need for overpressure protection.

B. Scenario 2 – Hydronic water system with make-up water

The following design parameters are used for this example:

- Pressure source 1: Bell & Gossett series e-90 pump, 1.5AAB model with 5.25" impeller, operating up to 3450 RPM
  - Pump curve (ref. PDF page 12)
- Pressure source 2: Make-up water connection to potable municipal water
  - Pressure regulating valve set at 60 psig
  - Pressure relief valve set at 90 psig
- System fill pressure: 60-psig make-up water supply pressure
- Normal operating pressure: 100 psig
- System Design Pressure: 125 psig

In this scenario, a hydronic water system (e.g., heating or cooling water for HVAC) is supplied pressure by a water pump. The system connects to a make-up water system that normally supplies water at a pressure of 60 psig via a pressure regulating valve. The normal operating pressure is 100 psig, which combines the 60-psig make-up water pressure and the normal operating pump differential pressure of 40 psi (92.4 ft). There are two feasible modes of failure that need to be evaluated:

1. Failure mode 1 – Pump dead-head condition

   This failure mode is similar to 4.A Scenario 1, except that the system fill pressure, normal operating pressure, and system Design Pressure are higher. The pump dead-head pressure is approximately 115 ft. head, or 50 psig.

Combining system fill pressure and pump dead-head pressure results in a maximum potential system pressure of 110 psig. This pressure system cannot be overpressurized in the worst-case failure scenario. Therefore, the pressure system is protected from overpressure by system design. For more information on overpressure protection by system design, see ASME BPVC Section XIII, Part 13.

2. Failure mode 2 – Make-up water pressure regulating valve failure

This failure mode assumes that the pressure regulating valve on the make-up water supply line fails fully open, ceasing regulation of make-up water pressure. The make-up water line includes a pressure relief valve set at 90 psig, limiting the make-up water pressure supply to 90 psig. The hydronic water pump is operating normally at 100%, with a pressure differential of 40 psig to provide the needed water flow.

This results in a discharge pressure of 130 psig, which exceeds the system Design Pressure of 125 psig. A relief device is needed to protect the system from overpressure. At 125 psig total pressure (90 psig make-up, 35 psig pump differential), the pump head will be ~80 ft, resulting in a flow of ~145 GPM per the pump curve.

One relief valve that is deemed to be sufficient for this system is an Aquatrol series 740 with a "G" size orifice. Its Section VIII liquid flow capacity at 125 psig setpoint is 195 GPM (see data sheet page 8), which exceeds the failure flow of 145 GPM. This relief valve is available from 1-1/4" to 2" inlet, so a 1-1/4" or 1-1/2" inlet size will need to be selected to not exceed the 1-1/2" piping system size.

NOTE: An alternative approach is to lower the set pressure of the pressure relief valve on the make-up water from 90 psig to 85 psig or less (down to 65 psig). The designer would need to check that the relief capacity is still adequate at this lower set pressure. This will depend on the capacity of the pressure regulator on the make-up water supply. Then another relief valve on the pump discharge is not needed.

5.0 FACILITY STEAM

The following design parameters are used for this example:

- Pressure source (P_1): 85 psig steam from a centralized distribution system, saturated (325 °F)
- Normal operating pressure: 15 psig
- Steam control valve: Armstrong Python 1500 series, 2" valve size with 1-1/4" trim (Cv=21)
- Piping system size: 2"
- System Design Pressure: 50 psig
- Assume bypass valve with a Cv less than or equal to the control valve Cv

In this scenario, either the steam control valve fails fully open or the bypass valve is fully opened during service of the control valve, resulting in an 85 psig pressure downstream of the control valve & bypass valve. This pressure exceeds the 50 psig Design Pressure of the downstream system, so a relief device set no higher than 50 psig is needed.

To determine the required relief capacity, the maximum failure flow rate through the regulator needs to be determined. LANL's "MassFlowRate-SteamThroughRegulator" Excel tool (found here) may be utilized to make this determination based on whether the steam will be in a sonic or subsonic flow condition:

$$P_2/P_1 \leq .54 \text{ (sonic condition)}$$

$$P_2/P_1 > .54 \text{ (subsonic condition)}$$

P_1 = 85 psig upstream pressure
P_2 = relief device set pressure (assume 50 psig)
P_2/P_1 = 50/85 = 0.59, therefore subsonic condition

Mass Flow Rate of Steam Through a Regulator (Subsonic Flow Conditions)		
Given Inlet Pressure:	**85**	**psig**
LANL Atm. Pressure	11.1	psia
Upstream Pressure (P1) [psia]	96.1	psia
Given Downstream Pressure:	**50**	**psig**
LANL Atm. Pressure	11.1	psia
Downstream Pressure (P2) [psia]	61.1	psia
Flow Coefficient (Cv)	**21**	
Mass Flow Rate of Steam	**3271.14**	**lb/hr**

The selected relief device therefore needs to meet or exceed 3271.14 lb/hr steam. One relief valve that is deemed to be sufficient for this system is a Kunkle 910 series with a "J" size orifice. Its Section VIII steam flow capacity at 50 psig setpoint is 4268 lb/hr (calculated via linear interpolation, see data sheet page 17), and then derated for altitude by (50+11.1)/(50+14.7) = 4031 lb/hr which exceeds the failure flow of 3271.14 lb/hr. This relief valve has a 2" nominal inlet, which is acceptable for use with a 2" piping system size.
NOTE: As the pressure is dropped, the steam becomes superheated. However, it is not enough to use a superheat correction factor in this case.

6.0 SECTION I POWER BOILER

The following design parameters are used for this example:

- Pressure source: ASME Section I (1995 construction) power boiler, rated for 3381 lb/hr maximum steaming capacity, saturated
- Normal operating pressure: 50 psig

- Boiler MAWP: 150 psig
- Boiler relief nozzle size: 3”
- Existing relief valve: 100 psig Kunkle 6010 Section I “V” stamp, 1-1/2” inlet with “H” orifice

In this scenario, the boiler controls fail such that an uncontrolled heating process occurs, which has the potential to build pressure that exceeds the MAWP of the boiler. All Section I boilers are required by ASME Section I to have a relief valve either directly attached to a boiler nozzle or close coupled to the discharge piping with no intervening stop valves between the relief valve and boiler discharge nozzle. Additionally, the nominal size of the relief valve inlet cannot be larger than the size of the connection (e.g., a 4” inlet relief valve cannot be connected to a 3” boiler relief nozzle or 3” discharge piping).

The minimum required capacity of the boiler relief valve is recorded by LANL’s Chief Boiler Inspector during inspections. A master list of boilers at Los Alamos National Laboratory (LANL) that provides this information is available via a link in the PSD and on the Pressure Safety Program website. This list can be utilized as a pre-approved overpressure protection evaluation for protecting the boiler itself. Per the boiler master list, the maximum designed steaming capacity is 3381 lb/hr.
NOTE: Overpressure protection needs of the connected pressure system may need to be evaluated separately, particularly if there are steam regulators or other integrated pressure sources (e.g., pumps) in the pressure system.

The existing relief valve has a capacity of 4593 lb./hr. per the Kunkle 6000 series data sheet (see page 9). This relief device exceeds the boiler’s maximum steaming capacity and is therefore acceptable for this application.
NOTE: the MAWP is 150 psig, the operating pressure is 50 psig, and the set pressure of the relief valve is 100 psig. It is a safe and acceptable practice for the relief device setpoint to be below the system MAWP when operating conditions warrant.

7.0 SECTION IV HEATING WATER BOILER

SThe following design parameters are used for this example:

- Pressure source: ASME Section IV (1994 construction) power boiler
  - Heating surface area: 67 sq. ft.
  - Maximum boiler output: 490,000 BTU/hr.
  - Gas-fired watertube boiler
- Normal operating pressure: 30 psig
- Boiler MAWP: 150 psig
- Boiler relief nozzle size: 0.75”
- Existing relief valve: 45 psig Watts M1 740 Section IV “HV” stamp, 3/4” inlet

In this scenario, the boiler controls fail such that an uncontrolled heating process occurs, which has the potential to build pressure that exceeds the MAWP of the boiler. All Section IV boilers are required by ASME Section IV to have a relief valve either directly attached to a boiler nozzle or close coupled to the discharge piping with no intervening stop valves between the relief valve and boiler discharge nozzle. Additionally, the nominal size of the relief valve inlet cannot be larger than the size of the connection (e.g., a 4” inlet relief valve cannot be connected to a 3” boiler relief nozzle or 3″ discharge piping) AND cannot be less than ¾″ unless meeting special circumstances permitted by code.

The minimum required capacity of the boiler relief valve is recorded by LANL's Chief Boiler Inspector during inspections. A master list of boilers at LANL that provides this information is available via a link in the PSD and on the Pressure Safety Program website. This list can be utilized as a pre-approved overpressure protection evaluation for protecting the boiler itself. *NOTE: Overpressure protection needs of the connected pressure system may need to be evaluated separately, particularly if there are other pressure sources (e.g., pumps or makeup water) in the pressure system.*

Per the boiler master list, the minimum relief valve capacity is 670,000 BTU/hr. Therefore, this boiler shall be provided a relief device that meets or exceeds 670,000 BTU/hr. The existing relief valve has a capacity of 1,245,000 BTU/hr per the Watts data sheet. This relief device meets code and is acceptable for this application.

8.0 POTABLE WATER HEATER

The following design parameters are used for this example:

- Pressure source: 25 kilowatt (kW) potable water heater
- Normal operating pressure: 30 psig
- Water heater MAWP: 125 psig
- Water heater relief nozzle size: 0.75″
- Existing relief valve: 125 psig Apollo 18C-402, ¾″ inlet, 3″ temperature sensing element length

In this scenario, the water heater controls fail such that an uncontrolled heating process occurs, which has the potential to build pressure and/or temperature that exceeds the MAWP of the water heater. Water heaters come equipped with temperature and pressure (T&P) relief valves that open when either the pressure reaches the pressure setpoint or the water temperature reaches 210 deg F.

Depending on the size/construction of the water heater, T&P relief valves will either have only a Canadian Standards Association (CSA) BTU/hr. rating or both a CSA and ASME BTU/hr. rating. Generally, water heaters that are *not* built to ASME Section IV standards (i.e., greater than 200,000 BTU/hr. input or nominal capacity of 120 gallons) will utilize the CSA BTU/hr. rating when sizing relief devices. Subsequently, ASME Section IV "HLW" stamped water heaters will utilize the ASME BTU/hr. rating when sizing relief devices.

Additionally, T&P relief valves have a temperature sensing element with lengths that vary. The Apollo 18C-402 used in this example can be procured with either 3″ or 8″ length elements. Element length may impact temperature sensing if it is too long or too short, so the best practice when planning preventive maintenance replacements of water heater T&P relief valves is to utilize the same or very similar element length compared to what was installed by the manufacturer. Ideally, the exact PRV model installed by the manufacturer should be used when possible.

The manufacturer-installed T&P relief valve is an Apollo 18C-402, which has a CSA rating of 105,000 BTU/hr. and an ASME Section IV rating of 500,000 BTU/hr. The water heater in this example is *not* an ASME Section IV water heater, therefore, the CSA rating of the T&P relief valve is to be used for sizing the relief device. The electric heating maximum input of 25 kW converts to 85,305 BTU/hr. (1 kW = 3412.2 BTU/hr.). The 105,000 BTU/hr. capacity exceeds the converted 85,305 BTU/hr. input rating of the water heater, so the relief valve is sized appropriately.

9.0 CRYOGENIC LIQUID LOCK

Comprehensive example evaluations for cryogenic liquid lock overpressure scenarios are available for reference on the "Reference Data" SharePoint linked on the ESM Chapter 17 website.

Generally, these evaluations utilize the equations provided by CGA S-1.3 (2020 edition) publication sections:

- Assuming loss of vacuum insulation in a double-walled pipe or vessel *without* fire – CGA S-1.3 section 6.2.2 "Insulated containers for liquefied compressed gases"
- Assuming loss of vacuum insulation in a double-walled pipe or vessel *with* fire – CGA S-1.3 section 6.3.2 "Liquefied compressed gases, refrigerated fluids, and refrigerated (cryogenic) fluids in uninsulated or insulated containers that lose insulation during fire"

10.0 REFERENCES

There are links to external websites throughout this document that go to product pages and data sheets for equipment or components used in this guide. PDF versions of the linked content are available for reference on the "Reference Data" SharePoint linked on the ESM Chapter 17 website.

TABLE OF CONTENTS

RECORD OF REVISIONS

Rev	Date	Description	POC	RM
0	9/22/23	Initial issue as attachment GUIDE-2.	Ari Ben Swartz, *ES-FE*	Dan Tepley, *ES-DO*

Contact the Standards POC for upkeep, interpretation, and variance issues.

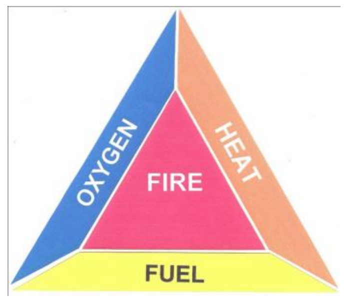
Chapter 17	**Pressure Safety POC**

This document is online at https://engstandards.lanl.gov

1.0 Oxygen Pressure System Hazards

A. Oxygen System Hazards

The fire triangle is a model for conveying the three elements required to generate a fire: fuel, oxygen (oxidizer), and heat (ignition). The three elements must be combined in the right proportions for a fire to occur. If one of the three elements is removed, the fire does not occur or is extinguished.



Oxygen is a strong oxidizer that supports combustion and is reactive at ambient conditions. The reactivity of oxygen increases as the oxygen concentration, pressure, or temperature within a pressure system increases. An increase in oxygen reactivity increases the risk of an oxygen fire.

Oxygen systems always have two of the three elements to generate a fire. The container or pressure system supplies the fuel. The oxygen is the oxidizer.

B. Control of Oxygen System Hazards

The only way to prevent an oxygen system from burning is to prevent ignition. Control of ignition is achieved by selecting and controlling the materials used in the system, and minimizing the heat generation that can lead to ignition.

The degree the materials and ignition mechanisms must be controlled is a function of the oxygen concentration, the design pressure, and design temperature. Application of requirements to oxygen system is a graded approach. As the hazard of the oxygen system increases, the rigor necessary for a safe system increases.

At low oxygen concentration, low pressures, and low temperatures, where the risk of an oxygen fire is low, cleaning may be the only control necessary. For example, the medical industry uses National Fire Protection Association (NFPA) 99 for oxygen at **less than 350 psig** regularly with nonmetallic materials. LANL defines high-pressure oxygen as 350 psig or higher because it will require an evaluation of non-metallic materials.

High-pressure oxygen systems **greater than 350 psig** must by necessity use a more rigorous approach on the design, material selection, component selection, cleaning, maintenance, and operation. Most materials, both metals and nonmetals, are flammable in high-pressure oxygen; therefore, systems must be designed to control ignition hazards.

The method to perform an Oxygen Hazards Analysis is a Failure Modes and Effects Analysis (FMEA). Below are general references on how to perform an FMEA.

https://asq.org/quality-resources/fmea#Procedure

https://www.sixsigmadaily.com/steps-in-failure-modes-and-effects-analysis/

https://www.juran.com/blog/guide-to-failure-mode-and-effect-analysis-fmea/

The LANL FMEA reference is FSD-300-3-001, *Hazard Analysis Manual*. This FSD is related to P300, *Integrated Work Management*.

2.0 Material Selection

A. There are four basic criteria when selecting a pipe or tubing material for gaseous oxygen service: concentration of oxygen, design pressure, design temperature and oxygen flow velocity. Per Fig. 1, if the system operates below 200 psig at 200°F then carbon steel or stainless steel would be suitable material at almost any velocity. However, above those markers, velocity becomes an issue and the material selection narrows.

B. In operating conditions at or below 200°F and 200 psig, carbon steel, 316 SS or, copper (Type K) is acceptable for use in 99.5 mole percent oxygen (ref. Material Selection for Gaseous Oxygen Service, William M. Huitt). Above those operating conditions, copper (Type K) would be acceptable.

C. If a system is operating in a range above the curve in Fig. 1, copper tubing should be selected. This applies also in flow-through valves, where velocity could be an issue, and where oxygen gas impinges directly on ferrous piping. Where velocity of flow through a valve may approach sonic velocity, copper-based materials will be required. Where direct impingement on ferrous piping occurs, velocity should be reduced to one half the values of Fig. 1, or the impingement surface must be a copper-based alloy. One major factor when selecting material for oxygen service is the material's Melting Point Burn Ratio (BR_{mp}). This is defined in ASTM G94 as: *Numerous metals burn essentially in the molten state. Therefore, combustion of the metal must be able to produce melting of the metal itself. The BR_{mp} is a ratio of the heat released during combustion of a metal to the heat required to both warm the metal to its melting point and provide the latent heat of fusion. It is further defined by:*

$$BR_{mp} = \Delta H_{combustion} / (\Delta H_{rt\text{-}mp} + \Delta H_{fusion})$$

Where:

ΔH = *heat of combustion*

$\Delta H_{rt\text{-}mp}$ = *heat required to warm the metal from room temperature (rt) to the melting point (mp)*

ΔH_{fusion} = *latent heat of fusion*

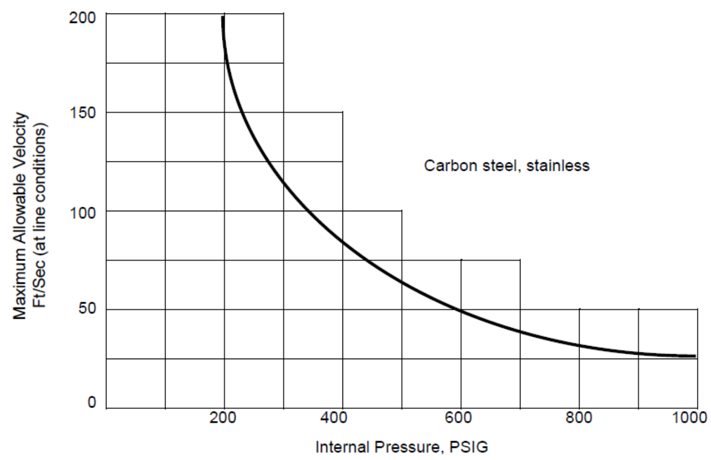


Figure 1 Maximum velocity versus internal pressure for steel pipelines (99.5 mole% or higher oxygen) *(Griffith and Wallis, Journal of Heat Transfer, August 1961)*

Table 1 Calculated Melting-Point Burn Ratios[A]

Material	BR_{mp}
Silver	0.40
Copper	2.00
90-10 copper-nickel[B]	2.39
CDA 938 tin bronze[B]	2.83
CDA 314 leaded commercial bronze[B]	2.57
Monel 400[B]	3.02
Cobalt	3.50
Monel K500[B]	3.64
Nickel	3.70
CDA 828 beryllium copper[B]	4.49
AISI 4140 low alloy steel[B]	5.10
Ductile iron	5.10
Cast iron	5.10
AISI 1025 carbon steel[B]	5.10
Iron	5.10
17-4 PH[B]	5.32
410 SS[B]	5.39
CA 15 stainless steel[B] (see A296)	5.39
304 stainless steel[B]	5.39
Titanium	13.1
Lead	18.6
Zinc	19.3
Lead babbit[B]	20.6
Magnesium	22.4
Aluminum	29.0
Tin Babbit[B]	42.6
Tin	44.8

[A] From Monroe, Bates & Pears, *Flammability and Sensitivity of Materials in Oxygen*

[B] Presented for comparison only. Alloys may exhibit flammability vastly inconsistent with the BR_{mp} ranking.

D. In Table 1, you can see the hierarchy of metals as it pertains to their burn ratios. Carbon steels, stainless steels, and coppers have the lower, more acceptable burn ratios, with copper being the lowest of those three. In the event flame propagation does occur due to some ignition mechanism, those metals will tend to impede combustion of the metals themselves. The same result is indicated in ASTM G94, Table X1.1 – Promoted Combustion Test results, where combustion tests were carried out in 99.5 mole% oxygen. Copper had a non-propagation rate at 1000, 5000 & 8000 psig. 316 stainless steel had a non-propagation rate at 500 psig and various declared burn rates from 1000 to 10000 psig. Ductile iron (closest example of carbon steel) had a burn rate of 0.14 in/sec at 500 psig (the lowest pressure at which these tests were performed).

3.0 Oxygen Cleaning

A. Cleaning of oxygen piping components including pipe or tubing and fittings involves the removal of contaminants including the surface residue from manufacturing, hot work, and assembly operations, as well as the removal of all cleaning agents and the prevention of recontamination before final assembly, installation, and use. These cleaning agents and contaminants include solvents, acids, alkalis, thread lubricants, filings, dirt, scale, slag, ling, weld splatter, organic materials such as oil, grease, crayon, or paint, and other foreign materials.

B. The ASME Designer is responsible for determining the required cleaning for the oxygen pressure system, for example:

1. The ASTM G93, *Standard Practice for Cleanliness Levels and Cleaning Methods for Material and Equipment Used in Oxygen-Enriched Environments*, CGA G-4.1, *Cleaning Equipment for Oxygen Service*, and EIG/IGC 33, *Cleaning of Equipment for Oxygen Service Guideline,* provide the methods to clean for oxygen service. The required clean level for oxygen service is addressed in ASTM G93, EIGA/IGA 33, and CGA 4.3, *Commodity Specification for Oxygen*.

2. Tubes, valves, fittings, station outlets, and other piping components shall have been cleaned for oxygen service by the manufacturer prior to installation in accordance with the mandatory requirements of CGA G-4.1, *Cleaning Equipment for Oxygen Service*, or equivalent standard except that fittings shall be permitted to be cleaned by a supplier or agency other than the manufacturer.

3. High-pressure oxygen systems require cleaning per ASTM G93 and G127 or equivalent standards to ensure removal of any foreign surface matter. This may be accomplished by the manufacturer, or at the job site on a final installed system.

4. High-pressure oxygen or other oxidizer pressure systems must be disassembled for cleaning. Each component must be cleaned prior to assembly. Non-volatile cleaning agents may remain in trapped spaces, which could react with oxygen. Cleaning solutions may degrade non-metals in an assembly. Caustic and acid cleaning solutions may cause crevice corrosion in assemblies.

5. Final cleaning after assembly and before introduction of oxygen to the system, by purging the system using clean, dry gaseous nitrogen or dry air to remove contaminants or moving them to an acceptable location.

C. The ASME Designer shall specify any necessary handling of oxygen cleaned piping components such as the following:

1. Tubing should be purchased in a pre-cleaned condition.

2. Each length of tube shall be delivered plugged or capped and labeled by the manufacturer and kept sealed until prepared for installation.
3. Finished fabricated pieces should be stored in a clean dry area away from construction pathways and activities.
4. Piping components, pipe, tube, fittings, valves, and other components shall be delivered, sealed, labeled, and kept sealed until prepared for installation.
5. The interior surfaces of tubes, fittings, and other components that are cleaned for oxygen service shall be stored and handled to avoid contamination prior to assembly and brazing.
6. Components cleaned for oxygen service must be handled with clean lint and power free gloves or handling devices to maintain oil-free cleanliness of component.
7. Component cleanliness must be maintained during the assembly/construction process.
8. To maintain cleanliness during assembly, it may be necessary to assemble the system in a laminar flow cabinet, for example a Class 100 flow bench.
9. Components or systems cleaned for oxygen service must not be left in the open or unprotected. Care should be taken to avoid contamination of particulate and oil deposits on surfaces that will be in direct oxygen service.
10. Ensure all tubing has been prefabricated, properly deburred, and cleaned prior to assembly.
11. Ensure all weld slag has been removed from interior of lines.

4.0 Material Exemptions

The table below lists exemption pressures for the alloys covered in Section 4.3.1 of CGA G-4.4-2020, *Oxygen Pipeline and Piping Systems*. The exemption pressures are based on a burn criterion of less than 30 mm (1.18 in) for a specimen.

Thickness is a very important variable in component flammability. The thickness of a metal or alloy shall not be less than the minimum prescribed in the table. If the thickness is less than the prescribed minimum, the alloy shall be considered flammable and velocity limitations appropriate for the system pressure shall be observed. Exemption pressures should not be extrapolated outside the given thickness range of 3.18 mm to 6.35 mm (0.125 in to 0.250 in).

Alternatively, flammability assessments can be made using appropriate characterization techniques described in CGA G4.4-2020, Section 4.2.1, which can result in a judgment that velocity limitations are not required.

Exemption Pressure

Exemption pressure is the maximum pressure at which a material is not subject to velocity limitations in oxygen enriched atmospheres where particle impingement may occur. At pressures below the exemption pressure, ignition and burn propagation is considered unlikely to occur based on ignition mechanisms listed in CGA G4.4-2020. The exemption pressures of the alloys listed in the table below are based on industry experience and under the conditions used for the promoted ignition combustion testing per ASTM G124, *Test Method for Determining the Combustion Behavior of Engineering Materials in Oxygen-Enriched Atmospheres*.

Table 2. Exemption Pressures and Minimum Thicknesses (Normative)

Engineering Alloys	Minimum Thickness	Exemption Pressure
Brass Alloys[1]		
(all)	None specified	20.68 MPa (3000 psig)
Cobalt Alloys[2]		
Stellite 6	None specified	3.44 MPa (500 psig)
Stellite 6B	None specified	3.44 MPa (500 psig)
Copper[3]		
(all)	None specified	20.68 MPa (3000 psig)
Copper-Nickel Alloys[1,3]		
(all)	None specified	20.68 MPa (3000 psig)
Tin Bronzes		
(all)	None Specified	20.68 MPa (3000 psig)
Ferrous Castings, Non-stainless		
Gray Cast Iron	3.18 mm (0.125 in)	0.17 MPa (25 psig)
Nodular Cast Iron	3.18 mm (0.125 in)	0.34 MPa (50 psig)
Ni Resist Type D2	3.18 mm (0.125 in)	2.07 MPa (300 psig)
Ferrous Castings, Stainless		
CF-3/CF-8,CF-3M/CF-8M,CG-8M	3.18 mm (0.125 in)	1.38 MPa (200 psig)
CF-3/CF-8,CF-3M/CF-8M,CG-8M	6.35 mm (0.250 in)	2.6 MPa (375 psig)
CN-7M	3.18 mm (0.125 in)	2.58 MPa (375 psig)
CN-7M	6.35 mm (0.25 in)	3.44 MPa (500 psig)
Nickel Alloys[3]		
Hastelloy C-276	3.18 mm (0.125 in)	8.61 MPa (1250 psig)
Inconel 600	3.18 mm (0.125 in)	8.61 MPa (1250 psig)
Inconel 625	3.18 mm (0.125 in)	6.90 MPa (1000 psig)
Inconel X-750	3.18 mm (0.125 in)	6.90 MPa (1000 psig)
Monel 400	0.762 mm (0.030 in)	20.68 MPa (3000 psig)
Monel K-500	0.762 mm (0.030 in)	20.68 MPa (3000 psig)
Nickel 200	None specified	20.68 MPa (3000 psig)
Stainless Steels, Wrought		
304/304L, 316/316L, 321, 347	3.18 mm (0.125 in)	1.38 MPa (200 psig)
304/304L, 316/316L, 321, 347	6.35 mm (0.250 in)	2.58 MPa (375) psig)
Carpenter 20 Cb-3	3.18 mm (0.125 in)	2.58 MPa (375 psig)
410	3.18 mm (0.125 in)	1.72 MPa (250 psig)
430	3.18 mm (0.125 in)	1.72 MPa (250 psig)
X3 NiCrMo 13-4	3.18 mm (0.125 in)	1.72 MPa (250 psig)
17-4PH (age hardened condition)	3.18 mm (0.125 in)	2.07 MPa (300 psig)

Note: This list does not include all possible exempt materials. Other materials may be added basedonthe results of testing as described in Section 4.2.1 of CGA G-4.4-2020.

Note: These exemption pressures are applicable for temperatures up to 200 °C (392 °F).

1) Cast and wrought mill forms.

2) These cobalt alloys are commonly used for weld overlay applications for wear resistance. Use atexemption pressures above those specified in Appendix D of should be justified by a risk assessment or further testing.

3) Nickel alloys have been used safely in some applications at thicknesses less than those shown in Appendix D. Use of thinner cross sections should be justified by a risk assessment or further testing.

5.0 Organic Materials

NOTE: This section is based on Emerson Product Bulletin 59:045, Material Guidelines for Gaseous Oxygen Service, *September 2017.*

Organic materials have ignition temperatures below those of metals. Use of organic materials in contact with oxygen should be avoided, particularly when the material is directly in the flow stream. When an organic material must be used for parts such as valve seats, diaphragms, or packing, it is preferable to select a material with the highest ignition temperature, the lowest specific heat, and the necessary mechanical properties.

Lubricants and sealing compounds should be used only if they are suitable for oxygen service and then used sparingly. Ordinary petroleum lubricants are not satisfactory and are particularly hazardous because of their high heat of combustion and high rate of reaction.

The approximate ignition temperatures in 138 bar (2000 psig) oxygen for a few organic materials are shown in Table 3.

Table 3. Typical Ignition Temperatures of Organic Materials in Oxygen

MATERIAL	TYPICAL IGNITION TEMPERATURE IN 138 BAR (2000 PSIG) OXYGEN	
	°C	°F
PTFE and PCTFE	468	875
70% Bronze-filled PTFE	468	875
Fluoroelastomer	316	600
Nylon	210	410
Polyethylene	182	360
Chloroprene and Nitrile	149	300

6.0 Metals

The selection of metals should be based on their resistance to ignition and rate of reaction. Following is a comparison of these two properties for some commonly used valve materials.

7.0 Resistance to Ignition in Oxygen

Materials are listed in order from hardest to ignite to easiest to ignite:

A. Copper, copper alloys, and nickel-copper alloys — *most resistant*

B. Stainless steel (300 series)

C. Carbon steel

D. Aluminum — *least resistant*

8.0 Rate of Reaction

Materials are listed in order from slowest rate of combustion to most rapid rate of combustion:

A. Copper, copper alloys, and nickel-copper alloys — *do not normally propagate combustion*

B. Carbon steel

C. Stainless steel (300 series)

D. Aluminum — *burns very rapidly*

NOTE: Stainless steel, once ignited, burns more rapidly than carbon steel. Nevertheless, the austenitic grades (300 series) of stainless steel are much better than carbon steel because of their high resistance to ignition.

9.0 Materials for Low-Pressure Oxygen Service

NOTE: This section is based on Glenn Research Center, Glenn Safety Manual GLP-QS-8715.1.5 Rev. C, Oxygen*. Additionally, NSS 1740.15,* Safety Standard for Oxygen and Oxygen Systems*, Tables B-5 and B-6 may be useful for material selection.*

A. Gaseous Oxygen

Metals acceptable for low-pressure (nominally less than 350 psia) gaseous oxygen service include:

a. Aluminum-nickel

b. Aluminum alloys-nickel alloys

c. Copper-stainless steel

d. Copper alloys

See GLP-QS-8715.1.5 Table C.2, Some Recommended Materials for Oxygen Service, for a partial list of these materials and their applications.

B. Liquid Oxygen

Metals recommended for service with liquid oxygen include the following:

a. Nickel and nickel alloys

1) Hastelloy B nickel

2) Inconel-X

3) René 41

4) K-Monel

b. Stainless steel types

1) 304–310

2) 304L–316

3) 304ELC–321

c. Copper and copper alloys

1) Copper-Cupro-nickel

2) Naval brass

3) Admiralty brass

NOTE: Refer to ASTM MNL36, Chapter 3, Materials Information Related to Flammability, Ignition, and Combustion, for more detailed materials information.

C. Prohibited Metals

Certain metals are prohibited from being used in oxygen systems (see ASTM MNL36, Chapter 3, Restricted Alloys).

1. Cadmium

The toxicity and vapor pressure of cadmium restrict its use.

2. Titanium

Titanium metal shall not be used with liquid oxygen at any pressure or with gaseous oxygen or air at oxygen partial pressures above 30 psia. Titanium and its alloys are impact sensitive in oxygen.

3. Magnesium

Magnesium metal shall not be used in oxygen systems. In addition, its alloys shall not be used except in areas with minimal exposure to corrosive environments. Reactivity with halogenated compounds constrains its use with lubricants containing chlorine and fluorine.

4. Mercury

Mercury shall not be used in oxygen systems in any form because it is toxic; in addition, mercury and its compounds can cause accelerated stress cracking of aluminum and titanium alloys.

5. Beryllium

Beryllium and its oxides and salts are highly toxic and shall not be used in oxygen systems or near oxygen systems where they could be consumed in a fire.

D. Nonmetallic Materials

1. The primary concerns about using nonmetals in oxygen systems are their potential reactivity with the oxidant and limitations at cryogenic temperatures. Their ignition temperatures are generally lower than those for metals, and their low thermal conductivity and heat capacity make them much easier to ignite. The selection of these materials for use in oxygen is based on experience and testing of impact, ignition, and flammability characteristics. For more information, consult NASA SP-3090 and ASTM MNL36, Chapter 3, *Nonmetallic Materials*.

2. GLP-QS-8715.1.5 Table C.2, Some Recommended Materials for Oxygen Service, contains a partial list of nonmetals and their applications. Nonmetals that have been used successfully include the following:

   a. Tetrafluoroethylene (TFE) polymers (Halon TFE, Teflon™ TFE, or equivalent)

   b. Unplasticized chlorotrifluoroethylene polymer (e.g., Kel F®, Halon CTF, or equivalent)

   c. Fluorosilicone rubbers and fluorocarbons (e.g., Viton™ (The Chemours Company) fluoroelastomers), batch-tested for acceptability

d. Lubricants such as Krytox™ (The Chemours Company) and Triolube 16 (Aerospace Lubricants)

e. Table 2 in NASA RP-1113 lists ignition variability of nonmetallic materials currently used in oxygen systems and of nonmetallic materials not requiring batch-testing control, along with some use restrictions.

10.0 General Oxygen System Design Guidelines

NOTE: This section is from NSS 1740.15, Safety Standard for Oxygen and Oxygen Systems.

Alone, the use of ignition- and burn-resistant materials for components in oxygen systems will not eliminate oxygen fires. Designs shall consider system dynamics, component interactions, and operational constraints, in addition to component design requirements, to prevent conditions leading to oxygen fires. Refer to ASTM G 88 (1985) for additional system design guidelines and to Chapter 3 of this document, ASTM G 63 (1985), and ASTM G 94 (1990) for materials use guidelines.

Although it is not always possible to use materials that do not ignite under any operating condition, it is normally understood that the most ignition-resistant materials should be used in any design. The designer should also avoid ignition modes wherever possible, but what may not be clear is that the designer must also consider the relative importance of the various ignition modes when designing new or modified hardware. This means that certain ignition modes are more likely than others to result in failures, either because of the amount of soft goods present or the likelihood of a particular event leading to component heating and subsequent ignition. To reduce the risk of ignitions, any ignition failure mode that involves soft goods, contamination, or rapid pressurization must be carefully scrutinized. The following design guides are presented roughly in the order of priority described above.

A. Design, fabricate, and install per applicable codes.

B. Use filters to isolate system particulate; however, they should be placed in locations where they can be removed and inspected and where no possibility of back flow exists. A helpful practice is to check the pressure differential across the filter to aid in tracking the filter status. Use filters at the following locations:

1. Module inlets and outlets
2. Disconnect points
3. Points required to isolate difficult-to-clean passageways
4. Upstream of valve seats

C. Design component and system combination to avoid chatter.

D. Ensure proper materials certifications.

E. Design for fire containment using methods such as fire break, fire blow out, or remote operation. Use fire-resistant materials.

F. Design to allow a blowdown of the system with filtered, dry, inert gas at maximum attainable flow rates and pressures after system fabrication. This serves to purge or isolate assembly-generated particulate.

G. Design to minimize choked flow. Consider shut-off valves, metering valves, relief valves, and regulators to reduce particle impact ignition risks.

H. Avoid captured vent systems. A relief valve or burst disk that is not open directly to the atmosphere, but rather has a tube or pipe connected to the outlet, is said to have a captured vent. If a captured vent is necessary, use high ignition-resistant materials such as Monel and copper (see 403d(2)(t)).

I. Bulk oxygen installations are not hazardous (classified) locations as defined and covered in Article 500 of NFPA 70 (1993). Therefore, general purpose or weatherproof types of electrical wiring and equipment are acceptable depending upon whether the installation is indoors or outdoors. Such equipment shall be installed in accordance with the applicable provisions of NFPA 70 (1993).

J. Electrical wiring in high concentrations of GOX should be encased in hermetically sealed conduits or conduits filled with inert helium or nitrogen gas. The instruments, switches, flow sensors, and electrical devices should be designed in modular structure and hermetically sealed, and filling with nitrogen or helium is recommended.

K. Materials for electrical and electronic equipment should be selected to meet the intent of specifications found in NFPA 70 (1993). Electrical terminals should not tum or loosen when subjected to service conditions; terminal points should be protected from shorting out by eliminating foreign objects and contaminants.

11.0 Specific Oxygen System Design Guidelines

NOTE: This section is from NSS 1740.15, Safety Standard for Oxygen and Oxygen Systems.

Oxygen system designers should:

- Minimize the amount of soft goods and their exposure to flow. Soft goods exposed to flow can be readily heated through rapid compression or readily ignited through kindling chain reactions. Minimizing soft goods exposure by shielding with surrounding metals can significantly reduce ignition hazards.
- Limit gaseous oxygen pressurization rates. Soft goods (such as seals, coatings, and lubricants) are susceptible to ignition from heating caused by rapid pressurization. For example, Teflon™-lined flexible hoses are sensitive to this ignition mode, and their use with rapid pressurization applications is discouraged. Pressurization rates of valve and regulator actuators shall be minimized. And in some applications, flow-metering devices are prudent for manually actuated valves, especially for quarter-tum ball valves.
- Limit GOX flow velocities. Limiting flow velocities minimizes erosion problems and reduces the risk of particle impact ignitions. Although each material and configuration combination must be reviewed individually, fluid velocities above 30.5 m/s (100 ft/s) should receive special attention, especially at flow restrictions.

- Minimize mechanical impact. Mechanical impact ignitions can ignite large parts, and the impacts can also ignite contamination and soft goods entrapped by the impact. Relief valves, shutoff valves, regulators, and subminiature parts should be reviewed for this hazard especially.
- Minimize frictional heating in oxygen. Frictional heating, such as heating that occurs with bearings and pistons, can cause ignitions (De and Peterson 1992). Any contamination near the heated region can also be ignited. Frictional heating hazards can be reduced by carefully controlling surface finishes, coefficients of friction, alignment, and flow-induced cooling. Frictional heating has also been found to ignite materials in cryogenic applications.
- Minimize blunt flow impingement surfaces. The risk of particle impact ignitions can be reduced if potential impact surfaces are designed with shallow impact angles to reduce the kinetic energy absorbed by the impact surface upon impact.
- Eliminate burrs and avoid sharp edges. Burrs and sharp edges on equipment provide ignition sources for particle impact, and they also provide the ingredients for kindling chain combustion propagation. Removal of this material is standard shop practice and is essential to avoid oxygen-enriched ignitions.
- Design to minimize use-generated particulate during manufacture, assembly, and operation, as this particulate could be a source of particle impact ignition. Designs should have provisions to minimize particulate generation through the normal operation of valve stems, pistons, and other moving parts. This can be accomplished by using bearings, bushings, and configurations to keep particulate away from oxygen-wetted regions. Additionally, the assembly, cleaning, and maintenance practices should minimize contamination.
- Avoid rotating valve stems and sealing configurations that require rotation on assembly. Rotating valve stems and seals can gall and generate particulate.
- Minimize electrical arcing. Electrical arcs in oxygen-enriched environments can lead to heating and subsequent ignition.
- Eliminate blind passages. Long, narrow passages or blind passages are difficult to clean and to inspect for cleanliness. Additionally, they can provide a location for particulate to accumulate during operation of the equipment. This contamination can make the equipment susceptible to particle impact, rapid compression, and resonant cavity ignitions.
- Avoid crevices for particulate entrapment and resonant cavities (Phillips 1975). Cavities, especially those formed at the intersection of mating parts in assemblies, create a location where contamination can accumulate and increase ignition risks, as in blind passages.
- Design dynamic seals to minimize particulate generation. Minimize coefficients of friction and surface finishes and choose seal configurations to minimize particle generation that can cause particle impact ignitions.

- Limit fluid-induced vibrations (overall operating ranges). Vibrations can cause fretting, galling, impacting, and particle generation in components and systems. Check valve chatter and valve poppet oscillations are examples of this phenomenon. Particulate accumulations will increase the risk of particle impact ignitions.

- Consider the effects of single-point seal failures. Seals will degrade with time and use. Eventually, they may be expected to fail to seal the contained fluid. When this happens, the effects of an oxygen-enriched external environment, high velocity leakage, and loss of mechanical integrity must be addressed.

- Eliminate rotation of seals and rotation against seats. Sealed parts that require rotation at assembly (such as O-rings on threaded shafts) can generate particles which may migrate into the flow stream. Particulate generation also occurs in ball valves where operation of the valve rotates a ball on a nonmetallic seat.

  A related phenomenon that may be described as "feathering" occurs when valve stems are rotated against some nonmetallic seats such as Kel-F®. Because of the mechanical properties of some nonmetalllc materials, a thin, feather-like projection of material is extruded from the seat. The feathered material is more ignitable than the seat itself. Kel-F®' and other nonmetallic materials subject to feathering should only be used with caution for seals and seats in rotating configurations. Ball valves are not recommended for oxygen systems because of their tendency to generate particulate and their fast opening times, which create rapid pressurization of systems.

- Avoid thin walls. The walls between inner cavities or passageways and the outer surface of component housings may become so thin that stress concentrations result when pressure is introduced. Because geometries both inside and outside can be complex, it may not be obvious from drawings or even from direct inspection that such thin, highly stressed areas exist. If such walls become too thin, they may rupture under pressure loading. The energy released by the rupture can raise the temperature in the rupture zone. The failed section can expose bare, jagged metal that can oxidize rapidly and may heat enough to ignite and burn.

- Be cautious of single-barrier failures. A single-barrier failure is defined as a leak in which only the primary containment structure is breached. Such a leak introduces oxygen into a region not normally exposed to oxygen. The materials or configuration of parts in this region may not be compatible with high-pressure oxygen.

  Any situation in which a single barrier may fail should be analyzed during the design phase. The single-barrier failure analysis may consist of an engineering evaluation of the configuration, including an analysis of the compatibility of materials exposed by the failure with the high--pressure oxygen. The purpose of the analysis should be to determine if a barrier failure is credible and if exposure of incompatible materials can create a hazard. If the hazard cannot be assessed adequately by analysis, a configurational test may be performed.

- Be aware of seat shape and seals. Designs in which an O-ring seals on an unusual seat shape may cause increased wear or accelerated extrusion of the O-ring material and the generation of particulate contamination.

  Although the design of sealing interfaces is a necessary compromise, the design should use standard seat shapes as much as possible. Past experience has shown that elastomeric 0-rings are successful in static environments but are usually poor choices in dynamic environments and should only be considered in designs where the exposure to oxygen is minimized, such as line exposure. In some instances, PTFE with Viton• as a backup (which exposes the most compatible materials preferentially to oxygen) has been used for seals where elastomers must be used and cannot be limited to line exposure. Rigid plastics such as Vespel© have been used as seats in valves and regulators; however, the noncompliance of the material requires a small contact area with a hard (metal or sapphire) mating surface to achieve a seal. An alternative to rigid plastics is to use a coined metal seat if the precautions to eliminate galling, discussed above, have been taken.

- Allow sufficient seal squeeze to avoid 0-ring extrusion. Standard manufacturers' dimensions and tolerances should be incorporated into designs unless an unusual overriding design constraint demands the change. Additionally, the dimensions of all parts in the valve assembly should be carefully inspected.
- Use metal-to-metal seals in some cases. Polymeric materials cannot be used as seals in valves that control the flow of hot oxygen at high temperatures and pressures, because they lose sealing properties, are easily ignited, and wear too rapidly.

  High pressures and high flow rates can produce side loads and oscillations on the poppet seal; these can cause metal deterioration by fretting or galling. (Galling is the more severe condition, because it involves smearing and material transfer from one surface to another.) Fretting and galling can cause several problems in oxygen systems.

  The valve poppet may seize, resulting in loss of function. The frictional heat of the fretting or galling may lead to ignition of the valve. The particles generated by the fretting or galling may cause malfunction or ignition of another component downstream.

  Where possible, the valve poppet should be designed for symmetrical flow, so no oscillatory side loads are created. The symmetrical flow centers the poppet in the bore and maintains design clearances between the poppet and bore surfaces.

  For gaseous systems, it may be possible to reduce the volumetric flow rate (and thus the magnitude of oscillations and side loads) by installing an orifice. The orifice should be downstream of the poppet to minimize the pressure differential across the poppet. It is also possible to flexure-mount the poppet in the bore and to incorporate labyrinth seal grooves in the poppet surface.

To minimize the possibility of ignition, poppet and bore materials should be relatively resistant to ignition by frictional heating. Both may be hardened by nitriding or a similar process to minimize material loss by fretting or galling.

- Consider the effects of long-term operation, including the following:
  - Cold flow of seals. Cold flow is a concern, especially for soft goods with little resiliency. With applied loads, these materials permanently deform, usually resulting in sealing loss.
  - Seal extrusion (avoid extrusion-generated particulate). Generally, seals with low hardnesses tend to provide better sealing. However, the softer seals will not withstand high temperatures and pressures. When such seals fail, they often extrude, generating particulate. Pressure and thermal reversal cycles can also result in seal extrusion. Although silicone seals are not recommended, they may be found in existing oxygen systems. If found, careful examination during maintenance procedures is recommended, because excessive cross-linking of silicone elastomers in oxygen environments may occur, leading to embrittlement and degradation.
  - High-temperature substrate. The oxide is then likely to become a source of particulate.
- Design equipment so that power losses, control pressure leakage, or other loss of actuation sources return the equipment to a fail-safe position to protect personnel and property in an accident.
- Consider the effects of thermal expansion. Buckling can create component failures.

A. Cryogenic Oxygen Systems

In addition to the design considerations for high-pressure and high-temperature oxygen systems, specific considerations for cryogenic applications are described as follows. Liquid cryogens can easily vaporize and produce high-pressure regions in systems assumed to be at low pressure (liquid lockup); if these potential high-pressure conditions are not considered when designing the system, serious hazards can exist.

1. Materials Guidelines

Materials requirements are similar to requirements for GOX. One additional consideration is that vaporization of LOX occurs around heat sources such as ball bearings; this increases ignition risks and requires compensation for possible elevated pressure.

2. General System Installation Guidelines

Design considerations relating to system installations are noted below.

a. Thermal conditioning of cryogenic systems is mandatory. A bypass flow path with pressure relief valve shall be provided. Thermal conditioning can be performed with liquid nitrogen or LOX. Carefully analyze system startup for LOX pumps, as cavitation from improper chill down can increase fluid pressures and damage parts (leading to premature failure of components) and can create startup instabilities (leading to ignition from frictional heating).

b. Avoid condensation on external surfaces because the cryogen can liquefy air or freeze water and other vapors and create falling ice or other hazards.

c. Avoid condensation on internal surfaces because the cryogen can freeze water and other vapors.

- Long-term storage of LOX and extended cyclic fill operations may concentrate low volatile impurities in the storage container as a result of the loss of oxygen by boiloff. Therefore, the oxygen used based on the original specifications may not be satisfactory. Pressure relief valves or other means should be designed to prevent the back aspiration of volatile impurities into storage systems.
- The contents of vessels should be analyzed periodically for conformance to the specifications to limit the accumulation of contaminants from cyclic fill-and-drain operations. An inspection and system warmup refurbishment shutdown cycle should be established, based on the maximum calculated impurity content of the materials going through the tank or system. This should allow frozen water and gas contaminants to vaporize and leave the vessels. Where practical, a mass balance of measurable contaminants should be made for all fluids entering or leaving the system or the component.

3. Design Specifications

The concerns are similar to those for high-pressure, high-temperature oxygen, with the addition of material embrittlement because of the low temperatures. Cracking and fractures of soft goods and metals can cause premature failures.

Apply NFPA 55, Compressed Gases and Cryogenic Fluids Code, Chapter 9 Bulk Oxygen Systems to the design of bulk gas or liquid oxygen storage locations that have a storage capacity of more than 20,000 scf (566 Nm3) of oxygen.

4. Hazard Considerations

Cryogenic hazards, such as cold injuries from exposure when handling equipment with LOX, shall be considered. Additionally, oxygen-containing equipment should not be operated over asphalt pavement because of spill hazards and the potential for ignitions from oxygen-enriched asphalt, which can be readily ignited because of its shock sensitivity. When use of LOX systems over asphalt cannot be avoided, all asphalt areas under uninsulated piping should be protected to prevent contact with oxygen.

5. Component Hardware and Systems Design Considerations

Liquid lockup can occur, requiring special pressure relief protection.

Avoid fluid expansion regions in which the fluid can vaporize. If expansion is allowed to occur, the resulting fluid downstream will have two phases, gas and liquid, and the following situations could occur:

a. Increased pressure caused by vaporization.

b. High surge pressures caused by liquid hammer effects (Mechanical damage as well as rapid compression heating and ignition of soft goods can occur if fluid hammer is not eliminated in oxygen systems.)

c. Decreased performance of metering valves and other components sensitive to fluid properties.

Avoid cavitation of rotating equipment, because the high pressures generated by the rapid vaporization during cavitation can exceed the rated capability of hardware. Additionally, dynamic instabilities can be created that allow rotating shafts and impellers to wear against housings, leading to failures from frictional heating.

Avoid geysering of LOX and GOX, caused by gas bubble formation in flowing liquid systems, because this can create rapid pressurization of soft goods, and it can create a fluid hammer condition with rapid over pressurization of components, leading to bursting of pressure- containing components.

Prevent hydrostatic over-pressurization of tanks and Dewars during filling operations by using a full tricock valve system or similar overfill protection to maintain an adequate ullage area.

6. Electrical Design Guidelines

In addition to the guidance in Sections 401.b(9), (10), and (11) of this chapter, electrical wiring inside LOX tanks should be encased in hermetically sealed conduits or conduit inerted with helium or nitrogen gas. The instruments, switches, flow sensors, and electrical devices should be designed in modular structure and hermetically sealed, and inerting with nitrogen or helium is recommended.

B. Gaseous Oxygen Piping Systems

The primary concern with high-velocity flow conditions is the entrainment of particulates and their subsequent impingement on a surface, such as at bends in piping. The effects of extremes in flow velocity and pressure are also concerns. Material erosion or ignition can be caused by entrained particulate impact and abrasion, erosive effects of the fluid flow, or to both.

Until a more quantitative limit can be established, the following practices are recommended:

- Where practical, avoid sonic velocity in gases; where impractical, use the preferred materials listed in Schmidt and Forney (1975).
- If possible, avoid the use of nonmetals at locations within the system where sonic velocity can occur.

- Maintain fluid system cleanliness to limit entrained particulates, and perform blowdown with filtered, dry gaseous nitrogen (GN2) at maximum anticipated pressure and flow before wetting the system with oxygen.
- Piping systems should be designed to ensure the gaseous oxygen in the system does not exceed specified velocities. Places where fluid velocities approach 30 m/s (100 ft/s) should be reviewed for particle impact ignition sensitivity (refer to Appendix Band CGA G-4.4 1984).
- For use at pressures above 4.83 MPa (700 psig), oxygen piping and fittings should be stainless steel, nickel alloys, or copper alloys (Laurendeau 1968), because of ignition susceptibility. Monel® is approved for tubing, fittings, and component bodies (Schmidt and Forney 1975). The choice of piping and fitting materials should take into consideration the external environment.

12.0 Oxygen System Fire Prevention and Considerations

Like in air systems, there is a series of control measures that must be taken to prevent fires in oxygen services, depending on the severity of the fire hazard. Progressively more stringent practices are applied in this order: cleaning, compatible lubricants, compatible polymers and other nonmetals, and compatible metals. When oxygen concentration and pressures are low, the hazard is lowest, and cleaning may be the only control necessary. As oxygen enrichment and pressure increase, all wetted material including lubricants, metals, and non-metals must be selected more carefully. The NFPA view of oxygen compatibility (ref. NFPA 99 para. A.5.1.3.5.4) is given as,

Compatibility involves both combustibility and ease of ignition. Materials that burn in air will burn violently in pure oxygen at normal pressure and explosively in pressurized oxygen. Also, many materials that do not burn in air will do so in pure oxygen, particularly under pressure. Metals for containers and piping must be carefully selected, depending on service conditions. The various steels are acceptable for many applications, but some service conditions may call for other materials (usually copper or its alloys) because of their greater resistance to ignition and lower rates of combustion.

Similarly, materials that can be ignited in air have lower ignition energies in oxygen. Many such materials may be ignited by friction at a valve seat or stem packing or by adiabatic compression produced when oxygen at high pressure is rapidly introduced in a system initially at low pressure.

Polytetrafluoroethylene (PTFE) and polychlorotrifluoroethylene (PCTFE) are commonly used in oxygen service. Yet even these materials begin to decompose at 200 to 300°C [400 to 600°F] and can ignite at higher temperatures.

As emphasized in ASTM Guide G63, the successful use of even the best materials depends on the design of the component and where it is used. For example, PTFE-lined flexible hose has a large surface area-to-mass ratio, and many instances involving the ignition of such hoses have been reported (Ref. Fig. 6 of ASTM G128). The use of PTFE-lined hose in high-pressure oxygen may require special provisions in the system design, such as a distance-volume piece which contains the heat of adiabatic compression.

MIL-PRF-27617 Performance Specification, *Grease, Aircraft and Instrument, Fuel and Oxidizer Resistant*

DOD-PRF-24574 (SH) Performance Specification, *Lubricating Fluid for Low and High Pressure Oxidizing Gas Mixtures*

13.0 References

There are links to external websites throughout this document that go to publicly available copies of reference material. PDF versions of the linked content are also available on the "Reference Data" SharePoint linked on the ESM Chapter 17 website. All reference listed below can be obtained via internet search, LANL's Engineering Workbench subscription, or LANL's CGA subscription.

Additionally, ASTM, CGA, NFPA, AIGA, EIGA, and NASA have published standards, guidance, and/or requirements for oxygen systems designed to minimize the control the materials and ignition of oxygen systems that may be beneficial resources.

ASTM International

- ASTM MNL36, *Safe Use of Oxygen and Oxygen Systems*
- ASTM G63, Standard *Guide for Evaluating Nonmetallic Materials for Oxygen Service*
- ASTM G72, *Test Method for Autogenous Ignition Temperature of Liquids and Solids in a High-Pressure Oxygen-Enriched Environment*
- ASTM G74, *Test Method for Ignition Sensitivity of Nonmetallic Materials and Components by Gaseous Fluid Impact*
- ASTM G88, *Standard Guide for Designing Systems for Oxygen Service*
- ASTM G93, *Standard Guide for Cleanliness Levels and Cleaning Methods for Materials and Equipment Used in Oxygen-Enriched Environments*
- ASTM G94, *Standard Guide for Evaluating Metals for Oxygen Service*
- ASTM G128, *Standard Guide for Control of Hazards and Risks in Oxygen Enriched Systems*
- ASTM G175, *Test Method for Evaluating the Ignition Sensitivity and Fault Tolerance of Oxygen Pressure Regulators Used for Medical and Emergency Applications*

National Fire Protection Association

- NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*
- NFPA 53, *Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres*
- NFPA 55, *Compressed Gases and Cryogenic Fluids Code*
- NFPA 99, *Health Care Facilities Code*

Compressed Gas Association

- CGA E-4, *Standard for Gas Pressure Regulators*
- CGA G-4.1, *Cleaning Equipment for Oxygen Service*
- CGA G-4.4, *Oxygen Pipeline and Piping Systems*
- CGA G-4.6, *Oxygen Compressor Installation and Operation Guide*
- CGA G-4.7, *Installation Guide for Stationary Electric Motor Driven Centrifugal Liquid Oxygen Pumps*
- CGA G-4.8, *Safe Use of Aluminum Structured Packing for Oxygen Distillation*

- CGA G-4.9, *Safe Use of Brazed Aluminum Heat Exchangers for Producing Pressurized Oxygen*
- CGA G-4.11, *Reciprocating Oxygen Compressor Code of Practice*
- CGA G-4.13, *Centrifugal Compressors for Oxygen Service*
- CGA P-8.4, *Safe Operation of Reboilers/Condensers in Air Separation Units*
- CGA P-8, *Safe Practices Guide for Air Separation Plants*
- CGA P-25, *Guide for Flat Bottomed LOX/LIN/LAR Storage Tank Systems*
- CGA PS-15, *Toxicity Considerations of Nonmetallic Materials in Medical Oxygen Cylinder Valves*
- CGA SB-2, *Definition of Oxygen Enrichment/Deficiency Safety Criteria*

Asia Industrial Gases Association

- AIGA 021, *Oxygen Pipeline and Piping Systems*

European Industrial Gases Association

- EIGA/IGC 4, *Fire Hazards of Oxygen and Oxygen Enriched Atmospheres*
- EIGA/IGC 10, *Reciprocating Oxygen Compressors For Oxygen Service*
- EIGA/IGC 13, *Oxygen Pipeline and Piping Systems*
- EIGA/IGC 27, *Centrifugal Compressors For Oxygen Service*
- EIGA/IGC 33, *Cleaning of Equipment for Oxygen Service Guideline*
- EIGA/IGC 65, *Safe Operation of Reboilers/Condensers in Air Separation Units*
- EIGA/IGC 73, *Design Considerations to Mitigate the Potential Risks of Toxicity when using Non-metallic Materials in High Pressure Oxygen Breathing Systems*
- EIGA/IGC 115, *Storage of Cryogenic Air Gases at Users Premises*
- EIGA/IGC 127, *Bulk Liquid Oxygen, Nitrogen and Argon Storage Systems at Production Sites*
- EIGA/IGC 144, *Safe Use of Aluminum-Structured Packing for Oxygen Distillation*
- EIGA/IGC 145, *Safe Use of Brazed Aluminum Heat Exchangers for Producing Pressurized Oxygen*
- EIGA/IGC 147, *Safe Practices Guide for Air Separation Plants*
- EIGA/IGC 148, *Installation Guide for Stationary Electric-Motor-Driven Centrifugal Liquid Oxygen Pumps*
- EIGA/IGC 154, *Safe Location of Oxygen, Nitrogen and Inert Gas Vents*
- EIGA/IGC 159, *Reciprocating Cryogenic Pump and Pump Installation*
- EIGA/IGC 179, *Liquid Oxygen, Nitrogen, and Argon Cryogenic Tanker Loading Systems*

National Aeronautics and Space Administration

- NSS 1740.15, JANUARY 1996, *SAFETY STANDARD FOR OXYGEN AND OXYGEN SYSTEMS, Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation*

- NASA/TM-2007-213740, *Guide for Oxygen Compatibility Assessments on Oxygen Components and Systems*
- GLP-QS-8715.1.5 Revision C, *Glenn Research Center, Glenn Safety Manual Chapter 5 Title: Oxygen*