**Department of the Air Force**
**HQ AEDC (AFMC)**
**Arnold AFB, TN 37389**

# Safety, Health, and Environmental Standard

**Title**: **PRESSURE VESSELS AND SYSTEMS (PV/S)**

**Standard No.:** D2

**Effective Date:** 10/15/2009

The provisions and requirements of this standard are mandatory for use by all personnel engaged in work tasks necessary to fulfill the AEDC mission. Please contact your safety, industrial health and/or environmental representative for clarification or questions regarding this standard.

Approved:

Contractor/ATA Director
Safety and Health Group

Air Force Functional Chief

## Record of Review/Revision

| Date/POC | Description |
|---|---|
| 10/07/09<br>Jennings | Complete rewrite with Working Group participation. Working Group included B. Walker, B. Dean, R. Parham, A. Voorhes, P. Medley, B. Reid, W. Kissel, D. Payne, V. Chapman, Lt Col Scribner, H. Stanfield. Added definitions for FIO, Category D fluid. Major revisions included definition of FIO; Section 4.2.4 Pressure testing; 4.7 Gauges; 4.9 Flexible Hose; 4.16.1 use of double block and bleed valve protection for work on high pressure systems; revision of Annex A; addition of steam and condensate in Annex B; and addition of Annexes C, D, and E. |
| 05/01/08<br>Roosa | Annual review administrative changes only: Corrected Paragraph 4.1 to require service records to be maintained per AEDC Engineering Standard T-2, Pressure Piping, reflecting current practice at the time of the revision. Annual review was coordinated with the Pressure Systems Subcommittee. |
| 05/29/07 | Annual review; no change required. |
| 06/15/06<br>J. Fitzgerald | Expanded definitions of pressure system devices in section 3.0 and deleted several unneeded definitions in Annex B to improve compatibility with AEDC Standards T-1 and T-2. Made minor word changes in Annex B. |
| 02/25/05<br>Fitzgerald<br>Jones | Expanded titles to referenced SHE standards and ASME Codes. Clarified definitions. Updated organization names to align with contract changes. Corrected item numbers shown within Items 4.10.2 and 4.14.2. Added note to 4.5.12 to indicate that “used hose installed in a new application also requires pressure testing.” Modified 4.15.1 to include requirement to “Document inspection by tags attached to the hoses.” Added missing reference titles in Section 5.0. Added “uncontrolled copy” statement in footer. At direction of Contractor Executive Management Steering Committee (03/04/05): Retitled standard to High Pressure Vessels and Systems (formerly Pressure Vessels and Systems). |
| 08/30/02 | Changed reference to AEDC Standards T-1 and T-2 to SHE Standard D2. Changed reference to ASME B40.100-1998 (latest year). Added reference to NFPA standards to Annex B Scope/Application Section. In ISI Plan changed NDE Report to Evaluation Report, piping to piping or ducting, added entry for tubing. Changed Inspection and Test Methods abbreviations to current nomenclature in the industry.<br>Changed ISI Plan sample notes – VE and VI are now called VT, updated UTT and Weld Map. Changed abbreviations for Planning Matrix Inspection & Test Methods. |
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# Safety, Health, and Environmental Standard

## PRESSURE VESSELS AND SYSTEMS (PV/S)

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# Safety, Health, and Environmental Standard

## PRESSURE VESSELS AND SYSTEMS (PV/S)

### 1.0 INTRODUCTION/SCOPE/APPLICABILITY

This standard establishes the requirements for the safe operation and maintenance of pressure vessels and systems (PV/S) at AEDC. AEDC Engineering Standards (AEDC-ENGR-STD) T-1, Pressure Vessels; T-2, Pressure Piping; T-3 Engineering Design and Drafting Practices; and T-5 Welding Practices provide the requirements for safe pressure system design, fabrication, modification, installation, inspection, and testing.

**NOTE:** Small-bore, enclosed calibration systems and commercial gas cylinders are excluded from this standard. See AEDC Safety, Health, and Environmental (SHE) Standard D4, Compressed Gas Cylinders.

### 2.0 BASIC HAZARDS/HUMAN FACTORS

The hazards of pressure systems are often caused by failures resulting from leaks, pulsation, vibration, corrosion, over-pressure, failure to perform required maintenance, or operator error. Damage or injury can be expected from the release of pressurized gases or liquids if a vessel or pipe ruptures, from the blowout of pressure gauges, or from the whiplash of broken pressure pipe, tubing or hose. The potential for injury and damage from high pressure system accidents is very high. The degree of hazard in pressure systems is proportional to the amount of energy stored, not the amount of pressure present. Therefore, low-pressure, high-volume systems can be as hazardous to personnel as high pressure systems.

A few specific examples of the potential hazards include the following:
- (a) Fire due to leaking of flammable liquids or gases
- (b) Burns due to loss of high temperature fluids
- (c) Explosive noise
- (d) Pressure shock wave
- (e) Shrapnel
- (f) Impact injury due to whipping of hose, pipe, or tube
- (g) Impact due to equipment motion
- (i) Cutting due to high velocity leaks
- (j) Gas embolism/inflation from high pressure gas jet

### 3.0 DEFINITIONS/TERMS

Calibration – The set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure of a reference material, and the corresponding values realized by standards.

Category D Fluid Service – From ASME B31.3-2008: A fluid service in which all the following apply:
- (a) The fluid handled is nonflammable, nontoxic, and not damaging to human tissues.
- (b) The gauge pressure does not exceed 150 pounds per square inch, gauge [1035 kiloPascals (kPa)].
- (c) The design temperature is from -20°F (-29°C) through 366°F (186°C).

Certification – The process of verifying configuration through walk-down inspections, nondestructive examinations and component information gathering, performing engineering gap analysis comparing the “as-is” configuration with required configuration referencing design codes, standards and system specifications, correction of deficiencies or elimination of gaps, testing in accordance with current codes and standards, developing an in-service or maintenance inspection program to sustain certification and finally releasing and vaulting all technical documentation developed during the certification process. Configuration management for documentation used in support of operations and maintenance is required.

Cognizant Engineer – A person who has the necessary qualifications to evaluate the design, operations, and maintenance of pressure vessels and systems with respect to applicable code and AEDC safety conformance.

Configuration Item Verification Review (CIVR) – A review of technical documentation used to operate and maintain a PV/S comparing the current released and vaulted version against the configuration of PV/S as configured in the plant or field. The verification ensures consistency between the configuration in the field being operated and the configuration as depicted in tech data used to operate and maintain the PV/S.

Flexible Metal Hose – A corrugated metallic non-rigid hose having annular or helical corrugation and with or without a wire braid cover.

Fluid – A substance, as a liquid or gas, that is capable of flowing and that changes its shape at a steady rate when acted upon by a force tending to change its shape.

For Indication Only (FIO) – A locally developed category for analog pressure gauges used only for indication. The authority for FIO is TO 33K-1-71. Calibration is not required for FIO gauges. A gauge may be designated FIO if 1 through 3 apply:

(a) It does not affect safety such as the release of the fluid or gas would not pose a threat of harm to personnel, operations, environment or equipment.
(b) Gauge is used in Category D Fluid Service only.
(c) The gauge is not designated as TMDE, [see definition for Test, Measurement and Diagnostic Equipment (TMDE)] and is not used to do one of the following:
    (1) Verify performance during a test
    (2) Decide if operation specifications are met
    (3) Determine safe operation levels
    (4) Make quantitative measurements
    (5) Set pressure or record data per a procedure/work instruction

Gauge – Analog, dial-type gauges, which, utilizing elastic elements, mechanically sense pressure and indicate it by means of a pointer moving over a graduated scale. Annex A describes information on purchasing gauges.

High Pressure – For safety practices, gas or liquid pressure greater than 150 pounds per square inch, gauge (psig).

In-Service Inspection/Test (ISI/T) – Inspection of an operational (may also include PV/S in mothballed or other sustainment status) PV/S as part of the Center's maintenance program as a preventive maintenance action to ensure continued safe, reliable and effective operation as well as to maintain the certification of the PV/S. The ISI/T may be performed in conjunction with CIVR. ISI/T required tasks are identified in Annex B of this document.

Non-Category D Fluid/Gas Service – A fluid that does not meet the requirements of Category D Fluid Service. It does affect safety such as the release of the fluid or gas would pose a threat of harm to personnel, operations, environment or equipment.

Nondestructive Examination (NDE) – A process involving the use of nondestructive tests (NDT) or inspections (NDI); visual, liquid penetrate, magnetic particle, ultrasonics, eddy current, radiography, etc) to examine welds or materials to assess and evaluate defects or flaws without damaging or rendering useless the article under examination. Reference American Society of Nondestructive Testing (ASNT).

Outside Contractor/Subcontractor – An organization employed by a contractor or the Air Force to do construction, maintenance, repair or other work at AEDC. There is no employment relationship, control or supervision of the subcontractor's employees by AEDC contractors. Also referred to as the construction contractor.

Pressure and Hazardous Material Systems (PHMS) – Systems that contain or transmit high pressure air, gases, fuels, cryogenics or other material that is a hazard when personnel are exposed, or other PV/S including process air ducting where failure of the system may result in unscheduled system down-time (forced outage) or result in damage to equipment or personnel from structural failure.

Pressure Piping – At AEDC, *pressure piping* is defined as ducting and piping used for the transportation of gases or liquids fabricated from industry standard pipe and fittings of 48 inches or less designed to withstand internal or external pressure greater than 15 psig. This includes pressure vessels fabricated from standard pipe, standard pipe fittings, and standard pipe flanges with a cross section diameter not exceeding six inches. At AEDC, ducting larger than 48 inches or fabricated from non standard pipe and fitting is defined as a Pressure Vessel and designed and fabricated to ASME Boiler and Pressure Vessel Code (B&PVC) Section VIII. For additional information, see ASME B31.3 Process Piping.

Pressure Relief Device – A device designed to open and relieve excess pressure to protect the PV/S on which it is installed from damage due to excess pressure. An example would be a rupture disc.

Pressure System Components – Mechanical elements suitable for joining or assembly into pressure-tight fluid-containing piping systems. Components include pipe, tubing, fittings, flanges, gaskets, and bolting.

Pressure System Devices – Valves, regulators, gauges, relief devices, filters, flow meters, flexible hoses, instruments, and other such devices.

Pressure Vessels – Pressure vessels are defined by the applicable ASME B&PVC or API code. See references.

Recertification – The renewal process for a PV/S that has lost its previous certification because of ineffective maintenance, configuration management, improper disposal, abandonment or similar situations. See Certification.

System Engineering **–** Designing, installing and operating a system in a manner intended to achieve optimum output while conserving manpower, materials and other resources. Designing and operating a system to achieve a predetermined level of performance, taking into consideration all of the factors that contribute to system performance, including manpower utilization and human factors.

Test, Measurement and Diagnostic Equipment (TMDE) – Those devices used to maintain, evaluate, measure calibrate, test, inspect, diagnose, or otherwise examine materials, supplies, equipment, and systems to identify or isolate actual or potential malfunction, or decide if they meet operational specifications established in technical documents. (Ref. TO 00-20-14.) TMDE includes those devices and systems used to take measurements for test project data and those devices and systems used to monitor and control AEDC assets.

**NOTE:** TMDE is support equipment that provides for measurement traceability.

## 4.0 REQUIREMENTS/RESPONSIBILITIES/TRAINING/INSPECTION

The Government is responsible for the management of all projects and activities at AEDC. The Government hires contractor(s) to operate and maintain the many test cells, plants, utility system including PV/S. The requirements for safe operation and maintenance of PV/S are included in the Performance Work Statement (PWS) or other contract statements of work and may include reference to this AEDC SHE Standard D2 as a reference or applicable document. The government shall ensure this document is updated, preferably on an annual basis, with the assistance of the AEDC operating, support and customer contractors. The government is responsible for ensuring that the performance measurement of these contractor's efforts meet the objectives of the PWS and are in compliance with work statements and applicable directives.

It is the responsibility of the AEDC operating contractor to comply with this standard and provide safe, reliable and effective PV/S at AEDC that support the Center's mission. It is the responsibility of outside contractor personnel to comply with this SHE standard and request deviations as necessary from the Government. When there are any conflicts noted between this SHE standard and industry or national codes, standards or regulatory requirements, the operating contractor shall notify the government.

### 4.1 Documentation

Complete, current, accurate, permanent and progressive service records shall be maintained as required by this SHE Standard and by AEDC-STD-CM-1 Configuration Management and AEDC-ENGR-STD T-2. These records include

(a) Maintenance records including repairs, alterations, and replacements
(b) Certification reports
(c) NDE reports including radiographic examination film and weld maps
(d) Where available, operational history to include design and operational parameters of temperature, pressure, and cycles. These pressure system assets are part of CMMS. Changes in design use, fluid uses should be recorded for that asset.
(e) ISI/T Plans and Reports
(f) Calibration Records

### 4.2 General Requirements for System Inspection and Testing

4.2.1 An In-Service Inspection/Test (ISI/T) Program (see Annex B of this standard) shall be established and executed for operational devices and components of non-category D Fluid Service PV/S. Inspections may include annual CIVRs, visual, NDE, calibrations and pressure tests. Inspection intervals shall be assigned based on applicable codes and standards and recognized and generally accepted good engineering practice. CIVRs are to be performed in accordance with CM-1 and contractor procedures. ISI/T shall be accomplished in accordance with this safety standard and AEDC-ENGR-STD-T-2 and contractor policies, procedures, or work instructions.

4.2.2 All operational pressure system components that are non-category D fluid (devices, gauges, hoses, etc.) shall be inspected by qualified system operation, maintenance or engineering personnel to identify and replace design deficient, broken, or failed components. A record of inspection and findings shall be maintained. This inspection may be performed in conjunction with CIVRs, safety, housekeeping or in-service/preventive maintenance actions.

4.2.3 New, repaired or altered pressure systems must be tested or examined in accordance with the AEDC-ENGR-STDs T-1 and T-2 and the applicable code of construction. All new or modified PV/S shall have a Leak Test performed per the National Board design code, NB-23, or similar standard.

4.2.4 Pressure Testing (Hydrostatic and Pneumatic)

If a pressure test is required, the system engineer or cognizant engineer must assess the risk prior to the activity and meet the requirements below.

4.2.4.1 A pneumatic pressure test is permitted only when one of the following prevails:

(a) PV/S cannot be safely filled with water or liquid due to their design and support system
(b) PV/S in which traces of testing liquid cannot be tolerated, (i.e. the hydrostatic test would damage linings or internal insulation, or contaminate a process which would be hazardous, corrosive, or inoperative in the presence of moisture, or would present the danger of brittle fracture due to low metal temperature during the test.

4.2.4.2 A system safety hazard analysis shall be performed and maintained as a valid and approved document for each PV/S pressure test to be performed, see 4.2.4.3 for exceptions. This hazard analysis may be included as part of a test cell, plant or facility baseline hazard analysis.

4.2.4.3 If a pressure test is to be conducted, a hazard analysis must be approved prior to the pressure test unless the system manager or cognizant engineer of the system/component being pressure tested approves the pressure test without a hazard analysis. This shall be documented on Form GC-648 Pressure Test Instruction and Record and noted as a potential low severity of injury (Risk Assessment Severity of III/RPC3 – Minor Injury) or equipment damage (Risk Assessment Severity of IV/RPC3 - < $10,000), per SHE Standard A4 System Safety. This risk assessment will be noted on Form GC-648.

4.2.4.4 A procedure shall be developed to define the criteria to conduct pressure testing.

4.2.4.5 Personnel must be evacuated from the area where pressurization for testing is being performed. Personnel separation distances, shielding and/or barricades for pressure tests shall be included in an approved hazard analysis (when required; see 4.2.4.3) for the test. Annex C gives general guidance on separation distance determination.

4.2.4.6 The test area must be barricaded off and monitored to ensure personnel do not enter during pressure testing. Signs, lights, fences and barriers shall be employed as needed to limit unauthorized access.

4.2.4.7 When performing a hydrostatic pressure test, ensure all trapped gases are bled from the system where possible.

4.2.4.8 Prior to the pressure test, a check shall be made to ensure the flexible hose restraints are in place if installed.

4.2.4.9 During pressure testing, components used to perform the pressure test shall be rated for the test pressure to prevent lower pressure gauges/components/devices from being over-pressurized.

4.2.4.10 Pressure system devices not rated for test pressures must be removed from the system or isolated, and the ports plugged.

4.2.4.11 Fittings and flanges under pressure must not be tightened or loosened.

4.2.4.12 All pressurized components shall be evaluated and secured as necessary to prevent them from becoming missiles or whipping assemblies.

4.2.4.13 If the tested item is a vessel, the vessel support system shall be evaluated to ensure that vessel buckling will not occur during the hydrostatic test due to weight of the test fluid. The floor-loading conditions also shall be evaluated so as to safely transfer the vessel's weight and contents to the floor slab and the supporting grade. This evaluation shall be documented in the pressure test hazard analysis.

4.2.4.14 Component proof testing shall be conducted in barricaded test cells, behind adequate shielding, or at a distance so that blast or shrapnel are not hazards. Each barricade, shield or test cell shall be rated for an energy level for the test performed. This may be in foot-pounds, pounds of trinitrotoluene (TNT), or any other convenient energy term. Knowing the approximate internal volume and the test pressure, cognizant design engineering or safety personnel shall approve the barricade or cell before use.

4.2.5 Valve leakage during operation must be noted and evaluated, and a disposition formulated.

**4.3 Identification**

4.3.1 Piping systems must be identified as specified on engineering design drawings in accordance with AEDC SHE Standard D3, Identification of Piping Systems.

4.3.2 Components and devices must be identified in accordance with engineering drawings for the system prepared using AEDC-ENGR-STD T-3.

4.3.3 For device identification requirements (i.e. gauges, relief devices, valves) see the pertinent section in this Standard.

**4.4 Modification (Repair, Alteration, Replacement)**

4.4.1 Pressure systems shall only be repaired, altered, or replaced with approved engineering designs and drawings or written change orders. No changes are allowed on the basis of verbal instructions.

4.4.2 The hazard analysis for the modified system shall be reviewed and revised to incorporate any additional hazards or changes to countermeasures.

4.4.3 The system engineer shall ensure provisions of AEDC-STD-SE-1 Systems Engineering and AEDC-STD-CM-1 have been followed.

4.4.4 Before pressurizing a system after installation or modification, the contractor is responsible for ensuring that the system is inspected or examined to ensure compliance with safety requirements and that material substitutions and design deviations have been approved by a responsible engineering group.

4.4.5 Before pressurizing a system after repair, alteration, or replacement, the contractor is responsible for ensuring that the system is inspected to ensure that valve configuration is correct and that all safety devices are fully operational.

**4.5 Education and Training**

4.5.1 Personnel must become familiar with pressure system component and device locations and operational and safety procedures before operating pressure systems.

4.5.2 Personnel must be apprised of hazards associated with the process fluid and trained in the use of any escape/rescue equipment involved.

4.5.3 The operation of pressure systems must be performed only with current operational procedures or instructions.

4.5.4 Personnel performing maintenance, operations, inspections, and testing shall have the appropriate training and/or certifications in accordance with this SHE Standard, and applicable industry codes and standards.

### 4.6 Valves

High pressure valves must not be operated with system under pressure by employing excessive forces (i.e., cheaters, excessive operator pressure, or similar methods).

### 4.7 Gauges

4.7.1 All analog pressure gauges shall conform to the requirements of ANSI/ASME B40.100, Gauges – Pressure Indicating Dial Type – Elastic Element.

**EXCEPTION:** Pressure gauges that are part of a cylinder regulator assembly such as those used with cutting, welding, or other industrial equipment are exempt from these requirements. Gauges associated with pneumatic controllers, positioners and other standard process control equipment are also exempt if the gauge meets category D fluid/gas requirements. Digital pressure gauges must comply with ANSI/ASME B40.7 for calibration.

4.7.2 All pressure gauges must be inspected and calibrated before installation in pressure systems. The date of the last calibration must be marked on a tag on the gauge. Gauges installed in toxic/flammable systems must be calibrated at frequencies dictated by the ISI/T program – but at least annually. Pressure gauges that meet the definition of FIO and are labeled as such are excluded.

4.7.3 Pressure gauges are required on pressure systems or portions of systems that can be isolated from the main system.

4.7.4 When practical, gauges should be selected as required by AEDC-ENGR-STD-T-2 so that the normal reading falls in the middle third of the gauge scale, but in no case is the gauge range to be less than $1^{1}/_{4}$ or more than 4 times the design pressure.

4.7.5 Pressure gauge installations must be designed with adequate back clearance per AEDC-ENGR-STD-T-2 to allow unrestricted venting should a sensing element rupture.

**NOTE**: If the gauge is manufactured with standoff cleats that are designed to allow adequate venting, then the back clearance may be less than the 1 inch minimum. Personnel or critical equipment must be protected from hazards of the blow-out zone. If the gauge is installed flush with the backing plate, a hole larger than the blowout disk shall be drilled through the plate in line with the blowout disk.

4.7.6 Pressure gauges must not be installed in spaces in which leakage into the space could cause asphyxiation unless there is adequate mitigation to prevent personnel injury.

4.7.7 Gauges must be supported in such a manner that they do not place excessive stress on the piping system

4.7.8 Gauges must not be removed or worked on in any manner while the gauge is under pressure. Pressure must be relieved prior to any work being performed on the gauge while the system is under pressure. Double-valve protection, as indicated in Paragraph 4.16.1, is required for gauge removal work if performed on systems above 150 psig, or the system contains asphyxiates, toxic, or flammable fluids.

4.7.9 When practical, pulsating dampeners, orifice plates, or similar devices should be installed at each gauge location if the gauge:

(a) Undergoes frequent surge pressure.
(b) Is installed in an inert-gas system in a closed area with inadequate ventilation.
(c) Is used in a system with toxic, corrosive, or flammable fluids.

4.7.10 Pressure gauges (in Category I) shall be tagged or labeled with the date of the last calibration. Gauges that fall into Category II, III and IV are exempt (Paragraph 4.7.11).

4.7.11 Gauge Calibration General Guidance (Refer to Annex D.)
Analog dial type pressure gauges fall under one of the categories described below. Requirements for each category are specified below and elsewhere in this standard.

4.7.11.1 Category I – Gauges that fall under this category are TMDE or have to be calibrated in accordance with TMDE requirements and require periodic calibration if any of the following is true;

4.7.11.1.1 If the gauge is a non-category D Fluid Service.

4.7.11.1.2 If the gauge is a category D Fluid Service and is otherwise determined to pose a threat to personnel, operations, equipment and/or environment.

4.7.11.1.3 The gauge is used to accomplish the following:

(a) Verify performance during a test
(b) Decide if operation specifications are met
(c) Determine safe operation levels
(d) Make quantitative measurements
(e) Set pressure or record data per a procedure/work instruction
(f) Verify a safe condition under LOTO

4.7.11.2 Category II – These gauges are used only to indicate presence of pressure. Category II pressure gauges are exempt from the TMDE calibration requirements. These gauges may be designated and labeled FIO. Required documentation for FIO gauges consists of a GC-1817, For Indication Only label affixed to the item and a Microsoft Excel spreadsheet attached to the CMMS Asset showing: device ID; gauge range; system design pressure; and system fluid.

A pressure gauge may be designated Category II if **ALL** of the following are true:

(a) Gauge is used in a Category D Fluid Service
(b) Gauge is determined not to be TMDE
(c) Gauge does not affect safety. The release of the fluid or gas would not pose a threat of harm to personnel, operations, environment or equipment.
(d) Gauge indicates greater than 30 psig but less than or equal to160 psi, full scale.

4.7.11.3 Category III – These gauges are similar to Category II, but are exempt from TMDE and FIO labeling and documentation requirements. Minimum documentation for these gauges is an annotation on the system drawing. A gauge may be designated Category III if **ALL** of the following criteria are true:

(a) Gauge indicating range 30 psig or less
(b) Gauge dial face 2 1/2 inches or less
**NOTE:** If gauge dial face indicates more than $2^1/_2$ inches, then the gauge falls into Category II.
(c) Gauge is used in Category D Fluid Service
(d) Gauge is determined not to be TMDE (see above)
(e) Gauge does not affect safety. The release of the fluid or gas would not pose a threat of harm to personnel, operations, environment or equipment.

4.7.11.4 Category IV – Pressure gauges that are part of a cylinder regulator assembly such as those used with cutting, welding, or original equipment manufacturer items such as, grease guns, shop air tools etc. Category IV gauges are exempt from requirements in this standard. Gauges on hydraulic torque wrenches require calibration.

A pressure gauge may be designated Category IV if **ALL** of the following are true:

(a) Gauge is used in a Category D Fluid Service
(b) Gauge is determined not to be TMDE
(c) Gauge does not affect safety. The release of the fluid or gas would not pose a threat of harm to personnel, operations, environment or equipment.

4.7.12 Analog pressure gauges (Category I) with ranges greater than 160 psig shall have a solid-front case design, an optically clear shatter-resistant window made of high-impact, non-cracking plastic, heat-treated glass, or laminated glass, and a pressure-relieving back panel or pressure blow out plug(s) oriented to the back of the gauge, sufficiently sized to discharge the maximum system pressure and prevent rupture of the case.

4.7.13 Analog pressure gauges (Category II) with ranges of 0 to 160 psig or less shall have an optically clear shatter-resistant window made of high-impact, non-cracking plastic, heat-treated glass, or laminated glass and a case design with pressure relief means consisting of pressure relief blow-out plug or a case opening sufficiently sized to discharge maximum system pressure to the back or side and prevent rupture of the case.

**NOTE:** If the gauge does or cannot meet this requirement, then this must be documented in the systems' hazard analysis in accordance with SHE Standard A4 with appropriate safeguard countermeasures to protect personnel.

4.7.14 Analog pressure gauges (Category III) with indicating ranges of 30 psig or less, having a gauge face diameter of $2^{1}/_{2}$ inches or less and a polycarbonate (plastic) window may be of open front, solid case construction without pressure relief of the case.

4.7.15 Differential gauges must use the maximum allowable working pressure (MAWP) to determine the pressure relief requirements. MAWP above 160 must meet the requirements of Paragraph 4.7.14 above. MAWP of 160 and below must meet Paragraph 4.7.12 above. If the gauge does not or cannot meet this requirement, then this must be documented in the systems' hazard analysis with appropriate safeguard countermeasures to protect personnel.

4.7.16 Vacuum gauges do not have to have pressure relief of the case.

### 4.8 Pressure-Relief Devices/Pressure Regulators

4.8.1 All relief devices must be in accordance with ASME B&PVC Section VIII or Section I.

4.8.2 Pressure-relief devices must be oriented, vented and/or shielded to prevent personnel injury or equipment damage.

4.8.3 Pressure-relief devices must be installed so that adverse weather conditions cannot affect their operation.

4.8.4 Discharge lines from pressure-relief devices must be arranged to prevent the discharge of the fluid into a confined space or into the path of personnel in or passing by the area

4.8.5 Discharge lines from pressure-relief devices must be designed and installed so as to prevent abnormal back pressure that would affect the flow capacity of the relief device

4.8.6 Isolation valves shall not be installed upstream or downstream of a pressure relief device, unless an approved lockout procedure is implemented. Shutoff valves shall not be installed in safety relief lines in such a manner that the safety relief device can be rendered ineffective.

4.8.7 Safety relief valves shall be tagged with the date of the last set point test along with the set point and capacity or orifice size. This information should be on the manufacturer's nameplate.

4.8.8 Burst disks shall be tagged or labeled with date of installation and the burst pressure.

4.8.9 Pressure-relief valves must be inspected as frequently as specified in the ISI/T Program.

4.8.10 Relief valve capacity must exceed the maximum possible system flow rate.

4.8.11 Pressure regulators must not be repaired, altered, replaced, or modified without the written approval of the responsible engineering group. Any such regulators must not exceed the capacity of downstream relief valves.

### 4.9 Flexible Metal Hose, Rubber and Thermoplastic Hose

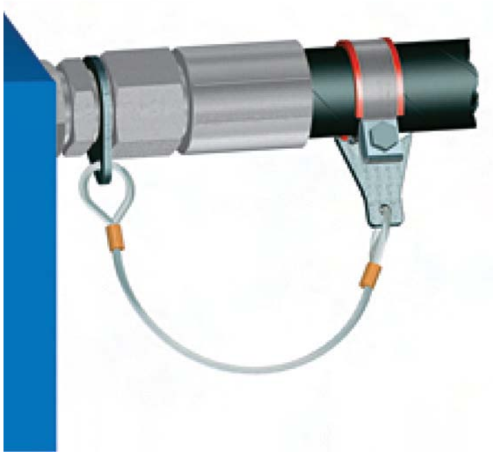
4.9.1 These hoses shall not be used for gaseous service at pressures above 150 psig unless it is absolutely necessary (i.e., when rigid piping is not feasible). When used, design and installation shall be in strict accordance with all the requirements of AEDC-ENGR-STD-T-2. Employees must be directed away from the immediate area when the pressure is increased in flexible metal hose.

4.9.2 New system designs shall select the use of a flexible versus hard lines based on the assessed risk (both probability and severity) of personnel injury and equipment damage for the design life of the system. If a flexible hose is used, it shall be designed and installed according to AEDC-ENGR-STD-T-2.

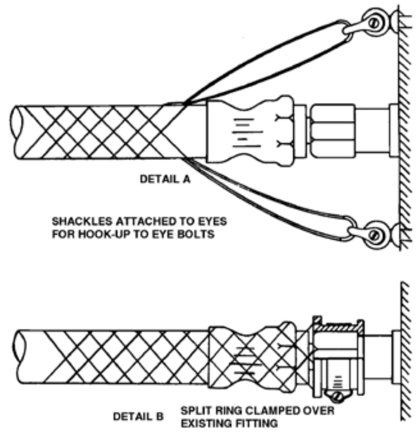
4.9.3 PV/S hose must be inspected and pressure tested before initial use and in frequencies specified in the maintenance/inspection program thereafter. The date of the last pressure test must be marked on a tag on the flex hose.

**NOTE:** Used flex hose installed in a new application also requires pressure testing.

4.9.4 Flexible metal, rubber, and thermoplastic hose with a length and pressure greater than that shown in Annex E must have end restraints to prevent whipping in the event of failure. (See Paragraphs 4.9.4.1. 4.9.4.2, and 4.9.5 for exemptions.) Refer to Annex E to determine restraint requirements based on fluid, pressure, hose diameter, etc. These restraints shall be separated from the hose and shall in no way interfere with normal flexibility of the hose. Hose containment assemblies similar to those manufactured by Parker (illustrated below left) and Hubbell Wiring Device-Kellems (illustrated below right), are examples of the desired type; however, other assemblies may be used.



Parker Assembly




Hubbell Wiring Device-Kellems Assembly

4.9.4.1 If end restraints are not feasible, shielding and/or other safety measures shall be used to protect personnel and documented in the system's hazard analysis.

4.9.4.2 An exemption is allowed to not require hose end restraint where there is not a risk of personnel injury due to the failure of the hose. An example would be a hose that is intended for use inside a test cell where personnel will not be present during operation. In all such cases, the risk to equipment must be accepted and documented in a hazard analysis.

4.9.5 If there is no potential for injury or damage, restraints are not required. This shall be documented in the system's hazard analysis.

4.9.6 Flexible hose must be protected from chafing.

4.9.7 Isolation valves that pressurize flexible hose must be located a safe distance from the hose or shielded from the hose to prevent injury to the valve operator if a hose fails.

4.9.8 Prior to operation of the system, a check shall be made to ensure the hose restraints are in place.

4.9.9 Checks must be performed to ensure armor protection is present for flexible metal hose, as specified in AEDC-ENGR-STD-T-2.

4.9.10 Outside contractors who use designs with flexible metal hose must comply with the requirements of AEDC-ENGR-STD-T-2.

4.9.11 Temporary flexible hose installations may be weighted with 50-pound sand bags or other suitable weights at intervals not to exceed 6 feet. Hose clamp-type restraining devices shall not be used.

4.9.12 Hydraulic injection from hose leak is potentially hazardous and must be considered in the design and operation of the system.

**4.10 Hose Inspection and Identification**

4.10.1 Before installing hose for use, hose assemblies must be inspected and pressure tested in accordance with applicable requirements documents. Ensure that hose and hose assemblies for which contractors are accountable (including those held as spare parts or in storage) are identified by a durable tag as follows:

(a) Identification number
(b) Date of latest pressure test (month and year)
(c) Allowable working pressure at a specified temperature.

4.10.2 Hose that cannot be identified in accordance with Paragraph 4.10.1 must be condemned or pressure-tested and identified as in Paragraph 4.10.1

4.10.3 Hose that is damaged, worn, or defective shall be condemned, tagged, and removed from service.

4.10.4 Hose shall be periodically inspected for twists, kinks, frayed or damaged braiding, or abrasion damage in accordance with AEDC-ENGR-STD-T-2 and the ISI/T Plan. Damaged and deteriorated hose shall be removed from service. Inspections must be documented by durable tags attached to the hose.

**4.11 Test Unit Windows and Instrumentation Bulkheads**

Test unit windows, instrumentation bulkheads, and penetrations for the use of instrumentation wiring or connectors must be designed or approved by responsible engineering groups.

**4.12 Defective Components/Devices**

4.12.1 PV/S Components and devices found defective must be removed from pressure systems or locked and tagged out according to Standard B2 Lockout/Tagout (LOTO). PV/S that are isolated/disconnected and abandoned in place must be made safe through LOTO, elimination of energy source, etc.

4.12.2 Defective PV/S components and devices must be tagged as defective.

**4.13 Used Devices**

4.13.1 Used devices (valves, regulators, etc.) to be installed in pressure systems must be disassembled, inspected for device integrity and fluid compatibility before installation unless documented evidence of system suitability is available. Pressure testing of devices prior to placing back into service is required for Non-Category D fluids if the pressure boundary is modified or the device disassembled. Additional NDE may be performed as necessary to investigate specific observed degradation.

4.13.2 Used components (pipe, couplings, elbows, etc.) to be installed in pressure systems shall be inspected for degradation and fluid compatibility before installation unless documented evidence of system suitability is available. If the component is degraded or the possibility of a future failure is suspected, appropriate NDE or pressure testing shall be performed before installation. If a component is repaired or altered, a leak test or alternate NDE, if permitted by code of construction, shall be performed prior to placing into service.

**4.14 Pressure Rating of Components/Devices**

4.14.1 Unmarked pressure system devices and components shall not be installed in pressure systems.

If the device or component is not marked, then one of the following must occur:

(a) A pressure and temperature rating must be obtained from the manufacturer.

(b) An analysis must be performed by a responsible engineering group and the device subsequently marked with the new pressure and temperature rating prior to installation

(c) The device must pass proof test (not hydrostatic test). (Consult Operating Contractor Design Engineering for methodology.)

4.14.2 For existing PV/S, unmarked pressure system devices and components shall not be used in pressure systems. If the device or component is not marked, Paragraph 4.14.1 must be complied with.

**4.15 Engineering**

4.15.1 Piping systems must have drawings or schematic diagrams approved and issued by responsible engineering groups before operation. These drawings shall be walked down and verified as-built after any repair, alteration, or replacement prior to system pressurization. Any discrepancies shall be noted on the drawing and resolved by the system engineer prior to operation.

4.15.2 Drawings must be corrected and issued as soon as practical to include approved modifications or material substitutions.

4.15.3 Aluminum, brass, or cast iron fittings must not be used on high pressure systems unless approved by a responsible engineering group or specified on the drawing.

4.15.4 Non-conforming fittings or components found in pressure systems must be replaced with conforming fittings or components as soon as practical.

4.15.5 Pressure devices designed for specific gases must not be used for other gases unless approved by a responsible engineering group.

4.15.6 Pressure must be regulated only by the use of positive sensing means. Orifice and valve regulation of pressure must not be employed except when the downstream piping design pressure is equal to or exceeds source pressure, or when the downstream piping is protected by relief devices.

4.15.7 Pressure systems designed with dead legs are inherent hazards. Maintenance, adequate drain capability and appropriate countermeasures shall be incorporated to reduce risk of freezing, PV/S rupture, etc.

4.15.8 Push-On pipe joints may be used outside of buildings above or below ground. If used above ground, the piping shall either be secured to prevent disengagement at the fitting or the piping system shall be so designed that any spill resulting from such disengagement could not unduly expose persons, important buildings or structures, and could be readily controlled by remote valves.

**4.16 General Safety Requirements**

4.16.1 When work is required on Non-Category D pressure systems, double block and bleed valve protection of the work area shall be used and a gauge or other method shall be available to confirm depressurization on the system being worked on. Where this is not possible, waivers may be granted by contractor safety on a case-by-case basis. The waiver will require that a hazard analysis be approved prior to the activity.

4.16.2 Pipelines and components/devices vulnerable to damage from routine activity must be shielded and have warning signs posted.

4.16.3 Before operating a system after repair, alteration, or replacement, the contractor is responsible for performing pressure testing and/or other inspections in accordance with the appropriate construction or post-construction code.

## 5.0 REFERENCES

**AEDC Engineering Standards**

T-1 Pressure Vessels

T-2 Pressure Piping

T-3 Engineering Design and Drafting Practices

T-5 Welding Practices

A4 System Safety

STD CM-1 Configuration Management

STD SE-1 System Engineering

**AEDC Safety, Health, and Environmental Standards**

A4 System Safety

B2 Lockout/Tagout

C5 Welding and Cutting

D3 Identification of Piping Systems

D4 Compressed Gas Cylinders

**Air Force Publications**

**AF Technical Orders**

AFTO 00-25-223 Integrate Pressure Systems and Components

AFTO 00-20-14 Air Force Metrology and Calibration Program

AFTO 33K-1-71 USAF Calibration and Measurement Summary and Work Unit Code Manual for Test System Support Equipment (SE) Located at Arnold Engineering Development Center Addendum

**Other AF Publications**

ESMC-TR-88-01 A Guide for Recertification of Ground Based Pressure Vessels and Liquid Holding Tanks

**American National Standards Institute (ANSI)**

ANSI B40.1 Gauges – Pressure Indicating Dial Type – Elastic Element

**American Petroleum Institute (API)**

API 510 Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration

API 570 Piping Inspection Code: Inspection, Repair, Alteration, and Rerating of In-Service Piping Systems

API 579 Fitness for Service

API RP 580 Risk-Based Inspection

**American Society of Mechanical Engineers (ASME)**

ASME B31.3 Process Piping

ASME B40.100 Pressure Gauges and Gauge Attachments

ASME Boiler and Pressure Vessel Code

ASME PCC-2 Repair of Pressure Equipment and Piping

ASME PCC-3 Inspection Planning Using Risk-Based Methods

**American Society for Nondestructive Testing (ASNT)**

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Test

**Code of Federal Regulations (CFR)**
**Occupational Safety and Health Administration (OSHA) Standards**

29 CFR 1910.110, OSHA Standard for Storage and Handling of Liquefied Petroleum Gases

**NASA Technical Standard**

NASA NPR 8715.4 Inservice Inspection of Ground Based Pressure Vessels and Systems
NASA STD 8719.17 NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems
NASA Glenn Research Center Safety Manual BMS Document GLM-QSA-1700.1

**National Board of Boiler and Pressure Vessel Inspectors**

NBIC/ANSI NB-23 Nation Board Inspection Code

**ATTACHMENTS**

Annex A Recommended Pressure Gauge Purchase Description
Annex B In-Service Inspection Guidelines
Annex C General Guidance on Pressure Testing Separation Distance
Annex D Pressure Gauge Calibration Requirements Flowchart
Annex E Flexible Metal Hose, Rubber and Thermoplastic Hose Restraint Determination Guide

## Annex A
## Recommended Pressure Gauge Purchase Description

Item – pressure gauge
Type of gauge – vacuum, compound, etc.
Pressure range – minimum to maximum, psig
Dial size – diameter
Dial range and color – x to y psig; white, etc.
Window material – plastic, glass, etc.
Case and ring materials – type, material and style
Case design – stem mount, flush mount, etc.
Elastic element – material and style
Type, location, and size of connection – welded, $^{1}/_{4}$ NPT (male), etc.
Accuracy – plus or minus XX psig
Environmental service conditions – outside, inside, shock, etc.
Fluid – type
Temperature – range

Analog pressure gauges shall be of one-piece, solid-front construction, using an optically clear shatterproof window made of high-impact, non-cracking plastic, heat-treated glass, or laminated glass in accordance with ASME B40.100. Pressure relief requirements are detailed in number 1 through 6 below:

1. Analog pressure gauges with <u>indicating ranges of 30 psig or less</u>, having a gauge face diameter of 2 $^{1}/_{2}$ inches or less and polycarbonate (plastic) window may be of open front, solid case construction without pressure relief of the case.
2. Analog pressure gauges with <u>indicating ranges of 0 to 160 psig</u> shall have an optically clear shatter-resistant window made of high-impact, non-cracking plastic, heat-treated glass, or laminated glass and case design with pressure relief means consisting of pressure relief blow-out plug or a case opening sufficiently sized to discharge the maximum system pressure to the back or side and prevent rupture of the case.
3. Analog pressure gauges with <u>indicating ranges greater than 160 psig</u> shall have a solid-front case design, an optically clear shatter-resistant window made of high-impact, non-cracking plastic, heat-treated glass, or laminated glass, and a pressure-relieving back panel or pressure blow out plug(s) oriented to the back of the gauge, sufficiently sized to discharge the maximum system pressure and prevent rupture of the case.
4. Differential gauges must use the maximum allowable working pressure (MAWP) to determine the pressure relief requirements. MAWP greater than 160 must meet Number 3 above. MAWP less than or equal to 160 must meet Number 2 above.
5. Vacuum gauges do not have to have pressure relief of the case.
6. Digital test gauges are exempt from pressure relief of the case.

## Annex B
## In-Service Inspection/Test (ISI/T) Guidelines

### 1.0 SCOPE/APPLICATION

This annex establishes ISI/T guidelines for ground-based, unfired pressure vessels and systems.

Inspections requirements and intervals are dependent on applicable codes, application/service of system, operational and maintenance history, facility experience in the application, results of certification analyses/evaluation, projected operation, manufacturer's recommendations and recognized and generally accepted good engineering practice. The inspection matrices provided in this annex reflect typical minimum inspection requirements for some applications based on code requirements but are not all-inclusive nor intended to rigidly establish inspection requirements and intervals. Each system must be evaluated specifically and all relevant factors considered in the development of the ISI/T plan. ISI/T will be integrated into the normal routine repair and maintenance programs now in effect. This annex is applicable to all new Pressure and Hazardous Material Systems (PHMS) and existing systems certified under the AEDC PHMS Certification Program.

The following items are excluded from this annex because their ISI/T criteria are covered by a national consensus standard or they do not present sufficient hazards to require other than normal routine maintenance:

1. Fire extinguishers – Covered by Federal Register, Vol. 37, No. 202, Title 29 – Labor, Chapter XVII – OSHA Part 1910, Subpart L
    - 1a. Portable – NFPA 10
    - 1b. Standpipe and hose systems – NFPA 25
    - 1c. Automatic sprinkler system – NFPA 25
    - 1d. Fixed dry chemical extinguishing systems – NFPA 17
    - 1e. Carbon dioxide extinguishing systems – NFPA 12
    - 1f. Halogenated extinguishing agent systems – NFPA 12A
2. Heating boilers – Covered by ASME Boiler and Pressure Vessel Code (B&PVC), Section VI
3. Power boilers – Covered by ASME B&PVC, Section VII
4. Air-pack rescue equipment or other breathing apparatus – Covered by Federal Register, Vol. 37, No. 202, Title 29 – Labor, Chapter XVII – OSHA Part 1910, Subpart I, Section 1910.134, .138, .139, and .140
5. Mobile equipment for gases and liquids – Covered by Department of Transportation (DOT) Regulations, Part 178
6. Heating, ventilation, air conditioning and refrigeration systems – Covered by manufacturer's installation, operation and maintenance instructions
7. Instrumentation – Covered by manufacturer's installation, operation and maintenance instructions

### 2.0 TERMS EXPLAINED

Certification Period – The period of time between inspections when a certified status is maintained through documented periodic inspections and tests to determine vessel or system condition (time between major inspections).

National Consensus Standard/Code – Any standard or modification thereof that has been adopted or promulgated by a nationally recognized standards producing organization under procedures whereby it can be determined by the Secretary of Labor or by the Assistant Secretary of Labor for Occupational Safety and Health that persons interested and affected by the standard have reached substantial agreement on its adoption.

Pressure Systems Engineer – A person who has the necessary qualifications to evaluate designs with respect to code conformance.

Radiographic Examination – A nondestructive method for detecting discontinuities in materials and components using penetrating radiation and recording media to produce an image.

Recertification – The procedure by which a previously certified vessel or system, by appropriate tests, NDE and documentation, is qualified to continue or be returned to operation at the designed conditions. To be recertified, original certification data and modification/alteration history must be available.

Technical Data Package (TDP) – The technical documentation, system schematic, weld map and ISI/T Plan which are placed under configuration control and are essential to PHMS operation, maintenance, ISI/T, and follow-on recertification.

Ultrasonic Testing (UT) – A nondestructive method of examining materials by introducing ultrasonic waves into, through or onto the surface of the article being examined and determining various attributes of the material from effects on the ultrasonic waves.

Visual Inspection (VT) – A nondestructive testing method that provides a means of detecting and examining a variety of surface flaws, such as corrosion, contamination, surface finish, and discontinuities. A VT shall be conducted by an individual qualified and certified per ASNT SNT-TC-1A as an NDT Level II Examiner in this method to determine the general mechanical and structural condition of the piping, devices, components and supports. VT may be external or internal.

An external visual examination (VTE) is an examination performed to determine the general mechanical and structural condition of the vessel or piping, devices, components and supports. The examination shall include checking welds, devices, supports and components for such conditions as cracks, wear, corrosion, erosion and physical damage. Additionally, a check should be made for the presence of loose parts and for supports not supporting pipe.

An internal visual examination (VTI) is an examination performed primarily for pressure vessels. In addition to general mechanical and structural condition and examination of welds as described in VTE above, internal piping, cladding, baffles, tie rods, tube sheets and liners should be examined as applicable for deterioration, excessive corrosion, disbonding and general condition.

## 3.0 IN-SERVICE INSPECTION PLANNING

### 3.1 Background

During new fabrication or certification of existing PHMS, comprehensive inspections, tests, analysis, evaluations and subsequent deficiency correction, as necessary, are performed to establish a baseline for that system, device, or component. Once these efforts are completed and a baseline is established, ISI/T must be performed to maintain this baseline. The development of a comprehensive ISI/T Plan must consider initial certification results, projected operating conditions and the likely failure mechanisms identified, as well as defects that are permitted to remain in the PHMS through advanced analysis techniques (e.g., fracture mechanics and finite element analysis). Initial PHMS certification requirements and documentation are outlined in AEDC-ENGR-STD-T-1 and T-2. Certification documentation includes the PHMS operating conditions and the NDE Plan. The NDE Plan is a detailed document that includes references, Safety, Health and Environmental Standards, inspection requirements and acceptance criteria, along with a listing of equipment necessary to perform required original certification inspections. The Evaluation Report, referenced in T-1 and T-2, contains inspection results and forms the baseline for ISI/T result comparison. These documents should be reviewed before commencing the ISI/T.

### 3.2 Integrity Assessment

Existing/new code PV/S shall be documented as meeting the requirements of the original construction code by means of record collection, physical measurements, and condition assessment. Original code information shall be retained. If original code information does not exist, then the PV/S must undergo the certification process.

Non-code PV/S shall undergo certification.

ASME Code stamped items shall only be repaired or altered by National Board (NB-23) certified organizations (e.g., R and/or VR stamp holders) in strict conformance with their approved quality manual.

### 3.3 Corrosion Rate Determination

Corrosion rate is determined by the difference between two thickness readings divided by the time interval between the readings. Short term corrosion rates are typically determined by the two most recent thickness readings. Long term rates use the most recent reading and one taken earlier in the life of the component/device. These different rates help to identify recent damage mechanisms from those acting over the long term. Corrosion rate shall be calculated each time that UT thickness measurements are taken per the ISI/T Plan. Refer to API 510 or 570, as applicable, for corrosion rate equations.

The mechanism of wall thinning is significant. The response and acceptability of a system will vary based on which of the following methods have occurred: general wall loss/pitting, cracks, mechanical degradation.

Determination of corrosion rates also needs to take into account changes in operation including change in operating pressure/temperature, changes to fluid including contaminants, frequency, change from usually stagnant to usually flowing, change in flow velocity, location of corrosion (elbow versus straight pipe), type of joints, potential for cold water corrosion in gas lines, estimation of corrosion cause/type, estimation if metal loss is due to corrosion, erosion, actions taken to mitigate future metal loss, etc.

### 3.4 Remaining Life Assessment

The remaining safe life of each PV/S shall be documented at the time of certification or recertification through a detailed integrity assessment based on nondestructive examination and inspection results, relevant damage mechanisms, cyclic service history, rates of degradation, and other appropriate factors.

When service life is limited by fatigue considerations the fatigue life assessment methodology of ASME Section VIII, Division 2 may be used. For Section VIII, Division 1 or non-code vessels, the allowable stress values from Division 1 should be used.

The rate of service related or environmentally induced (e.g., corrosion under insulation) **wall thinning** of PV/S shall be documented by means of periodic UT thickness measurements per ISI/T Plan with adjustments made to the remaining life calculation. Refer to API 510 or 570, as applicable, for remaining life equations.

Unless specifically documented in the original design, the certified remaining life shall not exceed 40 years, and the recertification period shall be on or before one-half the documented initial service life or one-half the calculated remaining life.

Recertification shall be performed as follows: when the PV/S service changes (e.g., commodity, design parameters, location, and orientation); if a repair, alteration, or modification is made; or if any unanticipated service degradation is identified that reduces estimated service life, changes probability of failure or failure modes, or changes the risk assessment.

### 3.5 Inspection Requirements

Inspection intervals for all relevant damage mechanisms shall be specified in the ISI/T Plan. ISI/T shall be performed to obtain sufficient data to ensure that unanticipated forms or rates of degradation, service changes, or other factors have not changed the remaining life. PV/S whose service life is limited by fatigue or brittle fracture shall have fatigue inspections performed no later than when the PV/S has experienced one-half of the specified number of cycles. Inspection intervals shall be reviewed and adjusted throughout the life of the PV/S to incorporate safety related code changes, unanticipated rates of degradation, or other relevant factors. To aid in selecting periods of inspection, Baseline Inspection Tables (BITs) for ISI/T have been developed. The tables shown in Figure 1 at the end of this annex are presented on the basis of system content. The tables provide a baseline; however, additional considerations may be necessary for developing specific tables. The BITs have identified categories of items. Each item to be periodically inspected within the system must be identified and placed in one of the following categories:

- pressure vessels
- tanks or dewars
- flex hoses
- gauges (pressure and temperature)
- tubing
- regulators
- piping or ducting
- relief devices
- expansion joints
- supports

### 3.6 Documentation Requirements

Documents and data that established certification, recertification, corrosion rates, remaining life, and ISI/T inspection period shall be maintained and retrievable by the system engineer for the life of the PV/S. PV/S records shall contain four types of information as follows: Construction and Design; Inspection History; Repair, Alteration, and Re-rating History; and Operating and Maintenance Records.

### 3.7 Risk-Based Inspection

Risk-based Inspection (RBI) can be used to determine inspection intervals and the type and extent of future inspections/examinations. RBI determines risk by combining the expected *probability* and the *consequence* of equipment failure. The certification process provides key information necessary in assessing the probability of equipment failure by identifying and evaluating potential damage mechanisms, current equipment condition, and inspection baselines. Additionally, certification data will be useful in the consequence of equipment failure assessment as well. The systematic evaluation methodology be further explained in API 580/581, ASME PCC-3, and NASA-STD-8719.17 Section 4.9 Tables 1, 2, 3, and 4.

## 4.0 IN-SERVICE INSPECTION PLAN

A typical PHMS ISI/T Planning Matrix, including notes and illustrating selection criteria for inspection intervals.

Figure 1 provides guidelines on inspection intervals for devices and components based on the commodity. This information is based on information obtained from NASA NPR 8715.4 – Inservice Inspection of Ground Based Pressure Vessels and Systems dated 26 March 2004, ESMC-TR-88-01 A Guide for Recertification of Ground Based Pressure Vessels and Liquid Holding Tanks, and various codes and standards.

Figure 2 contains a sample ISI/T Planning Matrix. A sample project containing five $GN_2$ pressure vessels and 500 ft of piping is presented. The ISI/T identified in the planning matrix does not take into account any significant ISI/T findings nor does it determine subsequent inspections or actions based on those findings. However, by reviewing the Certification documents, reviewing operational and maintenance history, and applying good engineering judgment, one can ascertain, plan and implement prudent inspections, actions or additional ISI/T. This methodology meets all the requirements as described and outlined in AEDC-ENGR-STD-T-1 and AEDC-ENGR-STD-T-2 for Pressure Vessels and Pressure Piping, respectively.

Figure 3 contains a blank ISI/T Planning Matrix for use.

Table 1 is a listing of Inspection and Test Methods and their corresponding abbreviations for completing the ISI/T Planning Matrix.

**Figure 1** - Inspection Interval Guidelines for ISI/T

| **Liquid Nitrogen, Air Argon, and Helium** | | | | | |
|---|---|---|---|---|---|
| **Category** | **Time Intervals (Years)** | | | | |
| | **1** | **2** | **5** | **10** | **20** |
| Dewars | | | I | | R |
| Piping | | | I | | R |
| Relief Devices | | | I | | R |
| Expansion Joints | | | I | | R |
| Flex Hoses | | | I | | R |
| Pressure Gauges | | | I | | R |
| Temperature Gauges | | | I | | R |
| Supports | | | I | | R |
| R = Recertification<br>I = Inspection | | | | | |

| **Gaseous Helium, Nitrogen and Dry Air** | | | | | |
|---|---|---|---|---|---|
| **Category** | **Time Intervals (Years)** | | | | |
| | **1** | **2** | **5** | **10** | **20** |
| Pressure Vessels | | | I | | R |
| Piping | | | I | | R |
| Relief Devices | | | I | | R |
| Flex Hoses | | | I | | R |
| Pressure Gauges | | | I | | R |
| Supports | | | I | | R |
| Regulators | | | I | | R |
| | | | | | |
| R = Recertification<br>I = Inspection | | | | | |

| **Gaseous Hydrogen, Oxygen and Natural Gas** | | | | | |
|---|---|---|---|---|---|
| **Category** | **Time Intervals (Years)** | | | | |
| | **1** | **2** | **5** | **10** | **20** |
| Pressure Vessels | | | I | | R |
| Piping | | | I | | R |
| Supports | | | I | | R |
| Relief Devices | | I | | | R |
| Flex Hoses | | I | | | R |
| Gauges | | I | | | R |
| Regulators | | I | | | R |
| | | | | | |
| R = Recertification<br>I = Inspection | | | | | |

| **Vacuum System** | | | | | |
|---|---|---|---|---|---|
| **Category** | **Time Intervals (Years)** | | | | |
| | **1** | **2** | **5** | **10** | **20** |
| Pressure Vessels | | | I | | R |
| Piping | | | I | | R |
| Supports | | | I | | R |
| Relief Devices | | | I | R | |
| Flex Hoses | | | I | R | |
| Gauges | | | I | R | |
| Regulators | | | I | R | |
| | | | | | |
| R = Recertification<br>I = Inspection | | | | | |

| **Steam and Condensate per NBIC/ANSI NB-23** | | | | | |
|---|---|---|---|---|---|
| | **Time Intervals (Years)** | | | | |
| | **1** | **3** | **5** | **10** | **20** |
| Pressure Vessels | I | | | | R |
| Piping | I | | | | R |
| Supports | I | | | | R |
| Relief Devices (>400 PSIG) | | I | | | |
| Relief Devices (<400 PSIG) | I* | | | | |
| Flex Hoses | I | | | | R |
| Gauges | I | | | | R |
| Regulators | I | | | | R |
| R = Recertification<br>I = Inspection<br>*Relief devices in steam/condensate service less than 400 psig shall be manually tested (via lifting lever) every 6 months and pressure tested annually. | | | | | |

**Figure 2** - ISI/T Planning Matrix for Sample Project- A sample project containing five $GN_2$ pressure vessels and 500 ft of piping is presented.

| DESCRIPTION | INITIAL CERT. | Baseline Year +1 | +2 | +3 | +4 | +5 | +6 | +7 | +8 | +9 | +10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Vessel #1 | RT, MT, VT, UTT, HPT | | | | | VT | | | | | VT |
| Vessel #2 | RT, MT, VT UTT, HPT | | | | | VT | | | | | VT |
| Vessel #3 | RT, MT, VT, UTT, HPT | | | | | VT, RT | | | | | VT |
| Vessel #4 | RT, MT, VT, UTT, HPT | | | | | VT | | | | | VT |
| Vessel #5 | RT, MT, VT, UTT, HPT | | | | | VT | | | | | VT |
| Vessel supports | MT, VT | | | | | VT | | | | | VT |
| Piping | RT, MT, PT, UTT, VT, PLT | | | | | VT, UTT | | | | | VT, UTT |
| Piping supports | VT | | | | | VT | | | | | VT |
| Relief devices | VT, RDC | | | | | VT, RDC | | | | | VT, RDC |
| Pressure gauges | VT, C | | | | | VT, C | | | | | VT, C |
| System | CIVR | CIVR | CIVR | CIVR | CIVR | CIVR* | CIVR | CIVR | CIVR | CIVR | CIVR* |

**Figure 2**

| DESCRIPTION | INITIAL CERT. | +11 | +12 | +13 | +14 | +15 | +16 | +17 | +18 | +19 | +20 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Vessel #1 | RT, MT, VT, UTT, HPT | | | | | VT | | | | | R |
| Vessel #2 | RT, MT, VT, UTT, HPT | | | | | VT | | | | | R |
| Vessel #3 | RT, MT, VT, UTT, HPT | | | | | VT | | | | | R |
| Vessel #4 | RT, MT, VT, UTT, HPT | | | | | VT | | | | | R |
| Vessel #5 | RT, MT, VT, UTT, HPT | | | | | VT | | | | | R |
| Vessel supports | MT, VT | | | | | VT | | | | | R |
| Piping | RT, MT, PT, UTT, VT, PLT | | | | | VT, UTT | | | | | R |
| Piping supports | VT | | | | | VT | | | | | R |
| Relief devices | VT, RDC | | | | | VT, RDC | | | | | R |
| Pressure gauges | VT, C | | | | | VT, C | | | | | R |
| System | CIVR | CIVR | CIVR | CIVR | CIVR | CIVR* | CIVR | CIVR | CIVR | CIVR | CIVR* |

**Inspection and Test Methods**

See Table 1 at the end of this annex.

**Notes for ISI/T Plan:**

(1) VT: A visual inspection (VT) shall be conducted by an individual qualified and certified per ASNT SNT-TC-1A as an NDT Level II Examiner in this method to determine the general mechanical and structural condition of the piping, devices, components and supports. The examination shall include checking all accessible welds, devices, supports, components and mechanical joints for conditions such as cracks, wear, corrosion, erosion and physical damage. In addition, the examiner should also check for the presence of loose parts and for supports that are not functioning properly (i.e., not supporting pipe).

(2) C: For baseline certification, pressure gauges were calibrated in accordance with this standard. Subsequent gauge calibration will be consistent. The following table lists the pressure gauges tested and each are hyperlinked to photographs of the devices *(hyperlinks dead for this sample project)*.

| **Pressure Gauges** | |
|---|---|
| GN-PG1-VG | GN-PG2-VG |
| GN-PG3-VG | GN-PG4-VG |
| GN-PG5-VG | GN-PG6-VG |
| GN-PG7-VG | GN-PG8-VG |

(3) UT: The pipe wall thickness of each section (identified in the table following this note) must be verified by an individual qualified and certified per ASNT SNT-TC-1A as an NDT Level II Examiner in ultrasonic testing (UT) examination, using the ultrasonic thickness (UTT) measurement method. If the wall thickness measurements made at the end of the first 5-year interval show no evidence of wall thinning when compared to the baseline readings (i.e., show no loss of metal within the accuracy and repeatability ranges of the equipment used), then subsequent inspections must be made at 10-year intervals, assuming the system will be recertified at the 20-year point. If evidence of wall thinning is detected during any inspection, then the inspection interval must revert to a 2-year interval and analysis be performed to determine if thinning will result in a lower design pressure and subsequent lower operating pressure. The Engineering Analysis section of the Evaluation Report contains a piping UTT Location Map. This map should be used in conjunction with this ISI/T Plan item.

For new piping, nominal wall thickness for that size and schedule pipe, obtained from the tables in AEDC-ENGR-STD-T2, must be used as baseline measurements from which subsequent in-service measurements must be compared. The NDE Level II Examiner working with the system engineer will establish the locations and schedule for additional pipe schedule maintenance.

**Piping - Ultrasonic Thickness ISI/T Data Table (Sample)**

***NOTE:*** *UTT measurements must be taken at each identified location (CML) [at $0^o$ (top), $90^o$, $180^o$ (bottom) and $270^o$ going clockwise with the direction of fluid flow] and compared with the baseline reading obtained during certification. Locations can be obtained from the UTT Location Map contained in the Evaluation Report.*

| ***Location (CML)*** | | ***Baseline*** | ***5 years*** | | | | ***10 years*** | | | | ***15 years*** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 90 | 180 | 270 | 0 | 90 | 180 | 270 | 0 | 90 | 180 | 270 |
| 1 | UTT-3 | 0.284 | | | | | | | | | | | | |
| 2 | UTT-14 | 0.405 | | | | | | | | | | | | |
| 3 | UTT-23 | 0.070 | | | | | | | | | | | | |
| 4 | UTT-31 | 0.044 | | | | | | | | | | | | |
| 5 | UTT-47 | 0.149 | | | | | | | | | | | | |
| 6 | UTT-53 | 0.040 | | | | | | | | | | | | |

(4) CIVR: A configuration item verification review (CIVR) must be performed annually on the PHMS system/project. The system engineer must walk down the system with the as-built drawings to verify all devices are properly tagged and that any configuration changes have been properly incorporated into the as-built drawings. The system specification must be reviewed to ensure it remains accurate and current. During walkdown, components or devices must be examined for damage, wear, corrosion, loose, missing parts, etc. Any problem and/or discrepancy must be forwarded for resolution.

CIVR* Every fifth year, the system engineer must be accompanied by a person designated by the Center Operating Contractor's Safety Office, knowledgeable in pressure systems, to perform the CIVR.

(5) RDC: For baseline certification, all relief devices were removed from the system and their set-point verified, orifice size measured and flow capacity determined. Subsequent relief device calibration (RDC) will consist of set-point verification only.

If replacement of a relief device is required in a certified system, appropriate certification documentation will be obtained prior to installation in the system and included in the system certification documentation to maintain system certification. If the relief device is an existing device (i.e. a device that has been previously used in another system or has been set aside for use as a spare) and has a current calibration date, the relief device documentation will be included in the system certification documentation and managed appropriately. If the relief device is new, appropriate certification will be obtained from the vendor, the calibration date tag installed and the documentation included in the system documentation. In either case, the adequacy of the relief device for the application should be documented. In the event a relief device is installed without proper management of change, the entire initial certification must be performed at the next inspection date. This may include removing the relief device from the system to verify the set-pressure.

For new relief devices, manufacturer's data sheets provided on set-point, orifice size, and flow capacity will serve as baseline data.

(6) RT: Example: During baseline certification, slag was detected in the following weld via radiographic testing (RT):

| Component | Weld |
|---|---|
| *Vessel #3* | *N-2* |

Even though, through fracture mechanics, this indication was determined to be benign, it is still a stress riser and warrants monitoring. This weld must be reinspected using the exact (documented) same method and technique and the results compared to the baseline certification radiograph to detect any anomaly that could have resulted from this stress riser area. If no anomaly is detected, the indication requires no further inspection until recertification is required at the 20-year point. However, if an anomaly is detected to the presence of the stress riser, a determination will be made whether to monitor the indication more aggressively or repair.

**Figure 3 - ISI/T Planning Matrix**

| DESCRIPTION | INITIAL CERT. INSP. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
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| **Inspection and Test Methods**<br>See Table 1 at the end of this annex. | | | | | | | | | |

**Table 1**
**Abbreviations for Planning Matrix**
**Inspection and Test Methods**

| | |
|---|---|
| AET | Acoustic Emission Examination |
| C | Calibration |
| CIVR | Configuration Item Verification Review |
| CML | Condition Monitoring Location |
| CST | Cold Shock Test |
| ET | Eddy Current Examination |
| HLT | Hydrostatic Leak Test |
| HMST | Helium Mass Spectrometer Test |
| HPT | Hydrostatic Pressure Test |
| LT | Leak Test |
| MFL | Magnetic Flux Leakage Examination |
| MT | Magnetic Particle Examination |
| PLT | Pneumatic Leak Test |
| PPT | Pneumatic Pressure Test |
| PT | Liquid Penetrant Examination |
| R | Recertification |
| RDC | Relief Device Certification |
| RT | Radiographic Testing/Examination |
| UT | Ultrasonic Testing |
| UTT | Ultrasonic Thickness Measurement |
| VB | Vacuum Box Test |
| VDT | Vacuum Decay Test |
| VT | Visual Examination |

# ANNEX C
# GENERAL GUIDANCE ON PRESSURE TESTING SEPARATION DISTANCE

## 1.0 SCOPE / APPLICATION

Due to the large amount of energy stored in compressed gas and the potential hazard of a sudden release of this energy, pneumatic testing should be avoided if at all possible. The method below provides a conservative approach to estimate the minimum safe distance from an article undergoing a pneumatic test to any personnel.

## 2.0 DETERMINATION OF SEPARATION DISTANCE
(From NASA Glenn Research Center)

2.1 During the application of pneumatic pressure, all non-essential personnel shall be located a safe distance from the test. Buildings and major structures inside this restricted area shall be protected. The graph at right was derived from a curve showing pounds of open-field TNT-equivalent explosive per 1000 $ft^3$ of gas as a function of rupture pressure. The method has been accepted by AEDC/SE and AEDC Operating Contractor Safety.

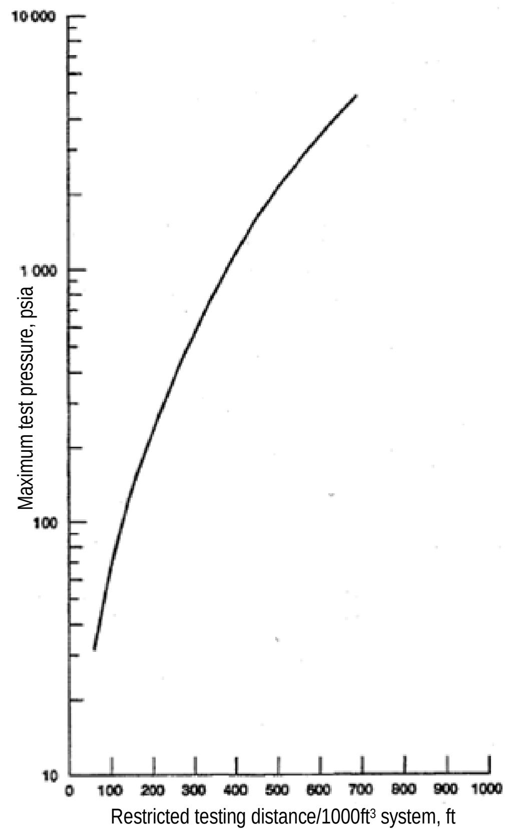
2.2 The restricted testing distance for a 1000 $ft^3$ system is given in Section 3.0 below. The curve can be applied to systems of other volumes. The restricted distance need not be strictly adhered to if alternate precautions are taken for personnel. Some alternate safety precautions include locating personnel behind adequate blast shields, sandbags, or other unmovable objects.

2.3 For basis and other alternate evaluations contact AEDC Operating Contractor Safety or Design Engineering.

## 3.0 METHOD

The formula below is used to calculate the "safe separation distance" for the pneumatic test.

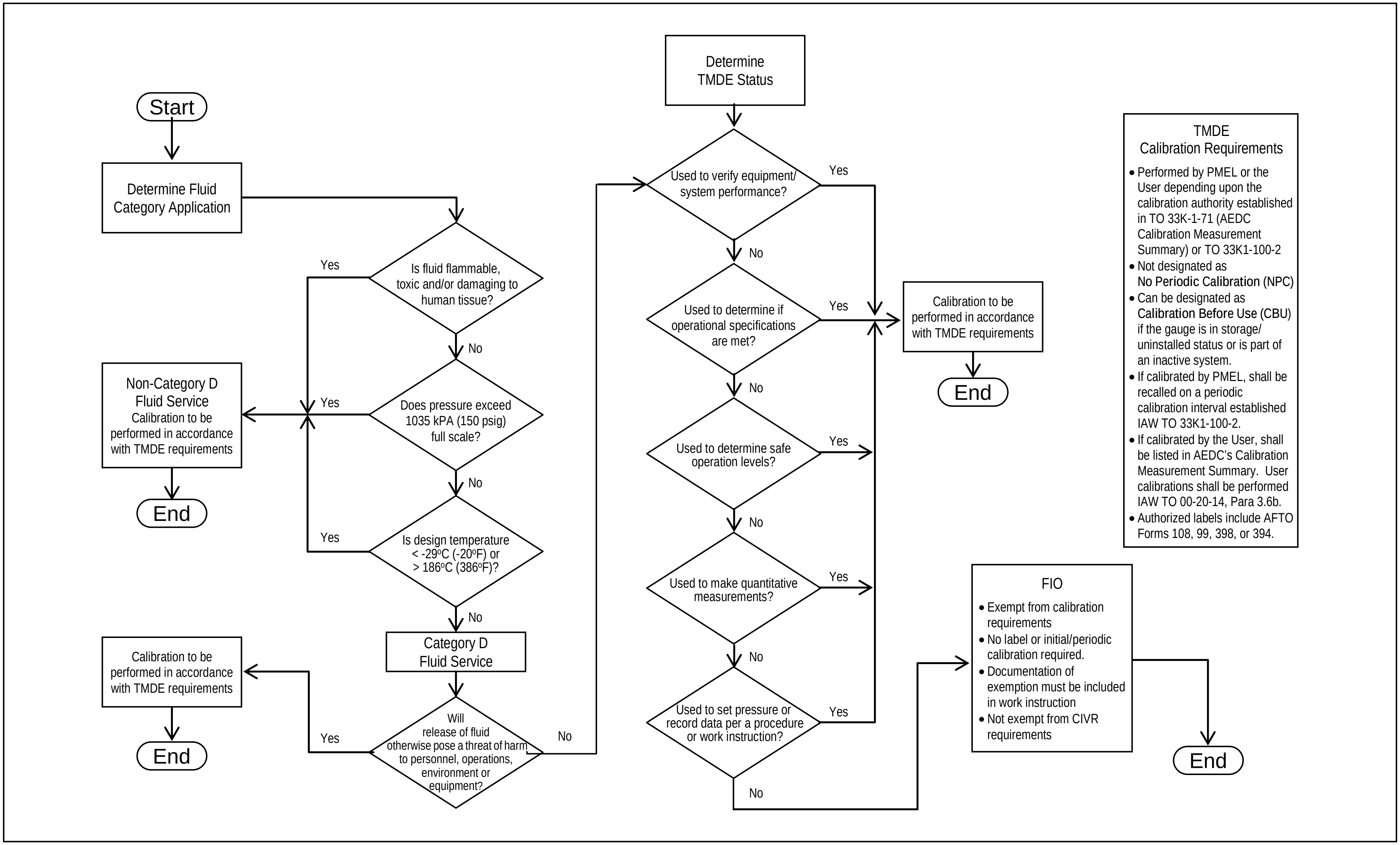
$$D_{Vessel} = \frac{D_{1000} \bullet \sqrt[3]{V_{Vessel}}}{10 \bullet X\ ft}$$




Restricted distance for pneumatic pressure testing

**$V_{Vessel}$ =** Volume of the piping/vessel/system being tested
**$D_{Vessel}$ =** Safe separation distance
**$D_{1000}$ =** Safe separation distance for a 1,000 $ft^3$ vessel per curve above right.

# ANNEX D
# PRESSURE GAUGE CALIBRATION REQUIREMENTS FLOWCHART



# ANNEX E
# FLEXIBLE METAL HOSE, RUBBER AND THERMOPLASTIC HOSE WHIP RESTRAINT DETERMINATION GUIDE

## 1.0 SCOPE/APPLICATION

This annex establishes the criteria for determining where hose whip restraints are required based on the type of system and specific circumstances. Refer to Section 2.0 for basic guidance based on hose inside diameter (ID), pressure, and hose length. Refer to Section 3.0 for specific direction on determining if liquid-filled hose restraint systems are required.

## 2.0 PRESSURE AND LENGTH THRESHOLD

The design pressure and length threshold where hose whip restraints are required is based on the specific hose ID. For all cases in gas service, hose whip restraints are required for pressures over 150 psig and for liquid service over 500 psig. Hoses operated at pressures below 25 psig do not necessarily require restraints. The system engineer shall consider the potential impact force from large hoses at less than 25 psig and determine if restraints are required.

**GAS HOSES**

| Hose ID (inches) | Operating Pressure (psig) | Hose Length (inches) |
|---|---|---|
| 0.375 or less | >150 | 12 |
| 0.5 | >80 | 12 |
| 0.75 | >36 | 12 |
| 1 | >25 | 12 |
| 1.5 | >25 | 12 |
| 2 | >25 | 18 |
| >2 | >25 | 24 |
| | | |

Based on 35 pounds force blow-off of hose end. F= 2 P A
Force = 2 x Pressure x Area.

Example 1: If the hose ID is .5 inch and the operating pressure is greater than 80 psig and the hose length is greater than 12 inches, hose restraint is needed unless the exemptions in Section 3.0 apply.

Example 2: If the hose ID is .5 inch and the operating pressure is less than 80 psig and the hose length is greater than 12 inches, hose restraint is not needed.

**LIQUID/HYDRAULIC HOSES**

| Hose ID (inches) | Operating Pressure (psig) | Hose Length (inches) |
|---|---|---|
| 0.5 or less | >500 | 12 |
| 0.75 | >250 | 12 |
| 1 | >150 | 12 |
| 1.5 | >60 | 12 |
| 2 | >35 | 18 |
| >2 | >25 | 24 |
| | | |

Based on 235 pounds force blow-off of hose end. F= 2 P A

### 3.0 Liquid-Filled Flexible Hose Restraint Guideline

This guideline is intended to be used as a check, along with Section 2.0, for determining whether liquid-filled flexible hoses must be fitted with restraint. For liquid systems, the system engineer must evaluate the system pressure, flow capacity, liquid reservoir and potential for injury for systems to determine if hose restraints are required. If there is no potential for injury or damage, restraints are not required. This shall be documented in the system's hazard analysis.

1. Use the LIQUID/HYDRAULIC HOSES chart in Section 2.0 to determine whether hose restraint is required based on hose size, system/ hose pressure and length. Is the hose longer than the length provided in the chart?

   If **YES**, continue.

   If **NO**, stop, no restraint is required. Document this in the system's hazard analysis.

2. Is there a potential for injury or damage from flexible hose whip?

   If **YES**, continue.

   If **NO**, stop, no restraint is required, and document this in the system's hazard analysis.

3. Is the hose shielded or otherwise positioned so that personnel are prevented from being potentially exposed to a hose whip?

   If **YES**, stop, no restraint is required, and document this in the system's hazard analysis.

   If **NO**, continue.

4. Is the hose only pressurized when personnel are evacuated from the area and cannot be exposed to hose whip?

   If **YES**, stop, no restraint is required, and document this in the system's hazard analysis.

   If **NO**, continue.

**In all cases where whip restraints are determined to be required:**

5. The Upstream end (closest to the pressure source) hose connection does not need hose restraint in most cases.

6. Hose Restraint may be required on both ends of the hose, depending on location pressure sources (e.g. accumulator, pump). If the hose is between the two potential pressure sources, then both ends would require restraint.

**NOTE:** An exception for liquid filled hose restraint (if required by this annex) may be approved through a hazard analysis with adequate engineering to assess the personnel and equipment risk to an acceptable level. For example: If personal protective equipment can be used to protect personnel, i.e. an adequate helmet, body armor, armor blankets used or portable shields, etc., then this mitigation needs to be documented in the appropriate hazard analysis and work instructions.