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

AEDC ENGINEERING STANDARD

TITLE: AEDC Standard Pressure Vessels

STANDARD NO.: AEDC-ENGR-STD-T-1

EFFECTIVE DATE: December 5, 2012

The provisions and requirements of this standard are mandatory for use by all AEDC personnel engaged in work tasks necessary to fulfill the AEDC mission. This AEDC Standard is <u>not</u> sensitive. Please contact AEDC/EN for clarification or questions regarding this standard.

<u>APPROVED:</u>

AEDC/EN

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CONTENTS

APPENDICES		PAGE

DATE	AFFECTED PAGES
	Vertical lines are not used in this revision to identify changes with respect to the previous issue due to the extensive changes. Users of AEDC-ENGR-STD-T-1 are cautioned to evaluate the requirements of this document based on the entire content.

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1.0 INTRODUCTION

1.1 PURPOSE

This standard establishes minimum requirements for design, materials, fabrication, assembly, erection, inspection, and testing of all new pressure vessels for operation at AEDC. The criteria in this standard also form the basis for evaluation, repair, alteration, defining limits of safe operation, and certification of all previously used vessels for return to service at AEDC. The Operating Contractor shall define specific roles, responsibilities, and other information processes to ensure the retention of engineering analysis and records of inspection, testing, and certification for all pressure vessels at AEDC.

1.2 SCOPE

For this standard, a pressure vessel is any container for media under pressure, either internal or external, as defined by the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME BPVC). This standard shall also include all carbon and alloy steel ducting not constructed per ASME B31 piping codes and these, hereinafter, shall be referred to collectively as *pressure vessels* when not specifically addressed. This standard applies to all pressure vessels for use at AEDC except:

1.2.1 Pressure vessels fabricated from standard pipe, standard pipe fittings, and standard pipe flanges of 6 inch nominal pipe size (NPS) or less. These shall be designed, fabricated, erected, inspected and tested in accordance with AEDC-ENGR-STD-T-2.

1.2.2 Shells, ducting, and piping fabricated from standard pipe, standard pipe fittings, and standard pipe flanges whose primary purpose is to convey gases or liquids. These shall be designed, fabricated, erected, inspected and tested in accordance with AEDC-ENGR-STD-T-2.

1.2.3 Portable commercial compressed gas cylinders designed in accordance with Department of Transportation (DOT) standards. These vessels shall be identified, inspected, tested, handled, and stored in accordance with AEDC-SHE-STD-D4 Compressed Gas Cylinders. Note: If a compressed gas cylinder has been repaired, altered or is installed for permanent use in a system at AEDC then that vessel shall be regarded as non-DOT compliant and is subject to the requirements of this standard.

1.2.4 Test cells, vacuum chambers, ballistic range launch tubes, or other unique AEDC pressure vessel configurations may be beyond the scope of industry standards. Any unique to AEDC design approach shall be documented and approved by the Operating Contractor’s design group.

1.2.5 Vessels furnished as part of a test article.

1.2.6 HVAC ducting. Heating, ventilating and air conditioning ducting shall be designed in accordance with ASHRAE.

1.2.7 Additional exclusions listed in the ASME BPVC section entitled “Scope”.

1.3 DEVIATIONS/WAIVERS

Under certain circumstances, compliance with all requirements of this standard may be impractical, perhaps impossible. In such cases, the AEDC Operating Contractor shall provide an engineering analysis or statement assessing risk and recommend a reasonable acceptance of risk and/or mitigation over the range of operation. Details of any deviation request for a non-compliance with this standard initiated before fabrication or installation has begun or waiver request for a non-compliance after fabrication or installation has begun shall be prepared and approved in accordance with AEDC-STD-CM-1 Configuration Management, AEDC Safety Standard A4 System Safety, and AEDC Operating Contractor procedures prior to operation.

1.4 GENERAL REQUIREMENTS

1.4.1 Governing Codes. Pressure vessels shall meet the requirements of the governing code as cited in paragraph 1.5 Applicable Codes unless code requirements are modified by this standard. Modified code requirements established by this standard are more restrictive than those contained in the code to provide a greater degree of safety over the operating range of the vessel based upon experience at AEDC.

1.4.2 Operational Limitations. This Standard does not set upper limits based on pressure, temperature, size, or other pertinent factors. However, it must be recognized that certain vessels subjected to ultra-high pressures, high temperatures, low temperatures, severe transient loads, and other unusual conditions may have to be evaluated on an individual basis requiring information that is not contained in this standard or the referenced codes. Therefore, this standard and the governing codes referenced herein should be considered as containing basic reference data and formulas and should not be considered as design handbooks covering all situations. Use of these documents does not eliminate the need for competent engineering judgment.

1.4.3 Vacuum or External Pressure Service. All vacuum vessels and ducting designed for vacuum or external pressures are within the scope of this standard as defined in paragraph 1.5. The factors in the following warning shall be considered in the design of these vessels.

WARNING

The requirements of the ASME Code, Section VIII for vessels designed for external pressure service may not be adequate. Experience at AEDC during structural evaluation of a large vacuum chamber revealed a size regime wherein a code-designed vessel could collapse under design load conditions. It is recommended that vessels for external pressure service be carefully evaluated to substantiate structural integrity. Axial compressive loading (from external pressure) and out-of-plane (torsional) buckling of stiffening rings must be considered.

1.4.4 Relocation or Reactivation of Pressure Vessels. Pressure vessels now in service that are to be relocated or vessels currently out of service that are to be reactivated shall be evaluated in accordance with paragraph 5.0 Certification.

1.4.5 Overpressure Protection. All vessels installed at AEDC shall be provided with overpressure protection in accordance with the applicable code. If a relief device is to be used for overpressure protection then that device shall be as specified and installed by the appropriate code. Specific requirements for relief devices are discussed in Appendix C.

1.5 APPLICABLE CODES

The selection of codes applicable for service at AEDC shall be in accordance with Appendix A and as follows:

1.5.1 ASME Boiler and Pressure Vessel Code Section VIII Divisions 1, 2, & 3. All pressure vessels covered by this AEDC standard shall be designed, fabricated, erected, inspected and tested in accordance with the applicable Division (1, 2, or 3) of Section VIII of the ASME BPVC. Use Division 1 which employs conservative "design by rule" methodology for vessels with design pressures less than or equal to the following: the lesser of 1) 3000 psig, 2) five percent of the material tensile strength at room temperature, and 3) five percent of the material tensile strength at design temperature. Division 1 shall be given preference over Division 2. However, Division 2 may be used in lieu of Division 1 when more rigorous analysis is justified. Divisions 1 and 2 both state that design pressures (internal and/or external) less than or equal to 15 psi are not within their scope. However, Section VIII shall be used for this pressure range unless excluded elsewhere in this standard. Design for external pressure shall be supplemented with sound engineering judgment and analysis. See paragraph 1.4.3. Division 3 is applicable to vessels with design pressure generally above 10,000 psi.

1.5.2 Modified Code Requirements for AEDC Service. Modified code requirements established specifically for AEDC service are noted in the table below:

Service/Feature	Standard Section
Hazardous Liquid Propellant Fuels and Oxidizers	Appendix A
Vacuum/external pressure service	1.4.3
Ducting not constructed per ASME B31 codes	Appendix B
Evaluation of used vessels	5.1
Vessels with unknown history	5.1
Impact test requirements	4.2.8
Multi-layer/banded vessels	Appendix A
Metal support structures	2.5.4
Concrete supports	2.5.5
Supports, anchors & attachments	2.5
Vessel identification	6.1
Pressure component identification	6.2
Air compressors	7.0
Windows	Appendix D

1.5.3 Pressure Vessels.

a. All newly procured pressure vessels for AEDC service shall be Code-stamped unless particular requirements preclude Code design or fabrication. When there is an application requiring pressure vessels, heat exchangers, or pressure containing devices, such as accumulators or filters, where a determination of Code Stamp applicability is needed, then that decision shall be documented and approved by the Operating Contractor's responsible engineering group.

b. Existing Code Stamped vessels at AEDC with a Code Stamp are to be repaired or altered in strict compliance with NB-23 and shall require the work to be performed by a company possessing "R" Code Stamp. All repairs and alterations of pressure vessels shall be governed by the latest edition of the National Board of Boiler and Pressure Vessel Inspectors ANSI/NB-23, National Board Inspection Code (NBIC) as noted in Appendix A.

c. Existing vessels at AEDC without a Code Stamp may be repaired or altered in accordance with this standard and do not require the work to be performed by a company possessing "R" Code Stamp. All repairs and alterations of pressure vessels shall be governed by the latest edition of the National Board of Boiler and Pressure Vessel Inspectors ANSI/NB-23, National Board Inspection Code (NBIC) as noted in Appendix A.

d. The Government and the Operating Contractor do not have the authority to affix ASME "U" and "R" Code Stamps to pressure vessels.

e. An ASME Code stamp is not applicable for ducting designed using this standard.

1.5.4 Welding. All welding shall be in accordance with AEDC-ENGR-STD-T-5 for welding, fabrication, etc.

1.6 DEFINITIONS

1.6.1 Alteration- Any change in the item described on the original Manufacturer's Data report which affects the pressure containing capability of the pressure-retaining item. Nonphysical changes such as an increase in the maximum allowable working pressure (internal or external) increase in design temperature, or a reduction in minimum temperature of a pressure retaining item shall be considered an alteration.

1.6.2 Certification – The process for ensuring through configuration verification/validation, non-destructive examination, engineering analysis and test, the integrity of a pressure vessel. Once certified, an in-service inspection and configuration management are required to sustain certification.

1.6.3 Design Pressure - The pressure used in the design of a vessel component together with the coincident design metal temperature, for the purpose of determining the minimum permissible thickness or physical characteristics of the different zones of the vessel. When applicable, static head shall be added to the design pressure to determine the minimum required thickness of any specific zone of the vessel. It is recommended that a suitable margin be provided above the pressure at which the vessel will be normally operated to allow for probable pressure surges in the vessel up to the relief set pressure of the pressure relieving devices.

1.6.4 Design Temperature:

a. **Maximum -** The maximum temperature used in design shall not be less than the mean metal temperature (through the thickness) expected under operating conditions for the part considered. If necessary, the metal temperature shall be determined by computation or by measurement from equipment in service under equivalent operating conditions.

b. **Minimum** – The minimum mean metal temperature shall be determined by consideration of the lowest operating temperature, operational upsets, auto refrigeration, atmospheric temperature, and any other sources of cooling. The Minimum Design Metal Temperature (MDMT) marked on the nameplate shall correspond to a coincident pressure equal to the Maximum Allowable Working Pressure (MAWP). When there are multiple MAWP's, the largest value shall be used to establish the MDMT marked on the nameplate. Additional MDMT's corresponding with other MAWP's may also be marked on the nameplate. MDMT is the lowest temperature at which a significant load can be applied to a pressure vessel as defined in the applicable construction code.

1.6.5 Ducting – Shells fabricated using rolled plate with longitudinal seam welds not constructed per ASME B31 piping codes and used as a conduit for fluids.

1.6.6 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.

1.6.7 In-Service Inspection/Test (ISI/T) – Inspection of an operational (may also include pressure vessel in mothballed or sustainment status) pressure vessel 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 vessel. The ISI/T may be performed in conjunction with CIVR. Reference: AEDC-SHE-STD-D2 pressure vessels and systems.

1.6.8 Maximum Allowable Working Pressure (MAWP) – The maximum gage pressure permissible at the top of a completed vessel in its normal operating position at the designated coincident temperature for that pressure. This pressure is the least of the values for the internal or external pressure to be determined by the rules of ASME BPVC Section VIII for any of the pressure boundary parts, including the static head thereon, using nominal thicknesses exclusive of allowances for corrosion and considering the effects of any combination of loadings listed in the code that are likely to occur at the designated coincident temperature. It is the basis for the relief set pressure of the pressure relieving devices protecting the vessel. The design pressure may be used in all cases in which calculations are not made to determine the value of the maximum allowable working pressure.

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

1.6.10 Operating Pressure – The pressure at which a pressurized vessel normally operates when in service. At AEDC, the operating pressure shall be equal to or less than the design pressure.

1.6.11 PSI - Units of pressure, pounds per square inch. In this standard, PSI refers to either gauge pressure (PSIG) or differential pressure (PSID) in the context where it is used. Absolute units (PSIA) are not used in this document or the ASME Code.

1.6.12 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.

1.6.13 Pressure Vessel – A pressure vessel is a container for media under pressure, either internal or external. For the purposes of this document, ducting and non-standard piping are included in references to "pressure vessel" as stated in paragraph 1.2.

1.6.14 Recertification – The renewal process for a pressure vessel that has reached the end of its certification period or lost its previous certification because of ineffective maintenance, configuration management, improper disposal, abandonment or similar situations.

1.6.15 Relief Set Pressure – The pressure at which the pressure relief device(s) is set to protect the pressure vessel from over-pressurization. The relief set pressure for a relief valve shall not exceed the vessel MAWP. If the pressure relief device(s) is also intended to protect the balance of a piping system associated with the pressure vessel, then relief set pressure will need to be specified to not exceed the lower design pressure of either and have adequate capacity at that lower pressure. Note: The burst pressure for a rupture disk or relief valve/rupture disk combination shall be selected per the applicable code.

1.6.16 Repair – The work necessary to restore pressure-retaining items to a safe and satisfactory operating condition.

1.6.17 Standard Pipe, Fittings, and Flanges – Pipe, fittings, and flanges designed to the appropriate standard as listed in ASME B31.3 Table 326.1 Standard Components.

1.6.18 Test Pressure – The pressure at which a system is tested based upon the design pressure, test method, and the applicable code.

1.6.19 Window - Ports used at AEDC in pressure system (vessel) applications to provide a means of photographing, inducing lasers, and performing other test processes.

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2.0 DESIGN

2.1 GENERAL REQUIREMENTS

2.1.1 New Pressure Vessels. All new pressure vessels shall be designed in accordance with the applicable code as designated by paragraph 1.5 Applicable Codes insofar as possible.

2.1.2 Used Pressure Vessels. All previously used vessels shall be certified in accordance with paragraph 5.0 Certification Requirements prior to use.

2.1.3 Repair and Alteration of Pressure Vessels. The design of all repairs and alterations to existing vessel shells, heads, or other components shall comply with the requirements of this standard and the applicable standard(s) listed in Appendix A. This shall include portable DOT cylinder/vessel systems modified from the original DOT configuration or installed for permanent use within a system at AEDC.

2.1.4 Ducting and Piping not constructed in accordance with ASME B31 Specifications. Appendix B provides guidance for the design of ducting and piping not constructed in accordance with specifications of the ASME B31 Piping Codes.

2.2 MATERIALS

2.2.1 ASME Code Materials. All materials used in the construction of new vessels should be selected from those allowed by the ASME BPVC. Code stamped vessels shall use ASME Code materials.

2.2.2 ASTM Code Materials. ASTM materials may be substituted for ASME BPVC materials if after an engineering evaluation in accordance with the ASME BPVC has been performed to demonstrate ASME BPVC requirements have been met.

2.3 ALLOWABLE STRESSES

2.3.1 Allowable stresses shall be taken from the applicable section of the ASME BPVC whenever possible.

2.3.2 Allowable stresses for materials not listed in the ASME BPVC shall be determined in accordance with the methods outlined in the applicable code therein. In addition, every effort shall be made to learn of any unusual characteristics which might influence the establishment of allowable stress levels for the material.

2.3.3 The higher allowable stress intensities of the ASME BPVC Section VIII, Division 2 shall be used only if all other requirements (e.g. design, materials, fabrication and inspection) of the division are met.

2.4 SUPPORTS AND WELDED ATTACHMENTS.

2.4.1 External Loads. External loads shall be considered in the design of all vessels. In the case where existing vessels are reused, these loads must be considered to determine if the vessel and its supports are adequate for the intended service. The latest edition of the International Building Code (IBC) shall be used to establish wind, ice, snow, and earthquake loads. For AEDC service, the design Wind Speed of 90 mph, Snow Load of 10 psf and Seismic Zone 1 shall be used unless otherwise specified.

2.4.2 Supports. Supports shall be designed as to cause no excessive localized bending or flattening of the vessel or harmful thermal gradients as determined by satisfying the requirements of the applicable ASME BPVC.

2.4.3 Attachments to Pressure Vessels. Process piping, conduits or other supports and attachments shall not be welded directly to the vessel if it can be avoided. If it cannot be avoided then stresses resulting from these attachments under both operating and hydrostatic test conditions shall be included in the combined stresses and considered in establishing the integrity of the vessel in accordance with the applicable ASME BPVC.

a. Integral attachments shall be of materials which are compatible for welding to the vessel. Preheating, welding and post heat treatment shall be in accordance with the applicable ASME BPVC.

b. Design temperatures for components or hangers in direct contact with the vessel shall be the design temperature of the vessel wall.

2.4.4 Metal Support Structures. All metal support structures shall be designed in accordance with the latest editions of the AISC Specifications and AISC Manual of Steel Construction (Allowable Strength Design).

2.4.5 Concrete Supports or Footings. Concrete supports or footings for metal support structures shall be designed in accordance with the latest edition of ACI Standard 318, Building Code Requirements for Structural Concrete.

2.5 Windows. The design of windows used in pressure vessels is not specifically addressed in the ASME BPVC. Appendix D contains considerations for the design and inspection of windows for service in test cells and vacuum chambers at AEDC.

3.0 FABRICATION AND ERECTION

3.1 BY AEDC OPERATING CONTRACTOR

3.1.1 **General.** All fabrication, assembly and erection shall be in accordance with the applicable code as designated by paragraph 1.5 Applicable Codes.

3.1.2 **Welding.** All welders, welding operators, and welding procedures shall be qualified in accordance with the applicable code.

3.1.3 **Heat Treatment.** All heat treatment shall be performed in accordance with the applicable code.

3.2 BY OUTSIDE CONTRACTORS

3.2.1 For pressure vessels fabricated or erected for service at AEDC by outside firms working under contract to AEDC or to any governmental agency, the relationships and design engineering responsibilities between AEDC and the vessel fabricator or erector shall be clearly defined in the contract and shall include all requirements of paragraph 3.1.

3.2.2 Pressure vessels shall be code stamped and registered with the National Board.

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4.0 INSPECTION AND TESTING

4.1 ACCEPTANCE INSPECTION

All inspections shall be performed in accordance with the applicable section of the ASME BPVC. Certification requirements are listed in Section 5 of this Standard.

4.2 TESTING

4.2.1 Pressure Testing (Hydrostatic & Pneumatic). All pressure testing shall be performed in accordance with the applicable code per Paragraph 1.5 and AEDC SHE Standard D2. A system safety hazard analysis shall be performed to assess risk and shall be documented on an approved pressure test certificate in accordance with AEDC SHE Standard D2 prior to performing the test.

4.2.2 Hydrostatic Testing. The vessel support system shall be evaluated to ensure that vessel buckling will not occur during the hydrostatic test. 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.

4.2.3 Pneumatic Testing. 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. A pneumatic pressure test is permitted only when one of the following prevails:

a. Pressure Vessel cannot be safely filled with water or liquid due to the design of the vessel and support system

b. Pressure Vessel 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 General Guidance on Pressure Testing Separation Distance. The method as outlined in the AEDC-SHE-STD-D2 provides a conservative approach to estimate the minimum safe distance from an article undergoing a pneumatic test to any personnel.

4.2.5 New Vessels. All new pressure vessels that were designed and fabricated in accordance with ASME BPVC requirements shall satisfy the requirements for pressure tests as given in the applicable section of the ASME Code. (Reference: AEDC-SHE-STD-D2)

4.2.6 Used Vessels. Vessels which are certified using the procedure given in paragraph 5.0 shall satisfy the pressure tests requirements of the certification program.

4.2.7 Vessels subject to External Pressure (vacuum service). Vessels designed for external pressure only are outside the scope of the ASME BPVC and thus, there is no code requirement to perform a pressure test. A positive pressure leak test, negative pressure leak test, or a vacuum test may be performed to confirm vessel integrity.

4.2.8 Impact Testing. Materials for all vessel components which are subject to stress due to pressure shall meet the impact test requirements of the ASME BPVC Section VIII unless governed by another code per Appendix A.

5.0 CERTIFICATION REQUIREMENTS

5.1 INTRODUCTION

A pressure vessel is certified when inspection, analysis, and testing are performed and documented in accordance with the requirements of this section. Certification of a new vessel may be performed by outside contractors who design, fabricate, inspect, test and place the vessel into an in-service inspection/test program prior to operation. Certification of a used vessel, whose history is not well documented, may be accomplished through reverse engineering/analysis, inspection, and test. Certification documentation for all pressure vessels, provided in a Certification Report, shall be retained by the AEDC Operating Contractor. The latest revision of API 510 and 579 can be used as a guide for maintenance inspection, repair, alteration, and rerating procedures for pressure vessels.

5.2 CERTIFICATION REPORT

The Certification Report includes documentation verifying that a pressure vessel has been designed, manufactured, inspected, and tested in accordance with this Standard and is safe for operation at AEDC. The format and content of the Certification Report are as follows:

5.2.1 **Section 1**. **Introduction. System Description**. This section shall include a description of the vessel, the system of which it is a component, and the design and operating conditions of the vessel and system for both new and used vessels. In addition, it should include any documentation of the history of the vessel, such as its point of origin, operational history, repairs, and alterations since original manufacture. A system specification, purchase description, schematic, preventive maintenance record (AEDC CMMS), or other records may be used to fulfill the requirement.

5.2.2 **Section 2. Identification.** This section shall include Manufacturer's fabrication drawings, Mill Test Reports, records of heat treatments, mechanical test records, Welding Procedure Specifications and Welding Procedure Qualification Records, and Manufacturer’s Data Reports for new vessels. For used vessels, the documentation may not be available and will require additional information specified in 5.2.3. Required data for new vessels includes:

a. Designer, manufacturer, inspector, and tester's name and address.

b. Procuring specification or contract.

c. Revision of drawings for which the vessel was designed and fabricated.

d. Drawing numbers.

e. Dimensions and details of fabrication sufficient to determine component thicknesses.

f. Design code (including section, division, revision date, and applicable addenda), or design basis.

g. Corrosion allowance

h. Identification of materials and their yield and ultimate tensile strength values.

i. Efficiency of welded joints

j. Method and extent of non-destructive examinations performed including acceptance and rejection criteria.

k. Types of pressure tests (e.g., pneumatic, hydrostatic) performed including location and date of test(s).

l. National Board Forms U-1, U-2, etc.: When a new, ASME Code stamped pressure vessel is purchased, the AEDC Operating Contractor shall retain (file records in AEDC CMMS) ASME Code Stamp information and design or other technical information that establishes certification for safe operation.

5.2.3 **Section 3. Evaluation and Analysis.** This section shall include calculations performed to develop new vessel design or verify used vessel design. When certification of a used vessel is required, cyclic conditions and operating environments shall be included in the evaluation and analysis. A combination of fatigue, fracture mechanics and finite element analyses may be used to analyze indications identified during nondestructive evaluation (NDE).

5.2.4 **Section 4. Inspection and NDE.** This section shall include inspection and NDE Plans and Reports prepared by the manufacturer or inspector. It shall also include radiographic film to be retained by the user for the life of the vessel or as specified in the system/vessel ISI/T Plan. New vessels shall meet inspection and NDE requirements identified in the ASME Code Section V and Section VIII. Used vessels shall meet those required for a new vessel plus:

a. **Visual Inspection (VT).** Detailed internal and external visual inspection. May require equipment such as bore scopes, flashlights, pit gauges, etc. to perform inspection.

b. **Magnetic Particle Test (MT).** All nozzle and support welds and areas that are suspect due to repairs, alterations, and anomalies detected during visual inspection. Liquid penetrate test (PT) shall be substituted if the vessel is manufactured of a nonferrous material.

c. **Radiographic Test (RT).** All circumferential and longitudinal welds and nozzle welds designed such that radiographic testing is feasible. For multi-layered vessels, radiography of circumferential and nozzle welds is required however; radiography of the longitudinal welds is not required.

d. **Ultrasonic Thickness Test (UTT).** At least 12 areas per head and 20 areas on the shell sections for documentation and verification. The extent necessary for dented areas and areas of suspect thinning will be determined on a case-by-case basis.

e. **Ultrasonic Shear Wave Test (UT).** Although radiography is the preferred volumetric examination method, in some cases ultrasonic shear wave may be substituted or used to augment radiography.

5.2.5 Section 5. Deficiency Correction. Documentation of repairs made as a result of inspection or analysis in 5.2.2, 5.2.3, and 5.2.4. Documents shall include repair procedures used, NDE reports (including weld maps identifying repair locations and linking NDE reports to current weld configurations), revised drawings, and additional calculations as necessary.

5.2.6 Section 6. Final Certification Tests. Pressure vessel test certificates shall be completed for the appropriate test. This section shall include documentation verifying pressure vessel relief devices/pressure gauges have been pressure tested or calibrated for the intended service. Relief device certificates shall specify model number, serial number, set points, orifice size, flow capacity detected, and signature of test technician. Gauge certificates shall specify gauge number (or identification number), date calibrated, and signature of calibration technician.

5.2.7 Section 7. In-Service Inspection/Test Plan. This section shall include the ISI/T Plan developed for each pressure vessel certified. The format of the ISI/T report shall be in accordance with the requirements of AEDC-SHE-STD-D2.

5.2.8 Section 8. Summary of Conclusions and Recommendations. This section consists of any other additional data necessary to document the certification, such as a Physical Configuration Audit/Functional Configuration Audit (PCA/FCA) certificate.

5.3 IN-SERVICE INSPECTION/TEST (ISI/T)

To maintain confidence in the safety of certified pressure vessels, an in-service inspection test program shall be established and executed. The comprehensive ISI/T program will include certification based on and design or projected operating requirements, combined with the monitoring of defects permitted to remain in the vessels. Routine monitoring of known flaws, which were deemed to be acceptable with ISI monitoring, shall be performed to assure that the discontinuity has not progressed to an unacceptable condition. ISI/T program requirements and frequencies shall be based on the failure mechanisms (pressure, thermal, vibration, fatigue, corrosion, etc.), vessel configuration, and performance requirements. For more detailed information on ISI, refer to AEDC-SHE-STD-D2.

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6.0 IDENTIFICATION

6.1 VESSEL TAGS

The following pressure vessels shall be identified by attachment of a metal tag as illustrated in Appendix E:

6.1.1 All new pressure vessels that are procured without Code stamps.

6.1.2 All pressure vessels which have been certified in accordance with this standard.

6.1.3 The requirement for identification is not retroactive and does not apply to vessels installed before the date of issuance of this revision of this standard if used under service conditions originally established by the contract operators.

6.1.4 Tags shall not be attached to the pressure shell. They may be installed on the skirt, supports, jacket, or other permanent attachment to the vessel.

6.1.5 No paint, tape, or decals shall be used for marking directly on stainless steel and aluminum vessels.

6.2 PRESSURE SYSTEM COMPONENTS

All pressure system components associated with a pressure vessel shall be tagged in accordance with AEDC-ENGR-STD-T-3.

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7.0 TANK-MOUNTED AIR COMPRESSORS (TMACS)

7.1 SPECIFICATIONS

When practical, specify an air compressor unit with the compressor and air receiver mounted separately, such as on a skid, so fatigue cycling is minimized. When portability, space limitations, or other restrictions dictate a tank-mounted air compressor unit, use the following statement to assure ASME BPVC requirements are included:

The TMAC shall meet the requirements of the ASME BPVC as outlined in the California Code of regulations, Title 8, Chapter 4, Subchapter 1, Article 3, dated 1990. All documentation pertaining to Title 8 shall be provided with the TMAC at the time of delivery.

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APPENDIX A. APPLICATION OF NATIONAL CONSENSUS CODES, STANDARDS & LAWS

Vessel Type or System by Media	Design, Fabrication, Installation, Inspection, & Testing (1)	Operation & Maintenance (1)	Repair & Alteration, ISI (1,2)
Unfired Pressure Vessels, Multi-layer or Banded Vessels, modified DOT Cylinders & Tanks per paragraph 1.2.3	ASME B&PVC Section VIII	AEDC Standards (1)	ANSI/NB-23, ASME PCC-2, ASME PCC-3, AEDC T-1, API STD 510, API RP (572, 580, 581), API 579/ASME FFS-1
Compressed Air Receivers	ASME B&PVC VIII, 29CFR1910.169	29CFR1910.169 AEDC Standards (1)	ANSI/NB-23, ASME PCC-2, ASME PCC-3, API RP (580, 581), API 579/ASME FFS-1
Power Boilers	ASME B&PVC Section I	ASME B&PV Section VII AEDC Standards (1)	ANSI/NB-23, ASME PCC-2, ASME PCC-3, API RP 573
Heating Boilers	ASME B&PVC Section IV	ASME B&PV Section VI AEDC Standards (1)	ASME PCC-2, ASME PCC-3, ANSI/NB-23
Acetylene Cylinders	29CFR1910.102 & 1910.253, 49CFR100-180, CGA G-1	29CFR1910.102 & 1910.253, 49CFR100-180, CGA (G-1, P-1) AEDC Standards (1)	CGA (C-1, C-6, C-8, G-1, P-1) 49CFR100-180
DOT Cylinders & Tanks (mobile)	29CFR1910.101, 1910.106, 1910.110, 49CFR100-180, CGA C-1	29CFR1910.101, 49CFR100-180, CGA P-1 AEDC Standards (1)	29CFR1910.101, 49CFR100-180, CGA (C-1, C-6, C-8, P-1, S-1.1, S-1.2, S-1.3), ANSI/NB-23
Tanks (fixed)	29CFR1910.106, 1910.110, ASME B&PVC VIII, API SPEC (12B, 12D, 12F), API STD (620, 650)	AEDC Standards (1) API STD 2000	ANSI/NB-23, ASME PCC-2, ASME PCC-3 API 579/ASME FFS-1, API RP (575, 580, 581), API STD 653, SP001-03

Table 1. Application of National Consensus Code, Standards & Laws

Vessel Type or System by Media	Design, Fabrication, Installation, Inspection, & Testing (1)	Operation & Maintenance (1)	Repair & Alteration, ISI (1,2)
Hazardous Liquid Propellant Fuels and Oxidizers: Vessels/Systems • Alcohols • Alkyl Boranes • Anhydrous Ammonia • Aniline • Chlorine Trifluoride • Ethylene Oxide • Fluorine • Hydrazine • Hydrogen Peroxide • Monomethylhydradazine • Fuming Nitric Acids • Nitrogen Tetroxide • Pentaborane • Perchloryl Fluoride • Normal Propyl Nitrate • Unsymmetrical Dimethylhydrazine • Oxygen Difluoride	ASME BPVC Section VIII Div. 1 Part UW-2 “Service Restrictions” AFM 160-39, AFTO 00-25-223, ASME B31.3 – Category M	AEDC Safety Standard D2	ASME PCC-2, ASME PCC-3, API (570, 576, 574), ASME FFS-1/API 579, API RP (580, 581), ANSI/NB-23
Power Piping Systems • Steam (NBEP) • Condensate (NBEP) • Liquid Fuel to Boilers • Water at Steam Generating Station • Compressed air at Steam Generating Station • Central or District Heating • Steam generating station Hot water supply for central or district heating system and condensate	ASME B31.1	ASME B31.1 AEDC Standards (1)	ANSI/NB-23, ASME PCC-2, ASME PCC-3, API 579/ASME FFS-1, API RP (574, 576, 580, 581), API STD 570

Table 1. Continued

Vessel Type or System by Media	Design, Fabrication, Installation, Inspection, & Testing (1)	Operation & Maintenance (1)	Repair & Alteration, ISI (1,2)
Process Piping Systems • Cryogenic Fluids (except CO2, H2, and O2) • Potable Water (except plumbing) • Chilled Water • Brine • Air Supply or Exhaust System • Vacuum System • Hydraulic Actuator System • Liquid Propane Gas • Gasoline & Kerosene Hydrocarbon Jet Propulsion (JP) Fuels • Hydrocarbon Rocket Propulsion (RP Fuels) • Refrigerants Cryogenics • Radioactive Fluids • Nitrogen • Helium Gas • Water Containing Solids in Suspension • Chemicals • Fluidized Solids • Compressed air • Raw water	ASME B31.3	AEDC Standards (1)	ANSI/NB-23, ASME PCC-2, ASME PCC-3, API 579/ASME FFS-1, API RP (574, 576, 580 581), API STD 570

Table 1. Continued

Vessel Type or System by Media	Design, Fabrication, Installation, Inspection, & Testing (1)	Operation & Maintenance (1)	Repair & Alteration, ISI (1,2)
Carbon Dioxide (CO2) Systems	Design & Testing per NFPA-12 Fabrication, Installation & Inspection per ASME B31.1	NFPA 12	ANSI/NB-23, ASME PCC-2, ASME PCC-3, API 579/ASME FFS-1, API RP (574, 576, 580, 581), API STD 570
Hydraulic Systems	AEDC ENGR STD T-2	AEDC Standards (1)	ANSI/NB-23, ASME PCC-2, ASME PCC-3, API 579/ASME FFS-1, API RP (574, 576, 580 581), API STD 570
Hydrogen Systems - Liquid	ASME B31.12 (4) CGA G-5.4, NFPA 55, ANSI/AIAA G-095-2004, 29CFR1910.103 (3)	NFPA 50B, 55, ANSI/AIAA G-095-2004	ASME PCC-2, API 570
Hydrogen Systems - Gaseous	ASME B31.12 (4) CGA G-5.4, NFPA 55, ANSI/AIAA G-095-2004, 29CFR1910.103 (3)	NFPA 55 (50B), ANSI/AIAA G-095-2004	ASME PCC-2, API 570
Natural Gas Systems	Case 1: Commercial Utilities Supply to AEDC service interface (custody transfer point) Design & Testing per ICC International Fuel Gas Code Fabrication, Installation, & Inspection per ASME B31.3 Case 2: AEDC service/Boiler Piping ASME B31.1 Case 3: AEDC service/Process Heating ASME B31.3	AEDC Safety Standard D2	ASME PCC-2, ASME PCC-3, API 570, 576, 574, ASME FFS-1/API 579, API RP (580, 581), ANSI/NB-23

Table 1. Continued

Vessel Type or System by Media	Design, Fabrication, Installation, Inspection, & Testing (1)	Operation & Maintenance (1)	Repair & Alteration, ISI (1,2)
Oxygen Systems - Liquid	29 CFR1919.104, ASME B31.3, NFPA (53 55), ASTM G88, ASTM MNL 36, NASA GPR 8710.7, NASA STD 8719.12, NASA KSC-C-123J NASA GLM-QS-1700.1	ASTM MNL 36, and 29 CFR1919.104	29 CFR1919.104, ASME PCC-2, ASME PCC-3, API STD 570 ASTM MNL 36, and NFPA 50, NASA NSS 1740.15
Oxygen Systems - Gaseous	ASME B31.3 NFPA 53, 55, ASTM G88, ASTM MNL 36, and 29 CFR1919.104 NASA NSS 1740.15 NASA KSC-C-123H NASA GLM-QS-1700.1	ASTM MNL 36, and 29 CFR1919.104	ASME PCC-2, ASME PCC-3, API 570 ASTM MNL 36, and 29 CFR1919.104
Oxygen and Fuel Gas Systems For Welding, Cutting and Allied Processes	AWS/ANSI Z49.1, ASME B31.3, NFPA 51	NFPA 55	ANSI/NB-23, ASME PCC-2, ASME PCC-3, API 579/ASME FFS-1, API RP (574, 576, 580, 581), API STD 570
Risk Based Inspection	N/A	N/A	ASME PCC-3, API STD (510, 570), API RP (580,581)

Notes:

1. All PV/S at AEDC shall be operated, maintained, and inspected in compliance with AEDC-ENGR-STD-T-1, AEDC-ENGR-STD-T-2, AEDC-ENGR-STD-T-3, AEDC-ENGR-STD-T-5, AEDC-STD-CM-1, AEDC-STD-CM-2, AEDC-SHE-D2, AEDC-SHE-D3, AEDC-SHE-D4, AEDC-SHE-E3, AEDC-SHE-E4, AEDC-SHE-E11, AEDC-SHE-E13, and the Operating Contractor's procedures and work instructions as they are applicable to a particular system.
2. Original Code of Construction may be used for initial evaluation criteria.
3. OSHA 1910.103(b)(1)(iii)(b) calls for the use of ASME B31.1-1968 for hydrogen piping and tubing. AEDC uses ASME B31.12 which is generally applied in industry. ATA Safety requested a formal OSHA ruling on this issue in FY2009.
4. Systems installed prior to FY10 were designed, fabricated, installed, and tested in accordance with ASME B31.3.
5. Reference Table 2 - National Consensus Codes, Standards & Laws by Number & Title for complete title information.

Table 1. Concluded

Code/Standard Number	Title
29CFR1910.101	Compressed Gases (compressed gas cylinders)
29CFR1910.102	Acetylene
29CFR1910.103	Hydrogen (system)
29CFR1910.104	Oxygen (system)
29CFR1910.106	Flammable and combustible liquids
29CFR1910.110	Storage and handling of liquefied petroleum gases
29CFR1910.169	Air Receivers
29CFR1910.253	Oxygen-fuel gas welding and cutting
49CFR100-180	DOT Compressed Gas Cylinders
AEDC-ENGR-STD-T-1	AEDC Standard For Pressure Vessels
AEDC-ENGR-STD-T-2	AEDC Standard For Pressure Piping
AEDC-ENGR-STD-T-3	AEDC Standard For Engineering Design and Drafting Practices
AEDC-ENGR-STD-T-5	AEDC Standard For Welding Practices
AEDC-STD-CM-1	Configuration Management
AEDC-STD-CM-2	AEDC Systems Identification Standard (ASIS)
AEDC-SHE-D2	Pressure Vessels and Systems (PV/S)
AEDC-SHE-D3	Identification of Piping Systems
AEDC-SHE-D4	Compressed Gas Cylinders
AEDC-SHE-E3	Gaseous Hydrogen
AEDC-SHE-E4	Pyrophoric Fuels
AEDC-SHE-E11	Oil Pollutions and POL Storage Tank Management
AEDC-SHE-E13	Cryogenic Fluids
AFTO 00-25-223	Integrated Pressure Systems and Components (Portable and Installed)
AIAA G-095	Guide to Safety of Hydrogen and Hydrogen Systems
AIAA 74-364	Pressure Vessel Certification Based on Fracture Mechanics technology
ANSI/NB-23	National Board Inspection Code
API SPEC 12B	Specification for Bolted Tanks for Storage of Production Liquids
API SPEC 12D	Specification for Field Welded Tanks for Storage of Production Liquids
API SPEC 12F	Specification for Shop Welded Tanks for Storage of Production Liquids
API STD 510	Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration
API STD 570	Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems

Table 2. National Consensus Codes, Standards & Laws by Number & Title

Code/Standard Number	Title
API STD 620	Designs and Construction of Large, Welded, Low-pressure Storage Tanks
API STD 650	Welded Tanks For Oil Storage
API STD 653	Tank Inspections, Repair, Alteration, and Reconstruction
API STD 2000	Venting Atmospheric and Low-pressure Storage Tanks
API RP 572	Inspection of Pressure Vessels (Towers, Drums, Reactors, Heat Exchangers, and Condensers)
API RP 573	Inspection of Fired Boilers and Heaters
API RP 574	Inspection Practices for Piping System Components
API RP 575	Guidelines and Methods for Inspection of Existing Atmospheric and Low-pressure Storage Tanks
API RP 576	Inspection of Pressure-Relieving Devices
API RP 580	Risk-based Inspection
API RP 581	Risk-Based Inspection Base Resource Document
API RP 582	Welding Guidelines for the Chemical, Oil, and Gas Industries
API 579-1/ASME FSS-1	Fitness For Service
ASME BPVC Section I	Rules For Construction of Power Boilers
ASME BPVC Section IV	Rules For Construction of Heating Boilers
ASME BPVC Section VI	Recommended Rules For The Care and Operation of Heating Boilers
ASME BPVC Section VII	Recommended Guidelines For The Care of Power Boilers
ASME BPVC Section VIII Div 1	Rules For Construction of Pressure Vessels
ASME BPVC Section VIII Div 2	Alternative Rules For Construction of Pressure Vessels
ASME BPVC Section VIII Div 3	Alternative Rules For Construction of High Pressure Vessels
ASME B31.1	Power Piping
ASME B31.3	Process Piping
ASME B31.12	Hydrogen Piping and Pipelines
ASME PCC-2	Repair of Pressure Equipment and Piping
ASME PCC-3	Inspection Planning Using Risk-Based Methods
ASTM MNL 36	Safe Use of Oxygen and Oxygen Systems: Handbook for Design, Operation, and Maintenance
ASTM G88	Standard Guide for Designing Systems for Oxygen Service
AWS/ANSI Z49.1	Safety in Welding, Cutting and Allied Processes
CGA C-1	Methods For Pressure Testing Compressed Gas Cylinders
CGA C-6	Standards for Visual Inspection of Steel Compressed Gas Cylinders
CGA C-8	Standard for Requalification of DOT-3HT, CTC-3HT, and TC-3HTM Seamless Steel Cylinders
CGA G-1	Acetylene
CGA G-4.4	Oxygen Pipeline Systems
CGA G-5.4	Standard For Hydrogen Piping Systems at User Locations

Table 2. Continued

Code/Standard Number	Title
CGA G-5.5	Hydrogen Vent Systems
CGA G-5.6	Hydrogen Pipeline Systems
CGA-G-5.8	High Pressure Hydrogen Piping Systems at Consumer Locations
CGA P-1	Safe Handling of Compressed Gases in Containers
CGA S-1.1	Pressure Relief Device Standards Part 1 – Cylinders For Compressed Gases
CGA S-1.2	Pressure Relief Device Standards Part 2 – Portable Containers For Compressed Gases
CGA S-1.3	Pressure Relief Device Standards Part 3 – Stationary Storage Containers For Compressed Gases
NASA IFGC	International Fuel Gas Code
NASA KSC-C-123	Specification For Surface Cleanliness of Ground Support Equipment Fluid Systems
NASA NSS 1740.15	Cryogenic Safety
NASA STD 8719.12	Safety Standard for Explosives, Propellants, and Pyrotechnics
NASA NSS 1740.15	Safety Standard For Oxygen and Oxygen and Oxygen System (CANCELLED ASTM MNL36)
NASA KSC-C-123J	Specification For Surface Cleanliness of Ground Support Equipment Fluid Systems
NFPA 51	Standard for the Design and Installation of Oxygen – Fuel Gas Systems for Welding, Cutting, and Allied Processes
NFPA 53	Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres
NFPA 55	Compressed Gases and Cryogenic Fluids Code
SP001-03	Standard For Inspection of In-Service Shop Fabricated Aboveground Tanks For Storage of Combustible and Flammable Liquids

Table 2. Concluded

APPENDIX B. GUIDANCE FOR DESIGN AND CONSTRUCTION OF DUCTING

The design and construction of ducting, especially for process air service at AEDC, must be robust and highly reliable. Failure of a duct could render a test facility inoperable for months to complete repairs.

There is no single applicable code or standard that addresses all aspects of the design and construction of ducting. Pressure, temperature, mass flow rate, and other design requirements for process air ducting are generally beyond the scope of ASHRAE design standards. For relatively small diameter ducting, the ASME B31.3 Process Piping Code provides suitable design rules and methods using "listed components" from referenced standards. For example, ASME B16.47 Large Diameter Steel Flanges lists standard sizes up to 60 inch diameter with predetermined pressure ratings. Items that are beyond the scope of the referenced standards are referred to as "unlisted components" and the designer is directed by B31.3 to fulfill the design requirements of Section 304 "Pressure Design of Components". Where Section 304 rules do not apply, B31.3 directs the designer to the ASME BPVC for alternate methods such as:

1. Determination of wall thickness and stiffening requirements for straight, curved, and mitered segments of pipe under external pressure using the procedure as described in Section VIII, Division 1, Part UG
2. Design of flanges not manufactured in accordance with listed standards using the procedures of Section VIII, Division 1, Appendix 2 or Appendix Y
3. Fatigue analysis using the methods of Section VIII, Division 2 or Division 3
4. Finite element analysis with results evaluated as described in Section VIII, Division 2, Part 5 but using B31.3 basic allowable stresses
5. Experimental stress analysis as described in Section VIII, Division 2
6. Proof testing in accordance with Section VIII, Division 1, UG-101

A significant percentage of process air ducting at AEDC is larger in diameter than can be designed using listed components from B31.3. Due to the potentially large volume of stored energy within this ducting, the design methodology of the ASME BPVC has been extensively employed. Section VIII Division 1 uses the "design by rule" approach and is preferable to both Division 2 and B31.3 because it will typically yield a more conservative design. At temperatures below the range where creep and stress rupture strength govern, the Division 1 allowable membrane stress is based in part on maintaining a safety factor of 3.5 on tensile strength which is higher than either Division 2 at 2.4 or B31.3 at 3.0. Additionally, the design analysis and inspection requirements for Division 1 are much less demanding than for Division 2. Division 1 does not contain rules and methods for all aspects of ducting design and construction. However, in accordance with paragraph U-2(g) of Division 1, it does intend that the methods of design and construction chosen, in these circumstances, shall be as safe as those provided by the rules of the Division. If the alternative methods of Division 2 are employed for thickness design, then it is highly recommended that the Division 1 allowable stress values be used in lieu of Division 2 values. Otherwise, the increased inspection required by Division 2 must be performed. Rules and analysis methods from B31.3 for piping, WRC for nozzle design, and EJMA for expansion joint design, etc. are also used. Fabrication, inspection, and testing should follow the rules of Division 1 as closely as possible along with any additional requirements imposed by the design. These design and construction methods will be fully documented and approved by the Operating Contractor's design organization.

Component flexibility factors from ASME B31.3 are typically used in the determination of the overall ducting system flexibility and support loadings. In some cases, component flexibility factors are determined using finite element methods.

No code stamp is required for the ducting or its components with the exception of relief devices as prescribed in Appendix C - Relief Device Requirements.

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APPENDIX C. RELIEF DEVICE REQUIREMENTS

ASME BPVC Section VIII requires that all pressure vessels within its scope be protected from overpressure. At AEDC, this requirement shall be applied to both stamped and legacy un-stamped vessels.

1.0 DESIGN

Consider any event that might lead to overpressure and develop a means to mitigate that risk. Events to be considered include but are not limited to the following:

A. Loss of pressure control.

B. Loss of temperature control.

C. Upstream or downstream valve position.

D. Control system failure during operation of a vessel.

E. Change of fluid phase.

F. Ambient heating.

G. Failure of a heat exchanger.

H. Fire.

To protect the vessel from overpressure, the Code allows for three approaches. A pressure relief device can be added to the vessel. Secondly, a pressure relief device can be installed in a piping system associated with the vessel in such a manner that both the piping system and the pressure vessel are protected. The third alternative for overpressure protection is by system design such that vessel is selected or designed to be inherently safe – i.e. with a higher pressure/temperature rating than it can possibly see during service.

If a relief device is used as protection from overpressure, then that device shall meet the requirements of ASME BPVC Section VIII. Historically at AEDC, code stamped relief valves and rupture discs are the typical choices except for limited use of locally designed non-Code reclosing hinged plate or guided plate pressure relief devices, discussed in paragraph 3.0 below.

The relief device selected shall have adequate flow capacity at its rated pressure to protect the vessel. The rated capacity of the device shall be greater than the maximum rated capacity of the upstream equipment or the maximum capacity of the upstream control device. If a vessel manufacturer is providing the relief device, then the procurement documents shall provide enough information for the relief device to be adequately sized.

There are a few limited exceptions to the use of relief devices where the hazards or environmental impact of a relieving event may create hazards greater than the overpressure. Refer to the Code for the exceptions and system requirements.

If a relief device is installed to protect a vessel, the designer is cautioned to consider the following in the installation:

A. Thrust loads generated by the relieving event and subsequent pipe supports loads. (Typically these loads can be reduced, but not eliminated, by using a pipe or tube tee at the exit.)
B. Thermal loads generated in the vent piping.
C. Blow back when slip elbows are used.
D. Hazards created by venting high energy fluids, asphyxiants, cryogenic, or flammable fluids.
E. Location of discharge point relative to personnel, particularly with regards to confined spaces.
F. Shields to protect equipment and/or personnel when a safe vent location is not available.
G. Effect of precipitation/environmental conditions on the device.
H. Access to remove the valve for periodic recertification.
I. Good piping practice leading into and out of the device to limit pressure drop and maintain good flow characteristics.
J. Set points should be staggered when multiple devices are installed.
K. Expansion cooling.
L. Resonant chatter.
M. Pipe organ effect with multiple valve installation of associated system piping.
N. Seat leakage from relief valves.

Rupture discs have additional limitations that need to be understood prior to use. These include:

A. Do not close after relief.
B. Burst pressure cannot be tested.
C. Require periodic replacement.
D. Sensitivity to mechanical damage.
E. Sensitivity to temperature.
F. Can be sensitive to vacuum.
G. Can discharge shrapnel.
H. Rupture-relief devices incorporating the reverse buckling/knife blade design shall not be used in liquid service.
I. Standard rupture discs should not be used in systems where the system pressure operates at or above 70 percent of the disc's rated value.
J. Composite rupture disc assemblies should not be used in systems where the system pressure operates greater than 80 percent of the disc's rated value.
K. Care should be exercised in specifying rupture disc temperature, i.e., rupture discs are rarely at system temperature and are normally close to ambient temperature. If the disc is selected based on the system temperature, it will probably cause the disc to fail at a system pressure higher than expected except for low temperature or cryogenic systems, where failure would occur at pressures lower than expected.

2.0 ASME CODE CASE 2203: OMISSION OF LIFTING DEVICE REQUIREMENTS FOR PRESSURE RELIEF VALVES ON AIR, WATER OVER 140^{O} F, OR STEAM SERVICE

The Code has specific manufacturing requirements for materials, flow ratings, set point tolerances, etc. In addition, for air, steam, and hot water, the Code obligates the valve manufacturer to include a lifting lever. A lifting lever is a feature used to confirm that the valve is able to lift and reset without taking a system off-line. At AEDC, this feature is not normally used since the entire valve is removed on a periodic basis and checked on a test bench or sent to an ASME Authorized facility to be re-certified. Provided the specific installation has documented procedures to perform periodic certification, the lifting lever can be omitted. To do so, the procurement documents must refer to ASME Code Case 2203. The following wording should be added to the procurement documents:

Lifting lever is omitted per ASME Code Case 2203.

3.0 NON-CODE RECLOSING HINGED PLATE OR GUIDED PLATE PRESSURE RELIEF DEVICES

Reclosing pressure relief devices of either hinged or guided plate configuration have been designed and used at AEDC to protect piping systems and related process equipment from overpressure when the use of rupture discs or relief valves was deemed to be impractical.

In either type, a plate rests upon a stationary flange and has one or more seals between, affixed to either the plate or the flange. The plate is designed to lift at a predetermined set point to provide venting for overpressure relief. Proper sizing of the plate for weight and the stationary flange port for cross-sectional area in conjunction with adequate travel distance of the plate from the flange is necessary to meet set point and flow capacity requirements. Each type is designed with mechanical stops to limit travel of the plate. The stop for the hinged type is designed to limit the arc of travel of the “flapper” plate to approximately 80 degrees such that, like the guided type, the plate will re-seat itself upon cessation of the overpressure event. In addition, the design may include devices such as springs to provide resistance to plate movement prior to reaching the set point and shock absorbers for the rising plate. To increase operational reliability, all seals should be checked and/or replaced on a periodic basis to minimize leakage and the tendency of the seal to adhere to the opposing surface.

Typically, the operating pressure range of hardware to be protected using a non-code relief device does not exceed 15 psi internal or external which is outside the scope of the Code. In this circumstance, relief pressure and flow capacity of the device may be verified by engineering analysis.

However, operation in excess of 15 psi is subject to the Code where only ASME BPVC relief devices may be used. For all new construction at AEDC, the decision to use a non-code relief device for service above 15 psi shall be deemed a deviation from the Code and shall be treated in accordance with paragraph 1.3 Deviations/Waivers. Documentation in support of the deviation must address performance verification of the relief device. In addition to engineering analysis, verification of pressure relief and flow capacity for the device shall be performed by testing and a copy of the test report must be included with the documentation.

The design of any non-code pressure relief device for use at AEDC shall be documented and approved by the Operating Contractor’s design organization.

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APPENDIX D. GUIDANCE FOR DESIGN AND INSPECTION OF WINDOWS

For service in test cells and vacuum chambers hereinafter referred to as test units, the design of windows constructed using brittle materials of low fracture toughness such as glass, fused quartz, and sapphire must be given special attention to minimize the possibility of fracture and sudden catastrophic failure.

1.0 DESIGN

The strength of a typical window material is highly dependent on the size, orientation, and distribution of flaws such as inclusions, occlusions, or micro cracks at or near the surface of the window in relation to the stress applied. Since the combined effects of these flaws upon the overall strength of a window may be difficult to ascertain, a conservative design approach is advised.

Historically at AEDC, for new window designs, the maximum allowable design tensile stress for static loading has been limited to no greater than the lesser of one-tenth of the material modulus of rupture or 1000 psi. A lower value for allowable design tensile stress may be required to account for material strength degradation due to window operation at elevated temperatures or exposure to water. Even at this low tensile stress level there is no guarantee that a failure will not occur. If the criticality of the window warrants the effort, it is recommended that a fracture mechanics analysis be performed to determine the tensile stress allowable based on the material fracture toughness, initial design flaw depth, and the required service life. NASA-STD-5018 and NASA-HDBK-5010 (see 3.0 References below) discuss appropriate safety factors and points of conservatism for the fracture mechanics analysis such as service life, design factors applied to loads, values for flaw length/depth ratio and shape factor, 100% moisture environment assumption, etc.

The design of windows should consider the following:

A. Application/Purpose (personnel stationed at window, photography, instrumentation, etc.).

B. Consequences of window failure (injury to personnel, damage to equipment and/or test article, effects of rapid pressurization or de-pressurization to vessel integrity, etc.).

C. Material selection (addressing both optical and mechanical/structural requirements).

D. Window geometry selection and material sizing (round is preferable if optical configuration and design will permit; rectangular should be avoided if possible).

E. Window support design: The window support frame should be designed to prevent glass-to-metal contact at the outer edge and the clamped surfaces. To minimize the potential for window damage during handling and installation/removal from the test unit, consider designing the window support as a bolted assembly that is more easily removable as one entity from the test unit, with lifting features if needed. The bolted assembly could be comprised of inner and outer frames with the inner frame closer to the test unit. The assembly would be designed to provide a controlled, uniform preload on the glass and prevent glass-to-metal contact under pressure loading. The outer frame could have an inverted L cross-section with the leg outboard of the edge of the glass making full metal-to-metal contact with the inner frame. A sufficient number of well distributed, properly torqued fasteners of adequate strength would be located in this leg. The window outer edge and portion of the window that will be clamped could be protected using rubber sheet gasket material. In addition, an O-ring and gland could be located on the surface of the inner flange that the window bears against. The dimensions of the outer frame would be such that, when metal-to-metal contact is achieved with the inner frame, the gasket material on each side of the glass will be compressed to a predetermined amount. The frame assembly could incorporate clearance holes in the inner and outer frames to accommodate screws that fasten it to the test unit flange. An O-ring and gland could be located on the test unit flange to prevent leakage. The inner flange could incorporate a water cooling passage if needed. This window support frame approach was used for the AEDC 12V Aerospace Research Chamber solar simulator window. See ARO, Inc. drawing 30A-1293.

F. Window pane failure modes such as

1. Surface micro-crack propagation under tensile loading over a period of time until the stress intensity at a crack tip exceeds the critical stress intensity and rapid failure occurs.

2. Impact by foreign object debris.

3. Foreign materials lodged between the window and its frame causing local stress risers and potential failure.

4. Foreign matter deposited on the window surface that could degrade the window's optical characteristics or absorb thermal energy from a light source directed through the window and potentially cause overheating, thermal stresses, and failure.

5. High stress concentrations due to undesirable window-to-metal contact.

6. High-energy laser applications and localized window absorption heating.

G. Survivability of window in an environment of excessive vibration.

H. Outgassing characteristics.

I. Potential for material strength reduction in the presence of water (liquid or vapor).

J. Strength reduction with temperature.

K. Thermal stresses resulting from heat sources/sinks.

L. Potential reactivity with other substances.

M. Flammability and heat softening.

N. Use of redundant structural window panes to maintain pressure conditions in the event either pane fails.

O. Use of non-structural panes laminated to the primary structural pane to protect it from damage due to scratches, debris impacts, etc. (with proper ventilation to accommodate pump downs and re-pressurization).

P. Features for personnel safety.

Q. Pressure testing of short duration using mounting hardware identical to the actual mounting hardware to demonstrate the structural adequacy of the window assembly before it is installed in the test unit. A proof test of short duration in an environment that will limit flaw growth during the test can also be performed for the purpose of screening for manufacturing flaws larger than the initial design flaw depth.

R. Beveling of window edges to reduce stress concentrations in those areas and diamond grinding of the perimeter during final fabrication to remove cracks/chips in critical stress locations.

S. Providing a protective cover for the window when not in use.

T. Susceptibility of gaskets to creep relaxation, chemical attack, overheating, etc.

2.0 INSPECTION

During the operational life of a window assembly, it should be inspected at a level of detail and frequency commensurate with its criticality as determined by the appropriate hazard analysis per SHE STD A-4 System Safety. The implementation of an in-service inspection plan is driven by the hazard analysis. If the hazard analysis concludes and documents that an in-service inspection plan with recurring inspection activity is not required, then the intent of this standard has been met.

For some applications, it might be necessary to inspect and photograph the window to establish a baseline flaw map prior to window installation as part of an in-service inspection plan. The plan might call for additional inspection and photography following window installation and prior to each facility operation to detect generation of new flaws and monitor growth of existing flaws. If, for the application, flaw growth is an important parameter to track, then the inspection method employed should be capable of detecting flaws that are equal to and larger than the initial design flaw depth. When performing a fracture mechanics analysis to predict remaining life of the window based upon this data, it is customary to use three times the total measured visible flaw depth for calculations since only a portion of the crack typically is visible.

An in-service inspection plan would typically address some or all of the following items as applicable and specify an approach for mitigating or eliminating the issues found:

A. Condition of the support frame, gasket/pot material and fasteners.

B. Surface impact damage.

C. Foreign matter on the window surface.

D. Signs of overheating or other distress.

E. Signs of metal-to-glass contact.

F. Foreign particles lodged in window frame.

G. Detection and mapping of new flaws (location and size) and monitoring growth of existing flaws. The location of the flaw is important with respect to the stress and can remain unchanged in areas of compressive stress.

H. “Go/No-Go” guidelines for window service and replacement based upon flaw size and window condition

For window cleaning activities, equipment and supplies should be selected that will not degrade structural or functional integrity.

3.0 REFERENCES

The following documents provide additional insight into the issues associated with windows constructed using brittle materials. Some of these documents include a list of references for further reading.

1. Doyle, Keith and Mark Kahan, Design strength of optical glass, SPIE, Vol. 5176, Optomechanics, 2003.

2. Dudzik, Michael, The Infrared and Electro-Optical Systems Handbook Vol. 4, Electro-Optical Systems Design, Analysis, and Testing, Chapter 3 Optomechanical System Design, Daniel Vukobratovich, ERIM and SPIE, available on DTIC, 1993.

3. Pigg, Orvis and Stanley Weiss, Apollo Experience Report – Spacecraft Structural Windows, NASA TN D-7439, 1973.

4. Robinson, James, Design of Viewing Windows for Controlled-Atmosphere Chambers, ORNL/TM-6864, 1980.

5. Steely, Sid, AEDC Criteria and Guidelines for Facility Window Applications, submitted to AF/AEDC Maintenance and Operations, 2008.

6. Willistein, Daniel, An Introduction to Optical Window Design, University of Arizona, 2006.

7. Fracture Control Implementation Handbook for Payloads, Experiments, and Similar Hardware, NASA-HDBK-5010, May 24, 2005.

8. Strength Design and Verification Criteria for Glass, Ceramics, and Windows in Human Space Flight Applications, NASA-STD-5018, 2011.

APPENDIX E. PRESSURE VESSEL IDENTIFICATION TAG

AEDC PRESSURE VESSEL

AEDC VESSEL NO. [1.] SERVICE [2.]

MANUFACTURER [3.] YEAR [4.]

MANUF. SERIAL NO. [5.]

CAPACITY [6.] CU. FT. DRY WT. [7.]

MAX. WORKING PRESSURE [8.] PSIG WHEN

WITHIN THE TEMPERATURES OF [9. --- 10.] F

HYDROSTATIC TEST PRESSURE [11.] PSIG

TEST DATE [12.] [12.] [12.]

Q/A CERT. [13.] [13.] [13.]

ASME NAT. BOARD NO. [14.]

1. Vessel number assigned by AEDC per AEDC-ENGR-STD-T-3
2. Type of media (Be specific - GN2, Methane, Air, etc.)
3. Manufacturer
4. Year of vessel manufacture
5. Manufacturer’s vessel serial number
6. Volume of vessel (cubic feet)
7. Weight of empty vessel (lbs)
8. Maximum allowable working pressure (MAWP) or design pressure (psig)
9. Minimum Operating temperature l (°F) at MAWP or design pressure
10. Maximum Operating temperature (°F) at MAWP or design pressure
11. Pressure (psig) at which vessel was last tested
12. Dates when the vessel was tested.
13. Agency performing Q/A.
14. The National Board Number.

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