BY ORDER OF THE COMMANDER
AIR FORCE SPACE COMMAND

AIR FORCE SPACE COMMAND
MANUAL 91-710, VOLUME 3

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Safety

RANGE SAFETY USER REQUIREMENTS MANUAL VOLUME 3 – LAUNCH VEHICLES, PAYLOADS, AND GROUND SUPPORT SYSTEMS REQUIREMENTS

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This manual implements Department of Defense Directive (DoDD) 3100.10, *Space Policy*, DoDD 3200.11, *Major Range and Test Facility Base*, DoDD 3230.3, *DoD Support for Commercial Space Launch Activities*, Air Force Policy Directive (AFPD) 91-1, *Nuclear Weapons and Systems Surety*, AFPD 91-2, *Safety Programs*, AFI 91-202, *The US Air Force Mishap Prevention Program* and the *Memorandum of Agreement between the Department of the Air Force and the Federal Aviation Administration on Safety for Space Transportation and Range Activities*. This volume contains information previously found in Eastern and Western Range 127-1, Chapter 3, *Launch Vehicle, Payload, and Ground Support Equipment Documentation, Design, and Test Requirements*. It establishes the system safety program requirements, minimum design, test, inspection, hazard analyses, and data requirements for hazardous and safety critical launch vehicles, payloads, and ground support equipment, systems, and materials for Air Force Space Command (AFSPC) ranges, including the Eastern Range (ER) and Western Range (WR). The following topics are addressed: general design policy, documentation requirements, pad safety console, material handling equipment, acoustic hazards, non-ionizing radiation sources, radioactive (ionizing radiation) sources, hazardous materials, ground support pressure systems, flight hardware pressure systems, ordnance systems, electrical and electronic equipment, motor vehicles, computer systems and software, seismic design criteria (WR only), and solid rocket motors and motor segments.

This volume applies to all Range Users conducting or supporting operations on the AFSPC ranges. Range Users include any individual or organization that conducts or supports any activity on resources (land, sea, or air) owned or controlled by AFSPC ranges. This includes such organizations as the Department of Defense (DoD), United States (US) government agencies, civilian launch operators, and foreign government agencies and other foreign entities that (1) use AFSPC range facilities and test equipment; (2) conduct prelaunch and launch operations, including payloads to orbital insertion or impact; and/or (3) require on-orbit or other related support. Commercial users intending to provide launch services from one of the ranges shall have a license or license application in process from the Department of Transportation's Federal Aviation Administration (FAA) or have a DoD sponsorship and be accepted by the DoD to use the ER or WR. Foreign government organizations or other foreign entities shall be sponsored by an appropriate US government organization or be a customer of a Range User. This volume applies to the Air National Guard. It does not apply to the Air Force Reserve Command.

In accordance with AFSPCI 91-701, *Launch and Range Safety Program Policy and Requirements,* all tailored versions of AFSPCMAN 91-710 are approved by the Space Wing Commander. The authorities to waive wing/unit level requirements in this publication are hereby identified as Tier 3 (“T-3”). See the AFSPC supplement to AFI 33-360, *Publications and Forms Management,* for a description of the authorities associated with the Tier numbers. Submit waivers through the chain of command to the appropriate Tier waiver approval authority through publication Office of Primary Responsibility (OPR). Ensure all records created as a result of the processes prescribed in this publication are maintained in accordance with (IAW) Air Force Manual (AFMAN) 33-363, *Management of Records,* and disposed of IAW Air Force Records Information System (AFRIMS) Records Disposition Schedule (RDS). Refer recommended changes and questions about this publication to the OPR using the AF Form 847, *Recommendation for Change of Publication*; route AF Forms 847 from the field through the appropriate functional chain of command.

This publication may be supplemented at any level, but all supplements must be approved by HQ AFSPC Directorate of Safety (HQ AFSPC/SE), the OPR of this publication, prior to certification and approval. Each Wing may incorporate unique requirements into documents other than a supplement, such as an operating instruction, which is only required to be coordinated internally within the local wing/base organization structure and approved at the local level.

Note: Volume 1 includes a complete table of contents for all the volumes of AFSPCMAN 91-710. In addition, each individual volume contains its own table of contents. Volume 7 contains a glossary of references, acronyms and abbreviations, and terms for use with all the volumes. Special publication formatting features are described in section **1.2** of this volume.

SUMMARY OF CHANGES

This document has been substantially revised and must be completely reviewed. Major changes include: incorporates multiple years’ worth of change requests; updates numerous consensus industry standard references; eliminates unnecessary test requirements; adds lithium-ion battery requirements (consistent with current 30/45 Space Wing approaches); removes outdated information and terminology; clarifies various topics based on tailoring lessons learned from range users; and eliminates confusing and incorrect flow-chart guidance for test requirements and hazardous area classification.

Additionally, based on range user feedback, several sections of requirements tied to periodic and recurring test and inspection requirements (as opposed to initial design, qualification and acceptance testing) were identified as more appropriately placed in Volume 6.

In accordance with AFI 33-360, **Attachment 1** has been added to reflect Volume 7 contains the references, prescribed forms, and adopted forms for the entire AFSPCMAN 91-710 series.

Chapter 1

INTRODUCTION.

1.1. General.

1.1.1. All Range Users operating on the AFSPC ranges, including the ER and WR, are subject to the personnel and resource protection requirements of this volume to ensure safety by design, testing, inspection, and hazard analysis. Air Force occupational safety and health standards do not apply to contractors or contractor employees except where Air Force personnel or property are endangered or if specifically required by contract.

1.1.2. When government and third party personnel, government resources, and/or shared resources with commercial entities are not involved or exposed to hazards from an operation, or when Range User activities are contained within the boundary of their operations space and do not impact areas outside of their control, deviation from these requirements through the tailoring process is permitted.

1.2. Organization of the Volume.

1.2.1. Main Chapters. The main chapters of this volume include common requirements for all vehicle classes. Appendixes include additional requirements to supplement the main chapters.

1.2.2. Open Text. The open text contains the actual mandatory performance-based requirements. The only tailoring expected for these requirements would be the deletion of non-applicable requirements. For example, solid rocket motor performance requirements would be deleted for launch systems that do not use solid rocket motors.

1.2.3. Bordered Paragraphs.

1.2.3.1. Bordered paragraphs, identified as tables in this document, are non-mandatory and are used to identify some of the potential detailed technical solutions that meet the performance requirements. In addition, bordered paragraphs (or notes) contain lessons learned from previous applications of the performance requirement, where a certain design may have been found successful, or have been tried and failed to meet the requirement. These technical solutions are provided for the following reasons:

1.2.3.1.1. To aid the tailoring process between Wing Safety and Range Users in evaluating a potential system against all the performance requirements.

1.2.3.1.2. To aid Wing Safety and Range Users in implementing lessons learned.

1.2.3.1.3. To provide benchmarks that demonstrate what Wing Safety considers an acceptable technical solution/implementation of the performance requirement and to help convey the level of safety the performance requirement is intended to achieve.

1.2.3.2. The technical solutions in the bordered paragraphs may be adopted into the tailored version of the requirements for a specific program when the Range User intends to use that solution to meet the performance requirement. At this point, they become mandatory requirements to obtain Wing Safety approval. This process is done to:

1.2.3.2.1. Provide an appropriate level of detail necessary for contractual efforts and to promote efficiency in the design process.

1.2.3.2.2. Avoid contractual misunderstandings that experience has shown often occur if an appropriate level of detail is not agreed to. The level of detail in the bordered paragraphs is necessary to avoid costly out-of-scope contractual changes and to prevent inadvertently overlooking a critical technical requirement.

1.2.3.3. The Range User always has the option to propose alternatives to the bordered paragraph solutions. Range User proposed alternative solutions shall achieve an equivalent level of safety and be approved by Wing Safety. After meeting these two requirements, the Range User proposed solutions become part of the tailored AFSPCMAN 91-710 for that specific program.

1.2.3.4. Wing Safety has final decision authority in determining whether Range User proposed detailed technical solutions meet AFSPCMAN 91-710 performance requirements.

Chapter 2

RESPONSIBILITIES AND AUTHORITIES.

2.1. Wing Safety, 30th and 45th Space Wings.

2.1.1. Unless otherwise noted, all references to Wing Safety in this volume refer to the Systems Safety organizations of the 30th and 45th Space Wings. Wing Safety is also commonly referred to as Range Safety. The Wing Safety offices are responsible for the review and approval of the design, inspection, and testing of all hazardous and safety critical launch vehicles, payloads, and ground support equipment, systems, subsystems, and material to be used at the ER and WR in accordance with the requirements of this volume. The responsibilities of Wing Safety at the 45th Space Wing may also encompass designs of launch vehicles, payloads, ground support equipment, systems, subsystems and material used at the National Aeronautics and Space Administration (NASA) Kennedy Space Center (KSC). Specific responsibilities of Wing Safety include review and approval of documents such as Missile System Prelaunch Safety Packages (MSPSP), System Safety Program Plans (SSPP), test plans, test reports, and other documents as specified in this manual.

2.1.2. During the review and approval process, both Wing Safety and the Range User shall assure timely coordination with other Wing agencies as appropriate. Other Wing agencies include, but are not limited to, Radiation Protection Officer, Bioenvironmental Engineering, Civil Engineering, Environmental Planning, Explosive Ordnance Disposal, and the Fire Department.

2.2. Range User Responsibilities. Range Users are responsible for establishing and maintaining a system safety program in accordance with AFSPCMAN 91-710 Volume 1, section 2.5.2 (as described in Volume 1 Attachment 3 and **Chapter 4** of this volume). The design, inspection, and testing of all hazardous and safety critical launch vehicle, payload, and ground support equipment, systems, subsystems, and materials to be used at the ranges shall be in accordance with the requirements of this volume, to include documentation as described in **Chapter 4** and **Attachment 2** of this volume. These responsibilities include the following:

2.2.1. Timely submission of an SSPP.

2.2.2. Timely submission of hazard analyses.

2.2.3. Timely submission of all required MSPSPs.

2.2.4. Timely submission of all MSPSP associated test plans and reports.

2.2.5. Coordinating with and supporting Wing Safety in carrying out tasks necessary for Wing Safety approval of design, inspection, and testing.

Chapter 3

GENERAL DESIGN POLICY.

3.1. General.

3.1.1. All systems shall be designed to tolerate a minimum number of credible failures, based on the degree of fault tolerance required.

3.1.2. The number of design inhibits required to prevent an overall system failure or mishap is based on the failure or mishap result. Specific inhibit requirements are addressed in the design criteria for each of the systems addressed in this volume.

3.2. Systems Without Specific Design Criteria . Those systems that do not have specific design criteria or systems not addressed in this volume shall be designed to the following general criteria:

3.2.1. If a system failure may lead to a catastrophic hazard, the system shall have three inhibits (dual fault tolerant).

3.2.2. If a system failure may lead to a critical hazard, the system shall have two inhibits (single fault tolerant).

3.2.3. If a system failure may lead to a marginal hazard, the system shall have a single inhibit (no fault tolerant).

3.2.4. Probabilities of hazard occurrence associated with launch and reentry that can endanger a population shall be taken into consideration when determining the number of required inhibits. (See AFSPCMAN 91-710, Volume 1, Chapter 3, Table 3.1.)

3.2.5. Systems shall be able to be brought to a safe state with the loss of an inhibit.

3.2.6. All inhibits shall be independent and verifiable. Common cause failures shall be assessed in determining inhibit independence.

3.2.7. Design inhibits shall consist of electrical and/or mechanical hardware.

3.2.8. Operator controls shall not be considered a design inhibit. Operator controls are considered a control of an inhibit.

Chapter 4

DOCUMENTATION REQUIREMENTS.

4.1. System Safety Program Plan (SSPP) and Hazard Analyses.

4.1.1. Range Users shall develop a preliminary SSPP in accordance with AFSPCMAN 91-710 Volume 1, Attachment 3 and submit to Wing Safety for review and approval within 45 calendar days of the Program Introduction (PI) and a final SSPP at least 45 calendar days before any System Requirements Review (SRR) or equivalent program activity. **Note**: Range Users should submit the preliminary SSPP and Preliminary Hazard List (PHL) to Wing Safety prior to the commencement of the tailoring process or prior to the SRR, whichever occurs first.

4.1.2. Range Users shall develop and submit hazard analyses to Wing Safety for review and approval in accordance with AFSPCMAN 91-710 Volume 1, Attachment 3.

4.1.2.1. Wing Safety shall review and provide comments to each of the hazard analyses submittals at or before the appropriate SRR, Preliminary Design Review (PDR), and Critical Design Review (CDR).

4.1.2.2. Range Users shall not transport hazardous materials to the Range or commence hazardous operations prior to receiving final approval of hazard analysis reports.

4.1.2.3. SSPPs and hazard analyses for DoD programs shall comply with MIL-STD-882, *Department of Defense Standard Practice for System Safety*, data requirements, or commercial equivalent for commercial FAA-licensed programs.

4.2. Missile System Prelaunch Safety Package (MSPSP).

4.2.1. MSPSP Submittal, Review, and Approval Process.

4.2.1.1. Range Users with overall responsibility for the launch vehicle, reusable launch vehicle, payload, or ground support systems shall submit an MSPSP; for commercial payloads, the payload MSPSP is normally submitted to Wing Safety through the launch vehicle contractor.

4.2.1.2. Incremental draft versions of the MSPSP shall be delivered to Wing Safety at least 45 days prior to the SRR, PDR, and CDR, or equivalent program activities.

4.2.1.3. Wing Safety shall review and provide comments to each of the MSPSP submittals at or before the appropriate SRR, PDR, and CDR, or equivalent program activities.

4.2.1.4. A final MSPSP that satisfies all Wing Safety concerns addressed at the CDR shall be submitted to Wing Safety at least 45 calendar days prior to the Pre-Ship Review (PSR) or equivalent program activity.

4.2.1.5. Wing Safety shall review the final MSPSP and if the MSPSP is found to be satisfactory, approve it within 10 calendar days of receipt. The final MSPSP shall be approved before shipment of associated hardware to the ranges.

4.2.2. MSPSP Preparation. Requirements for preparing an MSPSP can be found in **Attachment 2** of this volume.

4.3. Missile System Prelaunch Safety Package (MSPSP) Associated Test Plans and Test Results.

4.3.1. All MSPSP associated test plans shall be submitted at least 45 calendar days before the intended test plan use. Range User requests to eliminate or reduce testing shall be justified with clear and convincing evidence presented to the SW/CC for approval. The SW/CC may delegate approval authority to Wing Safety.

4.3.2. Wing Safety shall review and comment on or approve test plans within 45 calendar days of receipt. Disapproved test plans shall be corrected and resubmitted. An approved test plan is required before test performance.

4.3.3. Test reports shall be submitted at least 45 calendar days of intended system use.

4.3.4. Wing Safety shall review, comment, and approve test reports within 10 calendar days of receipt. Disapproved test reports shall be corrected and resubmitted. An approved test report is required before system use.

4.4. Nondestructive Examination (NDE) Plans.

4.4.1. Unless otherwise specified in a separate part of this document that addresses a particular class of system or equipment, a nondestructive examination (NDE) plan shall include the following:

4.4.1.1. NDE technique and acceptance criteria to be used on each single failure point (SFP) component or SFP weld after initial and periodic proof load tests.

4.4.1.2. Detailed engineering rationale for each technique and acceptance criteria. **Note**: Detailed engineering rationale may include manufacturer stated requirements/recommendations or recognized industry standards such as American National Standards Institute (ANSI) and the American Society of Mechanical Engineers (ASME).

4.4.1.3. A determination of whether the equipment is dedicated to only one function or whether it is multipurpose.

4.4.1.4. The environment and/or conditions under which the equipment will be used and stored.

4.4.1.5. The existence of any SFP component and weld materials susceptible to stress corrosion.

4.4.1.6. Corrosion protection and maintenance plans.

4.4.2. Unless otherwise specified in a separate part of this document that addresses a particular class of system or equipment, the NDE plan shall be submitted to Wing Safety for review and approval as soon as developed and no later than the program PDR, unless otherwise agreed to by Wing Safety.

Chapter 5

PAD SAFETY CONSOLE.

5.1. Pad Safety Console General Design Requirements.

5.1.1. Each launch control center, blockhouse, and firing room, as applicable, shall provide for a Pad Safety Console (PSC). MIL-STD-1472, *Human Engineering Design Criteria for Military Systems, Equipment, and Facilities*, shall be used as appropriate in designing the PSC. **Note:** The term 'Pad Safety Console' has also been known in the past as 'Operations Safety Console'; the terms shall be considered interchangeable.

5.1.2. The Range User (normally the launch vehicle provider) shall provide an ER/WR PSC unless otherwise agreed to by Wing Safety. Wing Safety shall approve the design, operation, and maintenance of the PSC.

5.1.3. The Range User shall provide ample and satisfactory space to install and operate the console.

5.1.4. No SFP components shall be in the ground support equipment (GSE) or firing room/launch control center/blockhouse system that will cause the loss of a safety critical system control or monitor (as determined by Wing Safety) at the PSC.

5.2. Pad Safety Console Controls, Monitors, and Communication Lines.

5.2.1. The PSC shall be in a dedicated position to provide the Pad Safety Supervisor/Pad Safety Officer sufficient information and communications capability to convey safety status and conditions to the appropriate authority (e.g., the launch complex control authority for day-to-day operations and the Mission Flight Control Officer [MFCO] during a launch operation).

5.2.2. At a minimum, the controls, monitors, and communication lines listed below are required at the launch complex PSC. These items are general in nature and may vary depending on the launch facility and/or launch vehicle configuration. The monitor circuit shall be designed so that the actual status of the critical parameters can be monitored rather than the command transmittal. It is important that this console does not have any flight termination system (FTS) command transmittal functions.

5.2.2.1. FTS safe and arm status for all FTS safe and arm devices.

5.2.2.2. Ignition safe and arm status for all solid rocket motor safe and arm devices.

5.2.2.3. An enable control switch and status for all solid rocket motor arming devices.

5.2.2.4. Launch vehicle liquid propulsion system inhibits and propellant tank pressure status (psig).

5.2.2.5. Fire suppression system status.

5.2.2.6. Launch complex warning beacon and horn control switch and status.

5.2.2.7. Emergency and normal electrical power status for critical locations.

5.2.2.8. Wind speed and direction readouts.

5.2.2.9. Communications Control Panel.

5.2.2.9.1. At least one Class A dial line.

5.2.2.9.2. Audio-selector push buttons for intercom net and direct lines in which four channels can be accessed simultaneously.

5.2.2.9.3. Direct line to the MFCO.

5.2.2.9.4. Direct line to the RCO.

5.2.2.9.5. Direct line to the Range Safety representative.

5.2.2.9.6. Direct lines to Test Conductor and Launch Control Officer.

5.2.2.9.7. Direct line to primary access control point for safety control areas.

5.2.2.9.8. Direct line to facility safety net.

5.2.2.9.9. Direct line to Launch Support Team Chief and fallback area.

5.2.2.9.10. Access to facility public address (PA) system with emergency override capability.

5.2.2.9.11. Radio frequency (RF) nets, as required.

5.2.2.9.12. Direct line to the Launch Director.

5.2.2.9.13. Direct line to the Aeronautical Control Officer (ACO).

5.2.2.9.14. Particular communication equipment as specified in applicable Range Safety Operations Requirements (RSOR).

5.2.2.10. Master countdown status.

5.2.2.11. Holdfire (stop launch sequencer) control switch, for pad launches only, active through T-0 (for ER only).

5.2.2.12. Ignition firing line enable and disable control switch and status.

5.2.2.13. Holdfire status.

5.3. Pad Safety Console Color Television System.

5.3.1. A PSC color television system shall be provided to ensure the coverage necessary to view all hazardous operations in the launch complex. **Note**: various feeds (e.g., infrared camera) may be desired for monitoring specific hazards.

5.3.2. Control of the television system shall be available at the PSC.

5.4. Pad Safety Console Communication and Video Recording.

5.4.1. The PSC shall be capable of recording and playback of hazardous operations.

5.4.2. Communication and video recording requirements shall be coordinated with the launch controller and test conductor before the start of an operation.

5.4.3. Designated recordings shall remain on file for 180 days.

5.5. Pad Safety Console Validation and Test Requirements.

5.5.1. At a minimum, a PSC validation and checkout test shall be performed to demonstrate the following:

5.5.1.1. The correct and reliable operation of PSC functions.

5.5.1.2. The validity of PSC outside interfaces.

5.5.1.3. The operating limits of the PSC.

5.5.2. Test plans, procedures, and test results shall be reviewed and approved by Wing Safety.

5.6. Pad Safety Console Data Requirements. PSC data requirements are identified in **Attachment 2**, **A2.2.5.16** of this volume.

Chapter 6

MATERIAL HANDLING EQUIPMENT, CRANES AND HOISTS, AND PERSONNEL WORK PLATFORMS.

6.1. Overview.

6.1.1. This chapter is divided into three major types of equipment: material handling equipment (MHE), cranes and hoists, and personnel work platforms.

6.1.2. MHE is comprised of below-the-hook lifting devices (BTHLD), handling structures, support structures, slings, load positioning (e.g., Hydra Set ®) and load indicating devices (LID), lifting assemblies, and rigging hardware. Slings, BTHLDs, lifting assemblies, rigging hardware, and LIDs are governed by industry standards (e.g., Occupational Safety and Health Administration [OSHA], ASME). Handling structures, support structures, and load positioning devices are governed by accepted engineering practices and requirements of this Chapter. Data requirements are provided in **Attachment 2** of this volume. These requirements are applicable to new or modified MHE. The requirements are also applicable to permanent or short-term use MHE and apply whether the equipment is owned, rented, or leased by the government, contractors, or commercial operators. Periodic/recurring test and inspection requirements are found in AFSPCMAN 91-710 Volume 6.

6.2. Material Handling Equipment (MHE). The design and initial test requirements for MHE used at the ranges for handling (lifting, supporting, or manipulating) critical and non-critical hardware are included below.

6.2.1. MHE General Requirements.

6.2.1.1. MHE Requirements Validation.

6.2.1.1.1. The Range User shall validate the requirements by providing a Compliance Check List IAW Attachment 2, **A2.3**.

6.2.1.1.2. Supporting data for commercial-off-the-shelf (COTS) equipment shall include the following information:

6.2.1.1.2.1. COTS name, description, model number, and part number.

6.2.1.1.2.2. Rated capacity (allowable working load).

6.2.1.1.2.3. Certifications of compliance with industry consensus standards from a Nationally Recognized Testing Laboratory (NRTL), manufacturer, or other qualified organization.

6.2.1.1.2.4. MHE shall have documented traceability of material, manufacturer, and acceptance testing to required codes and standards (e.g., OSHA, ASME).

6.2.1.2. MHE Single Fault Tolerance.

6.2.1.2.1. Critical MHE shall be designed without single failure points (SFPs).

6.2.1.2.2. Exceptions shall be identified, justified, and submitted to Wing Safety for approval. Supporting data shall include the following information: (See also Attachment 2, **A2.2.5.6**)

6.2.1.2.2.1. A list of all identified SFPs.

6.2.1.2.2.2. Risk assessment.

6.2.1.2.2.3. Risk mitigation considerations and inhibits.

6.2.1.2.2.4. A map of SFP locations (for example, weld map, system components).

6.2.1.2.2.5. Inspection and NDE requirements.

6.2.1.2.3. SFP components and welds shall be accessible for nondestructive inspection, maintenance, and repair.

6.2.1.3. MHE Inspection and Test Requirements.

6.2.1.3.1. MHE Test Weights and Load Test Devices.

6.2.1.3.1.1. Load tests shall be conducted with certified weights and/or certified weight fixtures.

6.2.1.3.1.2. These weights shall be identified and permanently and clearly marked with the total weight and owner or agency identification number.

6.2.1.3.1.3. Reinforcing steel (rebar) shall not be used for lift points.

6.2.1.3.1.4. Calibrated load devices such as dynamometers may be used to test slings and other lifting devices except cranes and hoists.

6.2.1.3.1.5. Requirements for Fabrication of New Test Weights and Weight Fixtures.

6.2.1.3.1.5.1. Weight fixtures shall be designed and load tested IAW requirements contained in **6.2.3.1.**

6.2.1.3.1.5.2. Weight fixtures shall be designed so that the loaded fixture center of gravity is centered below the crane hook for all required weight combinations.

6.2.1.3.1.5.3. Lifting lugs shall be provided if required to enable handling of empty test weight fixtures.

Table 6.1. Attachment Point Preferences.

A single crane hook attachment point on the fixture (e.g., a screw operated pin) is preferable to multiple attachment points that require use of slings.

6.2.1.3.1.5.4. Weight interlocking features shall be provided on both the weight fixture and the weights to help prevent sliding of weights and to help even stacking.

6.2.1.3.1.5.5. Weight lifting lugs shall be proof tested to 125% of the total weight before initial weight use.

6.2.1.3.2. MHE NDE.

6.2.1.3.2.1. NDE plans shall be developed for MHE used to handle critical systems and equipment and MHE containing SFPs.

6.2.1.3.2.2. The NDE plan shall include detailed methodology, acceptance criteria, frequency of inspection, and a clear schematic showing the exact location of the items to be inspected. For details of the NDE plan, see section **4.4**.

6.2.1.3.2.3. NDE shall be performed by qualified and certified personnel IAW the written practices and requirements contained in the American Society for Nondestructive Testing (ASNT) SNT-TC-1A, *Recommended Practice for Personnel Qualifications and Certification in Nondestructive Testing*.

6.2.1.4. MHE Marking and Tagging Requirements.

6.2.1.4.1. Marking Requirements. All equipment (new and modified) shall be permanently marked IAW applicable codes and standards and have a permanently attached identification tag with the following information:

6.2.1.4.1.1. Manufacturer.

6.2.1.4.1.2. Part number.

6.2.1.4.1.3. Serial number.

6.2.1.4.1.4. Date of manufacture or initial acceptance.

6.2.1.4.1.5. Rated capacity.

6.2.1.4.1.6. Weights of the top assembly and separate subassemblies.

6.2.1.4.1.7. Weight of bridge and trolley (cranes only).

6.2.1.4.2. Tagging Requirements.

6.2.1.4.2.1. Systems/equipment requiring testing shall be tagged and test data included in its data package.

6.2.1.4.2.2. The tags shall be of durable material, preferably corrosion resistant metal, properly secured with corrosion and abrasion resistant wire or string, and marked (stamped or etched) with the following minimum information:

6.2.1.4.2.2.1. Part number, serial number, and other unique identifier (reference designator).

6.2.1.4.2.2.2. Date of most recent test.

6.2.1.4.2.2.3. Test load.

6.2.1.4.2.2.4. Date of next load test.

6.2.1.4.2.2.5. Date of most recent NDE (if applicable).

6.2.1.4.2.2.6. Date of next NDE (if applicable).

6.2.1.4.2.2.7. A quality assurance or quality control indication certifying data on the tag.

6.2.1.4.2.3. The tags shall be accessible for inspection.

6.2.1.4.2.4. If the assembly is to be disassembled after proof testing, each component and subassembly shall be individually tagged with the reference designator; for example, removal and separate storage of a shackle bolt from the shackle after the proof load.

6.2.2. Slings. A sling is a flexible lifting assembly used between the load and hoisting device hook, comprised of alloy steel chain, wire rope, natural or synthetic webbing or synthetic rope, or metal mesh, with supporting fittings and attachment hardware.

6.2.2.1. Sling Design Standards and Requirements.

6.2.2.1.1. Slings shall be designed, manufactured, maintained and stored in accordance with ASME B30.9, *Slings*, and 29 CFR 1910.184, *Slings*.

6.2.2.1.2. Carbon steel or wrought iron chain slings shall not be used.

6.2.2.1.3. Wire rope slings shall be formed with swaged or zinc-poured sockets or spliced eyes.

6.2.2.1.4. Wire rope clips or knots shall not be used to form slings.

6.2.2.1.5. All synthetic slings shall be designed with an ultimate factor of safety of 5 or higher.

6.2.2.1.6. Natural fiber rope or natural fiber web slings shall not be used.

6.2.2.1.7. Rotation resistant rope shall not be used for fabricating slings.

6.2.2.2. Sling Inspection and Test Requirements.

6.2.2.2.1. Before their first operational use at the ranges and following modifications or repairs, slings shall be inspected and tested to 200% of their rated load in accordance with ASME B30.9 and 29 CFR 1910.184.

6.2.2.2.2. For slings used to support critical operations, volumetric and surface NDE testing shall be performed on all sling assembly SFP components, such as pins, bolts, shackles, and links after the proof load test IAW the Wing Safety approved NDE plan.

6.2.3. Below-the-Hook Lifting Devices (BTHLD). BTHLDs are structural and mechanical lifting devices and equipment (except for slings, load positioning devices, and load cells) used to connect a crane/hoist hook and a load being lifted, including lifting beams (and arms) and attachment hardware such as bolts and pins (lifting assemblies). Standards for BTHLDs are covered by ASME B30.20, *Below-the Hook Lifting Devices*, but the device may contain components such as slings, hooks, and rigging hardware addressed by other ASME B30 series standards (*Safety Standard for Cableways, Cranes, Derricks, Hoist, Hooks, Jacks, and Slings*) or other standards.

6.2.3.1. BTHLD Design Standards and Requirements.

6.2.3.1.1. BTHLDs shall be designed by a structural engineer and manufactured to the specified rated loads and load geometry of Design Category B (with a minimum yield safety factor of 3) in accordance with ASME BTH-1, *Design of Below-the-Hook Lifting Devices*, and ASME B30.20.

6.2.3.1.2. Material used in the construction of BTHLDs shall exhibit a ductile failure mode (for example, ultimate strain not less than 20% elongation). The intent is to have advanced warning of an upcoming failure via visually detectable deformation of structural components.

6.2.3.2. BTHLD Inspection and Test Requirements.

6.2.3.2.1. Before their first operational use at the ranges and following modifications or repairs, BTHLDs shall be inspected and proof tested to 125% of the rated load in accordance with ASME B30.20 methodology and the Wing Safety approved NDE plan. The rated load shall not exceed 80% of the actual test load. If the BTHLD contains components such as slings and shackles, then these components shall be proof tested individually to their respective proof load levels (200% of the rated load for slings and shackles) and the whole assembly then proof tested to 125% of the rated load.

6.2.3.2.2. For BTHLDs used to support critical operations, volumetric and surface NDE shall be performed on all SFP components and welds after the initial proof load test IAW the Wing Safety approved NDE plan.

6.2.4. Handling Structures. Handling structures are those structures used to handle and manipulate hardware or equipment, such as spin tables, equipment racks, and rotating devices.

6.2.4.1. Handling Structure Design Standards and Requirements.

6.2.4.1.1. Handling structures shall be designed with a yield factor of safety of 3 based on rated loads.

6.2.4.1.2. Handling structures whose failure would not result or propagate into a catastrophic event may be designed to a yield factor of safety of 2 based on limit loads.

6.2.4.1.3. Handling structures at the WR shall be designed to accommodate the worst case seismic load IAW **Chapter 17**.

6.2.4.1.4. Material (including fittings and attachment hardware) used in the construction of handling structures shall exhibit a ductile failure mode (ultimate strain not less than 20% elongation). The intent is to have advanced warning of an upcoming failure via visually detectable plastic deformation of structural components. Exceptions may be considered with Wing Safety approval, on a case-by-case basis.

6.2.4.2. Handling Structure Inspection and Test Requirements.

6.2.4.2.1. Before their first operational use, all new, altered, modified or repaired handling structures shall be inspected IAW applicable industry methodology and the Wing Safety approved NDE plan and load tested to 150% of the rated load.

6.2.4.2.2. Handling structures designed to a factor of safety less than 3, but greater than or equal to 2, shall be initially inspected and load tested to 125% of rated load.

6.2.4.2.3. For handling structures used to support critical operations, volumetric and surface NDE shall be performed on all SFP components and welds after the initial proof load test IAW the Wing Safety approved NDE plan.

6.2.5. Support Structures. Support structures are those structures used to support hardware or equipment, such as support stands and fixed and portable launch support frames.

6.2.5.1. Support Structure Design Standards and Requirements.

6.2.5.1.1. Support structures shall be designed with a yield safety factor of 3 based on rated loads. **Note**: For large structures, requirements from American Institute of Steel Construction (AISC), American Society of Civil Engineers (ASCE) 7 and pertinent building codes may also be considered.

6.2.5.1.2. Support structures whose failure would not result or propagate into a catastrophic event may be designed to a yield safety factor of 2 based on rated loads.

6.2.5.1.3. Material (including fittings and attachment hardware) used in the construction of support structures shall exhibit a ductile failure mode (ultimate strain not less than 20% elongation). The intent is to have advanced warning of an upcoming failure via visually detectable deformation of structural components. Exceptions may be considered with Wing Safety approval, on a case-by-case basis.

6.2.5.1.4. Portable ground support equipment, such as equipment racks, shall be designed not to tip when fully loaded and/or moved. For heavy moveable support and handling equipment, lifting lugs and forklift handling, such as fork tubes, shall be incorporated to provide for safe handling.

6.2.5.2. Support Structure Inspection and Test Requirements.

6.2.5.2.1. Before their first operational use, all new, altered, modified, or repaired support structures designed to a yield factor of safety of at least 3 shall be inspected and load tested IAW applicable industry methodology and the Wing Safety approved NDE plan to 150% of rated load.

6.2.5.2.2. Support structures designed to a factor of safety less than 3, but greater than or equal to 2, shall be inspected and load tested to 125% of rated load.

6.2.5.2.3. For support structures used to support critical operations, volumetric and surface NDE shall be performed on all SFP components and welds after the initial proof load test IAW the Wing Safety approved NDE plan.

6.2.6. Load Positioning and Load Measuring/Indicating Devices (e.g., Hydra Set ®). Load positioning devices are mechanical devices (e.g., Hydra Set ®), attached to a crane/hoist hook, and used to make fine adjustments to the load position during lifting operations. Load indicating devices (LID) are mechanical devices (e.g., load cells, dynaometers), attached to a crane/hoist hook, and used to measure the weight of the load being lifted.

6.2.6.1. Load Positioning Device and LID Design Standards and Requirements. Load positioning device and LID design allows use for a range of loads, with a specification of not-to-exceed rating. These devices should be used within 20% to 80% range of their rated load capacity due to lower accuracy in the extreme low and high ranges of the rated load.

6.2.6.1.1. Load positioning device and LID design shall ensure that positive control is maintained at all times, and no actions are initiated or continued without the appropriate controls command being given.

6.2.6.1.2. Failure of the load positioning device or LID shall not result in dropping or un-commanded movement of the suspended or supported load.

6.2.6.1.3. Load positioning devices shall be designed with a minimum ultimate factor of safety of 5.

6.2.6.1.4. LIDs shall be designed in accordance with ASME B30.26, *Rigging Hardware*.

6.2.6.1.5. A load positioning device and/or LID inspection plan, identifying all SFP and NDE requirements, methodology, and acceptance criteria, shall be submitted to Wing Safety for review and approval.

6.2.6.2. Load Positioning Device and LID Inspection and Test Requirements.

6.2.6.2.1. Before their first operational use, new, altered, repaired, or modified load positioning devices and LIDs shall be inspected and load tested to 200% of rated load to verify controls and performance (for example, structural, mechanical, electrical). Load positioning devices and LIDs shall be load tested by the manufacturer or if authorized, IAW the manufacturer instructions to prevent system damage.

6.2.6.2.2. NDE shall be performed during inspection and test per the NDE plan.

6.2.6.2.3. For load positioning devices and LIDs used to support critical operations, volumetric and surface NDE shall be performed on all SFP components and welds after the initial proof load test IAW the Wing Safety approved NDE plan.

6.2.7. Rigging Hardware. Rigging hardware consists of shackles, links, rings, swivels, turnbuckles, eyebolts, hoist rings, wire rope clips, wedge sockets, rigging blocks, etc., and may be components of BTHLDs.

6.2.7.1. Rigging Hardware Design Standards and Requirements. All rigging hardware shall be designed, manufactured, handled, and stored in accordance with ASME B30.26. All hardware will be marked and identified accordingly.

6.2.7.2. Rigging Hardware Inspection and Test Requirements.

6.2.7.2.1. Before first use, all new, modified, or repaired rigging hardware shall be load tested to the proof loads specified in ASME B30.26 prior to initial use.

6.2.7.2.2. For rigging hardware used to support critical operations, volumetric and surface NDE shall be performed on all SFP components and welds after the initial proof load test IAW the Wing Safety approved NDE plan. Any rigging hardware meeting removal criteria outlined in ASME B30.26 shall be removed from service.

6.2.8. MHE Data Requirements. MHE initial data requirements shall be submitted IAW Attachment 2 of this volume, **A2.2.4.6.2** and **A2.2.5.6.** MHE periodic/recurring data requirements shall be submitted IAW requirements in Volume 6.

6.2.8.1. For MHE used in safety critical operations, provide initial proof load test plans and test results.

6.2.8.2. Data Requirements Submission for Major Item MHE Designs. Unless otherwise agreed to by Wing Safety and the Range User or otherwise stated in this Chapter, all design engineering documents pertaining to major MHE items, such as cranes, shall be submitted to Wing Safety for review and approval 30 days prior to the following design review meetings: introductory; conceptual (30%); preliminary (60%); critical (90%); and final (100%). All design engineering drawings and specification packages shall have a space or block on the first drawing sheet reserved for the approval signature of the 45 SW/SE or 30 SW/SE reviewing official. All Review Item Discrepancies (RID) shall be addressed at each design review and resolved as soon as possible.

6.3. Cranes and Hoists. The following design, fabrication, testing, data submittal and WR specific seismic requirements are applicable to cranes and hoists used to handle critical and noncritical hardware. The requirements in **6.3.1** through **6.3.4** are applicable to all cranes and hoists. Additional requirements for critical cranes and hoists are specified in **6.3.5**. Requirements for existing Real Property Installed Equipment (RPIE) crane and hoists are specified in **6.3.6. Note**: Range Users shall ensure that handling processes are designed such that all crane and hoist testing requirements are met. Requirements of Volume 6, Chapter 6 shall also be met.

6.3.1. Crane and Hoist Design Standards and Requirements.

6.3.1.1. Cranes and hoists shall comply with the requirements in the following industry standards, as applicable, and the additional requirements described below:

6.3.1.1.1. 29 CFR 1910.179, *Overhead and Gantry Cranes*.

6.3.1.1.2. AFMAN 91-203, *Air Force Occupational Safety, Fire, and Health Standards.*

6.3.1.1.3. Crane Manufacturers Association of America (CMAA) 70, *Overhead Cranes*, and CMAA 74, *Overhead Hoists*, for overhead cranes and hoists.

6.3.1.1.4. ASME B30 series safety standards.

6.3.1.1.5. National Fire Protection Association (NFPA) 70, *National Electrical Code* (NEC) for all electrically powered cranes and hoists.

6.3.1.1.6. ASME Hoist (HST) Standards.

6.3.1.1.7. Hoist Manufacturing Institute (HMI) Standards.

6.3.1.1.8. American Welding Society (AWS) Standards.

6.3.1.1.9. American Institute of Steel Construction (AISC) Standards and Codes.

6.3.1.1.10. National Electrical Manufacturer's Association (NEMA) Industrial Control and Systems Standards.

6.3.1.1.11. Software safety hazard analysis shall be completed for critical cranes. Analysis shall include fish bone diagram (or other appropriate analysis method) that allows for controls system troubleshooting for fault detection.

6.3.1.2. Definitions and terminology used in test and NDE plans shall be IAW standard methodology used in the above applicable standards.

6.3.1.3. Crane, hoist, and hook NDE plans shall be submitted to Wing Safety for review and approval. The plans shall identify all SFPs, NDE requirements and methodology, and acceptance criteria.

6.3.1.4. All crane specifications, test plans, and test results shall be reviewed and approved by Wing Safety. Test plans shall include a detailed list of initial and periodic inspections, no-load tests, and proof tests, to include frequency of testing.

6.3.1.5. Crane and Hoist Service Classifications.

6.3.1.5.1. The service classifications found in CMAA 70 and 74 shall be used as the basis for selecting cranes and hoists to be used on the ranges.

6.3.1.5.2. Cranes used to handle critical loads shall be at least Class D in accordance with CMAA classification, unless otherwise agreed to by Wing Safety. **Note:** The class D requirement is used as additional margin to mitigate construction quality concerns. Class D requirements may be negotiated if quality requirements are implemented as safety requirements.

6.3.1.6. Bridge and Trolley Movement Marking.

6.3.1.6.1. Each overhead crane shall have the directions of its bridge and trolley movements displayed on the underside of the crane. These directions (North, East, South, and West) shall correspond to the directions on the operator station.

6.3.1.6.2. These markings shall be visible and legible from the floor and any operator station.

6.3.1.7. Crane and Hoist Component Accessibility.

6.3.1.7.1. Crane and hoist design shall provide for safe and adequate access to components to inspect, service, repair, or replace equipment.

6.3.1.7.2. Access platforms and/or footwalks with guard rails and personnel tie-offs shall be provided to perform the tasks in **6.3.1.7.1**.

6.3.1.7.3. Crane and hoist design shall provide for visual and physical accessibility of all SFP components and welds and other safety critical parts during initial inspection.

6.3.1.7.4. Clearances between the crane and stationary structures and clearances between parallel cranes shall be provided in accordance with 29 CFR 1910.179.

6.3.1.8. Wire Rope Requirements. Rotation resistant wire rope with swivel links installed shall not be used for any purpose. **Note:** Rotation resistant wire rope is not recommended because past experience has shown that this type of rope can incur damage that is not readily detectable; for example, internal wire rope core damage.

6.3.1.9. Use of Cast Iron. Cast iron and other similar brittle materials shall not be used in load bearing parts.

6.3.1.10. Crane and Hoist Hooks.

6.3.1.10.1. Hook shall be designed, fabricated, inspected, and tested in accordance with ASME B30.10, *Hooks*, and the additional requirements below.

6.3.1.10.2. All hooks shall be equipped with a positive latching mechanism to prevent accidental load disengagement.

6.3.1.10.3. The initial throat opening of a hook shall be measured and permanent reference marks placed on each side of the hook throat opening.

6.3.1.10.4. Hook load-bearing attachment holes shall be inspected and their dimensions recorded during initial inspection.

6.3.1.10.5. For hooks having load-bearing holes, the hook manufacturer shall specify the hole and pin diameter size to be used for attaching load-bearing fittings and the permissible diametral clearance pass/fail criteria for pin and hole to be used during hook inspection. Hooks with holes having cracks exceeding the manufacturer criteria shall be repaired or replaced.

6.3.1.10.6. Attachments such as handles and latch supports shall not be welded to a finished hook in a field application. **Note**: If welding of attachments such as these is necessary, it shall be done by the hook manufacturer before any required final heat treatment, load test, and NDE.

6.3.1.10.7. Before and after the hook initial proof-load test (before installation on the crane), volumetric and surface NDE shall be performed on the hook and its shank, shank threads, nut (including nut threads); or for pinned shank hooks, the attachment pin IAW the NDE plan.

6.3.1.11. Reeving.

6.3.1.11.1. For dual-reeved hoists, equalizer sheaves shall be self-aligning with the load line.

6.3.1.11.2. Load lines shall be attached to the crane by a rope termination method that develops 100% of the rope strength with the exception of rope-to-drum attachments. Newly installed rope termination sockets shall be volumetrically and surface inspected and certified before rope installation on the crane.

6.3.1.12. Crane and Hoist Motion Controls.

6.3.1.12.1. Controls shall provide positive motion control at all times. No un-commanded motion shall be allowed, including drum reversal during starting and stopping.

6.3.1.12.2. Controls shall be of the fail-safe “dead man” type.

6.3.1.12.3. Cranes shall be provided with pushbutton or lever-type control switches for controlling crane motion.

6.3.1.12.4. Controls shall have an inching (jog) capability when the speed selector switch is in the slowest speed position.

6.3.1.12.5. The controller(s) shall be capable of being adjusted for the desired amount of acceleration and deceleration rates.

6.3.1.12.6. Pendant control stations shall be suspended by a strain relief chain or cable to protect the electrical conductors from strain.

6.3.1.12.7. The control station(s) shall be located so that the crane operator has direct line of sight to the load at all times. If this is not possible, spotters or assistant operators shall have emergency stop capability at their location if inadvertent crane movement could result in personnel injury or death.

6.3.1.13. Hoist Limit Switches. All overhead cranes and hoists shall be equipped with two limit switches in the “up” direction to prevent “two blocking” and one limit switch in the “down” direction to prevent a slack rope condition when unladen.

6.3.1.13.1. The first “up” limit switch shall interrupt the movement control circuit and shall be reset by reversing the movement control.

6.3.1.13.2. The second “up” limit switch shall be a mechanical fail-safe switch that will interrupt power to the hoist mechanism, and require key-operated reset.

6.3.1.14. Bridge and Trolley Brakes. The overhead crane bridge and trolley shall be equipped with fail-safe brakes in both directions, designed IAW the stopping distance requirements of CMAA 70/74 and ASME B30.2, *Overhead and Gantry Cranes*.

6.3.1.15. Crane and Hoist Grounding and Bonding.

6.3.1.15.1. All cranes and hoists shall be grounded and bonded to provide hardware and personnel protection against electrical failures or lightning strikes.

6.3.1.15.2. Grounding and bonding between trolley, bridge, and runway shall use separate bonding conductors that may be run with electrical circuit conductors.

6.3.1.15.3. In accordance with NFPA 70/NEC, the trolley frame and bridge frame shall not be considered electrically grounded through the bridge and trolley wheels and its respective tracks.

6.3.2. Crane and Hoist Inspection and Test Requirements.

6.3.2.1. Crane and Hoist Initial Inspection and Test Requirements.

6.3.2.1.1. All new, reinstalled, altered, repaired, or modified cranes and hoists shall be rated load tested to 125% (+0%, -5%) in accordance with ASME B30.2 methodology.

6.3.2.1.2. Prior to, and after the rated load test, a full operational, no-load test shall be performed to test full functionality of crane, in accordance with ASME 30.2 methodology. At a minimum, testing will include (1) lifting and lowering, (2) trolley travel, (3) bridge travel, (4) all hoist-limit devices, (5) travel-limit devices, and (6) locking and indicating devices, if provided.

6.3.2.1.3. During rated load testing, the test weight shall be moved throughout the complete operating envelope of the overhead crane or hoist system, stopping and starting at various locations to verify smooth operation. The test weight shall be raised to a sufficient height to ensure that each tooth of the lifting gear train is subjected to the rated load. Lower load to 4-8 inches from ground level prior to traversing crane/hoist travel envelope.

6.3.2.1.4. The test weight shall be transported throughout the full length of the trolley and bridge envelope.

6.3.2.1.5. Cranes and hoists shall be inspected and tested, at a minimum, IAW the requirements specified by OSHA, ASME, AFMAN 91-203, and/or per manufacturer's recommendations.

6.3.2.1.6. Before and after the crane and hoist rated load test, a complete functional test of all control systems, safety devices, and warning indicators shall be performed.

6.3.2.1.7. The test weight shall be hoisted approximately 2 feet and suspended for a minimum of 3 minutes to verify hoist drum rotation and test weight drift are within acceptable limits.

6.3.2.1.8. With the trolley located at the center of the bridge, the test weight shall be raised to the maximum height and then lowered in three increments, stopping each time to verify there is no un-commanded drum rotation or test weight lowering.

6.3.2.1.9. The test weight shall be raised to sufficient height and at least one emergency stop shall be made at the fastest lowering speed to verify that brake application is positive and effective.

6.3.2.1.10. Bridge, trolley, and hoists shall be tested at each specified speed, including braking, bumping, and jogging.

6.3.2.1.11. Bridge and trolley brakes shall be tested to verify that they function in accordance with CMAA 70 and 74 and ASME B30 series requirements.

6.3.2.1.12. Before any crane operations, a full functional test of all cranes and hoists shall be performed.

6.3.2.1.13. Inspections and tests shall be performed by appointed competent persons or authorized persons. If state requirements mandate crane inspectors and certifiers are licensed (e.g., California), individuals shall identify the recognized certification authority and expiration date of the certification authority.

6.3.2.1.14. Following the load test, NDE shall be performed on crane and hoist SFPs IAW the NDE plan. For recurring NDE, disassembly is not required. NDE is only applicable to accessible parts of SFPs and shall only be surface NDE.

6.3.2.2. Crane Hook Initial Inspection and Test Requirements.

6.3.2.2.1. Crane hooks shall be load tested and inspected by the manufacturer before assembly on the hoist using the guidelines provided in ASME B30.10.

6.3.2.2.2. After the initial proof-load test but before installation on the hoist, volumetric and surface NDE shall be performed on the hook and its shank, shank threads, nut (including nut threads), or for pinned shank hooks, the attachment pin IAW the NDE plan.

6.3.2.2.3. Following the crane load test, hooks shall be inspected in accordance with ASME methodology; NDE shall be performed on exposed portions of the hook IAW the NDE plan.

6.3.2.2.4. Hook throat opening and load-bearing attachment holes shall be inspected, per the NDE plan, and throat and load-bearing hole measurements shall be taken and recorded. Measurements and inspection results shall be compared to the acceptance/rejection criteria in ASME B30.10 and manufacturer specifications. Hooks exceeding the inspection criteria shall be repaired or replaced.

6.3.3. Crane and Hoist Data Requirements. Crane and hoist data requirements shall be submitted IAW Attachment 2, **A2.2.5.7** and Volume 5, Attachment 2.

6.3.4. Unique WR Crane Design Standards and Requirements.

Table 6.2. California Occupational Safety and Health Administration Requirements.

All cranes and hoists on Vandenberg AFB locations within California Occupational Safety and Health Administration (Cal-OSHA) jurisdiction, and greater than 3 tons rated capacity are subject to Cal-OSHA regulatory requirements.

6.3.4.1. California Occupational Safety and Health Administration Requirements. In addition to the requirements in **6.3.1**, **6.3.2**, and **6.3.3**, at the WR, cranes not on VAFB exclusive federal jurisdiction property shall be inspected, tested, and certified IAW the Cal-OSHA requirements.

6.3.4.2. WR Crane and Hoist Seismic Design Requirements. The seismic design of cranes, craneways and support structures, and seismic loads calculations shall be IAW the requirements in **Chapter 17** of this volume and those listed below:

6.3.4.2.1. Seismic load calculations shall consider dynamic amplification effects and the dynamic characteristics of the crane or hoist and its craneway and support structure.

6.3.4.2.2. Provisions shall be made to prevent the crane bridge and trolley(s) from "jumping" their rail anywhere along the track, during a seismic event.

6.3.4.2.3. Seismic load calculations used for critical cranes shall ensure that the design and construction of the crane or hoist shall remain in place and support the critical load during and after a seismic event.

6.3.5. Additional Requirements for Cranes and Hoists Used To Handle Critical Hardware and Used in Hazardous Environments. In addition to the requirements in **6.3.1** and **6.3.2**, these requirements are applicable to all cranes and hoists used to support critical operations and cranes and hoists used in hazardous environments.

6.3.5.1. Overhead Crane and Hoist Design Requirements.

6.3.5.1.1. Controls.

6.3.5.1.1.1. Lever type switches shall be provided with a positive latch that, in the off position, prevents the handle from being inadvertently moved to the on position. **Note:** An off detent or spring-return arrangement is not sufficient.

6.3.5.1.1.2. All control panels shall have a lockout feature such as a keyed switch to prevent unauthorized operation.

6.3.5.1.1.3. Control stations shall have the built-in capability to test the integrity of all indicator lamps and aural/visual warning devices.

6.3.5.1.1.4. Cranes and hoists shall not be capable of being controlled by more than one control station at a time. Emergency stop capability from all emergency stop control stations shall be retained.

6.3.5.1.1.5. For RF controllers, in the event of an interruption in the radio link from the transmitter to the receiver, both the transmitter and receiver will shut down. When the transmitter and receiver shut down, the brakes on the crane shall be set and the crane controls will be placed into a safe mode.

Table 6.3. Smart Crane Controls.

Crane controls may feature technology for specialized speed and motion control, system self-diagnostics, load control safety features, and maintenance monitoring. For example: Inching and micro-speed. Drive controls shall be capable of selecting increments of motion between 2 to 100 mm and drive speed selectability of 1% to 99% of full speed. Shock load prevention. Controls shall have the capability to detect slack rope on lift to prevent shock load during lift train tensioning. Load floating. Control functions will allow for the ability to hold a load with precision torque, without hoisting or lowering, and with the brakes open. Snag detection/rope angle monitoring. Controls shall have the ability for real time monitoring of the wire rope and angle to detect unbalanced loads or a possible load snag. Hook centering. A control system shall allow for automatic repositioning of trolley and bridge over the load to prevent side loading. Operator panel/remote diagnostic capability. A control system shall allow for real time monitoring of parameters and status of all drives (speed, torque, current, temperature, etc.), fault and error indications, restricted zone operation, two-blocking load detection, and brake slip detection. For hard-to-access cranes, an operator control interface shall have the capability to troubleshoot and reset faults remotely (without the need to climb up on the crane to diagnose issues). It shall allow an operator to remotely modify drive parameters, log fault/alarm/runtime events (cycles, speeds, load lift history), and signal when preventative maintenance and inspections are due.

6.3.5.1.1.6. Emergency stop controls shall be hard-wired.

6.3.5.1.2. Bridge and Trolley Travel Limit Switches. Each bridge and trolley shall be equipped with travel limit switches that will first slow the bridge or trolley to “creep” speed and a second limit switch that will remove power and apply the brake before it engages the bumper or other mechanical stop, but with subsequent creep-speed override to enable hard stop contact.

6.3.5.1.3. Hoist Overload.

6.3.5.1.3.1. Hoists shall be designed with an adjustable hoist overload detection device. When triggered, the device shall activate an overload indicator light and overload indicator horn and shut down the hoist, requiring key-operated reset. The device shall be capable of being overridden to enable the load test. A keyed override switch shall be provided.

6.3.5.1.3.2. Hoists control panels shall be instrumented with a load readout. A load tare out button shall be provided to enable resetting the readout to zero with rigging on the hook.

6.3.5.1.4. Hoist Braking.

6.3.5.1.4.1. Powered hoists shall have dual fault tolerant braking systems.

6.3.5.1.4.2. The overspeed device shall be located so that it monitors drum rotation irrespective of a single failure in the drive train.

6.3.5.1.4.3. The braking system shall be capable of braking and holding at least 150% of torque exerted by full rated load on the hook.

6.3.5.1.4.4. The braking system shall be activated by the emergency stop button.

6.3.5.1.4.5. The dual fault tolerant braking system shall be capable of being tested in place.

6.3.5.1.4.6. The application of multiple braking systems shall be synchronized to minimize shock loading.

6.3.5.1.4.7. Brake systems shall be fail-safe; in other words, the brakes shall be applied automatically when power is removed.

6.3.5.1.4.7.1. The dual fault tolerant braking system shall be equipped with a limit switch and control panel indicator light that comes on when the brake is fully released.

6.3.5.1.4.8. The hoist shall be equipped with an uncommanded motion sensor to detect differences in speed ratio between the drum and the hoist motor. If uncommanded motion is sensed, all braking systems and audio and visual warning devices shall be activated.

6.3.5.1.4.9. Consideration for crane/hoist configuration, accessibility, and maintenance may require that the emergency brake be of a pneumatic-mechanical fail-safe type, directly mounted on the hoist drum(s). For pneumatic emergency brake fail-safe systems, redundant solenoid dump valves shall be used. An electrical switch that enables independent testing of these dump valves shall be provided. No lubricants, such as oil, shall be introduced into the pneumatic system without first performing a chemical compatibility analysis. **Note**: Valve softgoods and o-rings may swell up in contact with some lubricants. In some cases, the lubricant could be a potential source of fuel, or reactive in certain environments.

6.3.5.1.4.10. Overhead Crane and Hoist Torque-Proving System. A torque-proving system shall be provided for all hoist drives and motors to ensure that the hoist holding brakes are not released until the motor has been verified for its ability to energize. If microdrive systems with non-fail safe clutches are used, this torque-proving system shall be designed not to release the hoist brakes until the system has verified positive clutch engagement. The torque-proving system shall be designed to eliminate any undesirable hook jump.

6.3.5.1.5. Hoist Emergency Lowering System. Hoisting mechanisms shall have a fail-safe capability for emergency lowering of the load and moving the bridge and trolley in the event of a power failure or hoist drive mechanism malfunction.

Table 6.4. Hoist Emergency Lowering.

Provision shall be made for emergency lowering of the critical load by an alternative means of operation of the brakes. The alternative release mechanisms shall permit control of the braking torque and shall also provide the ability to restore the “brake set” condition promptly, allowing the operators to control the lowering speed.   For pneumatic type emergency lowering system, the manual release of the hoist emergency brakes should be by a dead man lever controlled pressure regulator. Controls to configure the emergency brake system into manual operation should be provided. An electric switch with a positive indicator light should be provided on the control panel to release the hoist holding brake(s). Emergency load lowering panels should be equipped with pressure gauges. A crane-mounted air compressor equipped with an air filter and drier should be used to provide the source of compressed air. Use of gaseous nitrogen, either bottled, or festoon supplied, is an acceptable alternative. A quick disconnect fitting should be provided in the system to enable the use of an external pressurized air source in an emergency.

6.3.5.1.6. Software. Crane computer hardware and software shall be designed and tested IAW applicable requirements in **Chapter 16** and/or applicable industry standards. Where feasible, a diagnostic port shall be provided on the crane control panel to enable downloading of programmable logic controller (PLC) data.

6.3.5.1.6.1. Software documentation shall include a ladder-logic diagram, or flowchart logic diagram.

6.3.5.1.6.2. Changes to software shall be well documented, to show traceability of requirements, item changed, and rationale.

6.3.5.1.6.3. The software shall be subject to configuration control. (See **Chapter 16**)

6.3.5.1.7. Hook Isolation and Grounding.

6.3.5.1.7.1. The hoist block shall be positively grounded through a separate insulated grounding cable synchronized with the hoist operation. Maximum resistance to crane ground shall not exceed 5 ohms.

6.3.5.1.7.2. Hooks shall have a grounding lug.

6.3.5.1.7.3. Hooks shall be isolated from the crane to a minimum resistance of 1 megaohm as measured with a 500 volt DC resistance tester.

6.3.5.1.7.4. Impedance testing shall be completed within one year of intended use.

6.3.5.1.8. Reeving.

6.3.5.1.8.1. Overhead cranes and hoists shall be capable of operating with a minimum 5-degree hoist offset angle, normal to the drum axis, without the load line contacting any structural member or obstructions and without the rope being pulled out of the drum or sheave grooves.

6.3.5.1.8.2. Cranes shall be dual reeved with all load lines terminated at an equalizer bar and drum(s). The equalizer system shall have the means to allow movement of the system to level the block.

6.3.5.1.8.3. Cranes shall be reeved with one right-lay rope and one left-lay rope to cancel the load block rotation tendency.

6.3.5.1.8.4. At least two wraps of the rope shall remain on the drum at the lower limit of lift.

6.3.5.1.8.5. All overhead cranes and hoists shall be equipped with a means (such as a level-wind device) for preventing the load line from coming out of the drum groove and overwrapping itself on the drum. As an alternative, a warning device may be used (such as a spooling monitor that will activate an aural/visual warning and stops hoisting, but enable drum reversal) when the rope comes out of the drum groove.

6.3.5.1.8.6. Vertical load displacement following a rope failure shall be minimized. This vertical load displacement shall be calculated and the analysis submitted. The design of the rope reeving system shall be such that a single rope failure will not result in the loss of the lifted load.

6.3.5.1.8.7. The effects of a broken rope on the entire system, including the load block and the equalizer assembly, shall be analyzed and reported.

6.3.5.1.8.8. In the event of one broken rope, the remaining intact reeving system shall not be loaded to more than 40% of the breaking strength of the remaining intact wire rope, including the dynamic and seismic loading effects of the load transfer.

6.3.5.1.8.9. Ropes shall be attached to the drum with a minimum of two clamps each. Clamp bolts shall be properly torqued.

6.3.5.1.8.10. Provisions shall be made to support the drum, to prevent disengagement of the drum gearing, and to prevent disengagement of the drum from its emergency brake in the event of drum shaft, drum hub, shaft bearing, or bearing support failure.

6.3.5.1.9. Cranes Used in Hazardous Environments.

6.3.5.1.9.1. All cranes and hoists used in hazardous environments shall be designed in accordance with NEC Article 501, *Class I Locations* and NFPA.

6.3.5.1.9.2. Runway systems for overhead cranes bridges and trolleys shall be provided with non-sparking cable feed systems (festoon cable or double shoe-sliding contactors) for supplying power to the bridge cranes.

6.3.5.1.9.3. Structural and mechanical parts shall not cause sparks during normal operation; sparks caused by emergency braking shall be prevented from falling into the work areas below.

6.3.5.1.10. Unique Cranes.

6.3.5.1.10.1. All unique cranes such as torus, polar, straddle, and winches used as hoists not covered in this document shall be justified to and approved by Wing Safety on a case-by-case basis.

6.3.5.1.10.2. Multiple cranes operating on the same runway or parallel cranes operating on different runways shall be equipped with an anti-collision system.

6.3.5.1.10.3. Specialized Bridge Cranes, Side Loaded Cranes and Hoists.

6.3.5.1.10.3.1. For those bridge cranes designed for intentional side pulls or for bridge cranes used in tandem crane operations where horizontal forces will be exerted on the crane because of angular pulls, special features shall be incorporated to prevent sliding of the crane bridge/trolley as a result of the horizontal forces applied and to shut down the hoist if the maximum side pull angle has been exceeded. **Note**: To prevent stressing the bridge/trolley brakes, rail clamps can be used to hold the bridge/trolley in place during these operations. Also, limit switches can be used to shutdown the hoist if the maximum allowable side pull angle on the crane ropes has been exceeded.

6.3.5.1.10.3.2. Specialized bridge crane design shall ensure the trolley remains stable (no potential danger of tipover due to the horizontal component of the resulting force) under worst case loading conditions.

6.3.5.1.11. Stationary Cranes. Stationary cranes (for example, jib, tower, portal, pillar, hammerhead cranes and derricks) used to handle critical hardware shall comply with applicable ASME standards and be submitted for review and approval to Wing Safety on a case-by-case basis.

6.3.5.1.12. Portal and Pedestal Cranes. Portal and pedestal cranes used to handle critical hardware shall be designed and tested in accordance with ASME B30.4, *Portal and Pedestal Cranes*, and incorporate the following items:

6.3.5.1.12.1. A load-indicating device with the readout located in the cab.

6.3.5.1.12.2. An upper limit switch at the boom point to prevent “two blocking.”

6.3.5.1.12.3. A boom-angle indicating device readable from the operator seat in the cab.

6.3.5.1.13. Field and Mobile Cranes.

6.3.5.1.13.1. Range users utilizing mobile cranes shall submit a data package to Wing Safety for review and approval that provides evidence that the mobile crane meets the following requirements:

6.3.5.1.13.1.1. ASME B30.5, *Mobile and Locomotive Cranes*, 29 CFR 1926, *Safety and Health Regulations for Construction*, and 29 CFR 1910.180, *Crawler Locomotive and Truck Cranes*.

6.3.5.1.13.1.2. A minimum of one upper limit switch.

6.3.5.1.13.1.3. Deadman levers and controls on fixed control panels.

6.3.5.1.13.1.4. The ability to deactivate free-fall features.

6.3.5.1.13.1.5. A reeving diagram shall be provided for each crane.

6.3.5.1.13.1.6. Current inspection and test records.

6.3.5.1.13.2. If the mobile crane can go into a limp or reduced power mode as a result of the diesel particulate filter (DPF) regeneration cycle, the regeneration cycle shall be bypassed prior to and for the duration of a critical lift. If the bypass feature is not provided on the crane, then the crane regeneration cycles shall be recorded and tracked to ensure the crane does not go into a regeneration cycle for the duration of a critical lift.

6.3.5.1.13.3. Nonconductive rigging shall be used between the crane hook and the load for those mobile and field cranes not equipped with isolated hooks, when used for critical lifts.

6.3.5.1.13.4. An emergency load lowering plan shall be developed and submitted to Wing Safety for review and approval for mobile and field cranes not equipped with emergency load lowering capability, when used for critical lifts. **Note**: Information should include emergency load lowering capability; requirements for another mobile crane, special rigging, load support structure, or other equipment needed to safely support emergency load lowering; procedures to safely accomplish emergency load lowering if the crane cannot be repaired in place.

6.3.5.1.14. Winches. Winches used to handle critical hardware shall be designed and tested in accordance with ASME B30.7, *Winches*. This includes electric, pneumatic, and hydraulic winches.

6.3.5.2. Inspection and Test Requirements for Cranes and Hoists Used To Handle Critical Hardware and Used in Hazardous Environments.

6.3.5.2.1. Initial Inspection and Test Requirements.

6.3.5.2.1.1. All requirements shall be verified via inspection and test. Any test anomaly shall be evaluated by Wing Safety as a cause for rejection.

6.3.5.2.1.2. The Range User shall prepare verification plans and procedures for Wing Safety review and approval.

6.3.5.2.1.3. The initial inspection and test shall include the following:

6.3.5.2.1.3.1. Full functional test of all crane control functions, including special protective systems; for example, overspeed, overload, uncommanded motion, fail-safe operation (loss of power), control station selection lock-out, emergency stop, limit switches, spooling monitor.

6.3.5.2.1.3.2. Full height hoist lift (100% of rated capacity).

6.3.5.2.1.3.3. Hoist(s) failure protection system test, including testing of the emergency stop control and manual and automatic activation of the hoist emergency brake system (110% of rated capacity). The test weight shall be raised to sufficient height and at least one emergency stop shall be made at the 110% lowering speed to verify that brake application meets specification requirements.

6.3.5.2.1.3.4. The hoist emergency load lowering system shall be tested to verify that it is fail-safe and functions properly. The load shall be lowered a minimum of 2 feet.

6.3.5.2.1.3.5. The hoist overload detection devices shall be tested to verify that they activate when the test weight is greater than 110% of rated capacity.

6.3.5.2.1.3.6. The un-commanded motion and load slippage detection system shall be tested for proper activation to ensure that the load does not slip and/or stops within the specified distance. If the crane is equipped with a non-fail safe creep speed, electrically operated clutch, a test that simulates clutch failure to engage (mechanical failure with coil energized) and clutch electrical failure during hoisting shall be performed. Maximum load drop shall be measured to ensure that it is within specifications and the detection system performs properly. For cranes equipped with non-fail safe electrical creep speed clutches, this test shall be performed by simulating a mechanical and electrical clutch failure.

6.3.5.2.1.3.7. For special purpose cranes designed for side angle pulls, the bridge brakes, trolley brakes, and special devices, such as the rail clamps and side angle pull limit switches, shall be tested at the maximum side pull angle to ensure proper function. The trolley should remain stable (no danger of tipover due to the horizontal component of the resulting force).

6.3.5.2.1.3.8. The manual means to move the trolley and bridge when power is off shall be tested and verified.

6.3.5.3. Analyses and Data Requirements for Cranes and Hoists Used To Handle Critical Hardware and Used in Hazardous Environments. Analyses and data requirements for cranes and hoists used to handle critical hardware and used in hazardous environments shall be submitted IAW Attachment 2, **A2.2.5.7.** and the following:

6.3.5.3.1. Analysis shall be conducted and provided as part of the Operating and Support Hazard Analysis (O&SHA). (See Volume 1, Attachment 2 and MIL-STD-882E.)

6.3.5.3.2. A failure mode effects and criticality analysis (FMECA) shall be performed IAW industry standards.

6.3.5.3.2.1. The FMECA shall identify failure conditions that could result in personnel injury, loss of load, or damage to critical hardware.

6.3.5.3.2.2. The FMECA shall encompass the complete power and control circuitry as well as the load path from hook to structure.

6.3.5.3.2.3. SFP components, SFP welds, and SFP modes shall be documented for tracking to elimination or acceptance.

6.3.6. Analyses and Data Requirements for Existing RPIE Cranes and Hoists. Analyses and data requirements for existing RPIE cranes and hoists used to handle critical hardware and used in hazardous environments shall be submitted IAW Attachment 2, **A2.2.5.7**. The following applies to all RPIE cranes and hoists:

Table 6.5. Existing Real Property Installed Equipment (RPIE) Cranes and Hoists.

These requirements are applicable to all cranes and hoists used to handle critical and noncritical hardware that are existing RPIE equipment, designed, installed and commissioned prior to the issuance of either EWR 127-1 or AFSCMAN 91-710; which do not have documented traceability for design, installation, and reliability.

6.3.6.1. For existing RPIE which do not have the required design safety information, the cranes and hoists shall undergo safety and reliability studies, including single failure points (SFP) analysis, recommended NDE plan, and existing condition assessment in accordance with CMMA 70/74, ASME B30.2, OSHA 1910.179, and applicable requirements.

6.3.6.2. An assessment shall be conducted on all subsystems, but not limited to, structural infrastructure, mechanical, electrical, and control systems. The assessment will document the following:

6.3.6.2.1. A FMECA shall be performed in accordance with industry standards and meet the requirements of **6.3.5.3.2.1** and **6.3.5.3.2.2**.

6.3.6.2.2. SFP Analysis.

6.3.6.2.3. NDE Plan for SFPs and critical components.

6.3.6.2.4. As-built/red-lined drawings.

6.3.6.2.5. Identification of deviations from requirements as defined in section **6.3**. and recommended crane upgrades required to meet the requirements of section **6.3**.

6.3.6.2.6. Risk mitigation recommendations for SFPs and critical subsystems and components identified during the analysis.

6.3.6.2.7. Manual translation and safing procedures.

6.3.6.2.8. Assessment findings and risk mitigation recommendations shall be submitted to Wing Safety for review and approval.

6.4. Removable, Extendible, and Hinged Personnel Work Platforms. Requirements for the design, inspection, and test of personnel work platforms are included below.

6.4.1. Removable, Extendible, and Hinged Personnel Work Platform Design Requirements.

6.4.1.1. Safety factors for the design of platforms shall be consistent with those of the overall structures on which they are permanently mounted. In no case shall the safety factors be less than that of the overall structure, the applicable national consensus standard AISC, the Aluminum Association, or a yield factor of safety of 2, whichever is greater.

6.4.1.2. Hinges, attaching points, and other high stress or abuse prone components and their interface hardware shall be designed with a yield factor of safety of at least 3. Yield strength shall be less than or equal to 85% of ultimate strength or the ultimate factor of safety shall be 5.

6.4.1.3. The greater of (1) a minimum of 60 pounds per square foot or (2) 300 pounds per occupant shall be used for the uniformly distributed live load.

6.4.1.4. A minimum of 2,000 pounds shall be used for concentrated loading (point loading).

6.4.1.5. Guardrail systems and toe boards shall be provided and designed in accordance with 29 CFR 1910.23(e)(3), *Design Requirements for Mobile Ladder Stand Platforms*.

6.4.1.6. Personnel platforms shall have a means of positive mechanical restraint when in the open, raised, folded back, or use position to prevent unintentional movement. Bolting shall not be acceptable. Latches, levers, tethered pins shall be used.

6.4.1.7. Movable platform structures shall be grounded with the bonding conductor size IAW the NEC Article 250-102, *Bonding Jumpers*.

6.4.2. Removable, Extendible, and Hinged Personnel Work Platform Marking Requirements.

6.4.2.1. All platforms shall be clearly marked with 2-inch letters minimum indicating maximum load capacity.

6.4.2.2. The following information shall be imprinted on a metal tag attached to the platform:

6.4.2.2.1. Maximum distributed load.

6.4.2.2.2. Maximum concentrated load (point load).

6.4.3. Removable, Extendible, and Hinged Personnel Work Platform Inspection and Test Requirements. At a minimum, the following tests shall be performed:

6.4.3.1. All new, repaired, or modified platforms shall be load tested to 125% of their rated capacity before initial use.

6.4.3.2. After the proof load test, volumetric NDE testing shall be performed on all SPF components and welds IAW the Wing Safety approved NDE plan.

6.4.3.3. For repaired or modified platforms, volumetric NDE testing of all repaired or modified SPF components and welds is required. Periodic inspection requirements for work platforms are found in Volume 6.

6.4.4. Removable, Extendible, and Hinged Personnel Work Platform Data Requirements. Personnel work platform data shall be submitted IAW Attachment 2, **A2.2.5.8**.

6.5. Man-Rated Baskets . Certification and load testing of man-rated baskets used with cranes shall be in accordance with 29 CFR 1926.1427, *Operator Training, Certification, and Evaluation*. Manlifts and extensible boom platforms are also discussed in 29 CFR 1910.67, *Vehicle-mounted Elevating and Rotating Work Platforms*.

6.6. Flight Hardware Used to Lift Critical Loads.

6.6.1. Flight Hardware Used to Lift Critical Loads Design Requirements. Lift fittings such as lugs and plates permanently attached to flight hardware shall be designed so that the loss of one fitting and/or structure will not result in the dropping of the load. If this requirement cannot be met, the minimum ultimate factor of safety shall be 1.5. **Note:** Flight hardware used to lift critical loads includes clampbands.

6.6.2. Flight Hardware Used to Lift Critical Loads Initial Test Requirements. At a minimum, the following tests shall be performed on permanently attached flight hardware lift fittings prior to their first operational use at the Ranges:

6.6.2.1. Lift fittings shall be load tested to 100% of limit load as an integral part of structural load testing.

6.6.2.2. After the load test, volumetric and surface NDE testing shall be performed on all lift fitting SFP components and SFP welds.

6.6.3. Flight Hardware Used to Lift Critical Loads Data Requirements. Data requirements for flight hardware used to lift critical loads shall be submitted IAW Attachment 2, **A2.2.5.6.8**.

Chapter 7

ACOUSTIC HAZARDS.

7.1. Acoustic Design Standards.

7.1.1. Systems shall be designed to ensure that personnel are not exposed to hazardous noise levels in accordance with AFI 48-127, *Occupational Noise and Hearing Conservation Program*, for AF programs and 29 CFR 1910.95, *Occupational Noise Exposure*, for non-AF programs. In all cases, noise shall be at the lowest practical levels.

7.1.2. Where total protection is not possible through the design process, hearing protection and/or access controls shall be used.

7.1.3. Workspace noise shall be reduced to levels that permit necessary direct person-to-person and telephone communication.

7.1.4. Bioenvironmental Engineering shall evaluate noise levels and determine the hazard potential.

7.2. Acoustic Data Requirements . Acoustic data requirements shall be submitted IAW Attachment 2, **A2.2.4.12.2**.

Chapter 8

NON-IONIZING RADIATION SOURCES.

8.1. Electromagnetic Frequency Radiation (EMFR) Emitters . The following requirements apply to EMFR emitters unless exempted by AFI 48-109, *Electromagnetic Field Radiation (EMFR) Occupational and Environmental Health Program*, and any Wing Supplements/Instructions.

8.1.1. EMFR Emitter Design Standards.

8.1.1.1. EMFR emitters shall be designed to ensure that personnel are not exposed to hazardous energy levels in accordance with ANSI/IEEE C95.1, *Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 Khz to 300 Ghz*, AFI 48-109, and any Wing Supplements/Instructions.

8.1.1.2. Where total protection is not possible through the design process, clearance areas and access controls shall be established.

8.1.1.3. The Range User shall contact the Installation Radiation Safety Officer (IRSO) and provide EMFR system design data for use in evaluation and approval of the EMFR system. The IRSO shall evaluate EMFR levels and determine the hazard potential for personnel.

8.1.2. EMFR Emitter Design.

8.1.2.1. EMFR Emitter General Design Requirements.

8.1.2.1.1. EMFR emitters shall be designed and located to allow test and checkout without presenting a hazard to personnel, ordnance, or other electronic equipment.

8.1.2.1.2. Where necessary, safety devices shall be provided to protect operating personnel and exposed initiators during ground operations. **Note**: Interlocks and interrupts are examples of safety devices that may be used to protect operating personnel and exposed initiators during EMFR emitter ground operations.

8.1.2.1.3. No ground-based EMFR system shall be installed, erected, relocated, or modified without site plan approval from Wing Safety and the IRSO.

8.1.2.1.4. Fail-safe systems shall be incorporated so that inadvertent operation of any hazardous EMFR emitting system is prevented.

8.1.2.2. Special Considerations for Electroexplosive Subsystem Exposure to EMFR.

8.1.2.2.1. Electroexplosive subsystems shall not be exposed to EMFR that is capable of firing the electroexplosive device (EED) by pin-to-pin bridgewire heating or pin-to-case arcing.

8.1.2.2.2. EMFR power at the EED shall not exceed 20 dB below the pin-to-pin direct current (DC) no-fire power of EED.

8.1.2.2.3. The siting of ground-based EMFR emitters in proximity to electroexplosive subsystems shall be IAW Table 2-5., "Recommended EED Safe

Separation Distances and Power Densities" in AFMAN 91-201, *Explosives Safety Standards*, and Defense Explosives Safety Regulation (DESR) 6055.09.

8.1.2.2.4. The effect of payload and launch vehicle system emitters on their own electroexplosive subsystem shall be evaluated by analysis or electromagnetic compatibility (EMC) testing.

8.1.3. EMFR Emitter Initial Test Requirements.

8.1.3.1. All EMFR emitters shall have their hazard area verified by the IRSO or a designated representative before the first operation and/or test.

8.1.3.2. Safety features shall be tested and verified by the Range User before coming to the ranges.

8.1.3.2.1. Test plans shall be submitted to Wing Safety for review and approval.

8.1.3.2.2. Test results shall be submitted to Wing Safety.

8.1.4. EMFR Emitter Data Requirements.

8.1.4.1. Site Plans. Site plans shall be submitted to Wing Safety and the IRSO for all ground-based EMFR transmitters. See Attachment 2, **A2.2.4.10.2.1** for site plan content.

8.1.4.2. EMFR Emitter Design and Test Data. The EMFR emitter design and test data requirements shall be submitted IAW Attachment 2, **A2.2.4.10.2.2**.

8.2. Laser Systems (Class 1M, 2M, 3B, and 4) .

8.2.1. Laser System Design Standards.

8.2.1.1. Laser systems shall be designed to ensure that personnel are not exposed to hazardous emissions IAW the requirements of ANSI Z136.1, *Safe Use of Lasers*, 21 CFR 1040, *Performance Standards for Light Emitting Products*, and AFI 48-139, *Laser and Optical Radiation Protection Program*, as applicable.

8.2.1.2. Where total protection against exposure is not possible through the design process, clearance areas and access controls shall be established.

8.2.1.3. The Range User shall provide laser design data for all Class 1M, 2M, 3B and 4 lasers.

8.2.2. Laser System General Design Requirements. In addition to requirements found in ANSI Z136.1, the following requirements apply to Class 1M, 2M, 3B and 4 laser systems that may pose harm, unless exempted by AFI 48-139.

8.2.2.1. Laser platforms shall comply with the requirements for mechanical ground support equipment used to handle critical hardware as described in **Chapter 6**.

8.2.2.2. Laser system mounts installed on moving or airborne vehicles shall be designed to compensate for the motion of the vehicle.

8.2.2.3. Heating effects on unprotected laser platforms shall be considered when siting and setting elevation and azimuth stops.

8.2.2.4. Hazardous materials used in laser systems shall meet the ground support requirements of **Chapter 10**.

8.2.2.5. Laser systems with pressurized subsystems such as cryogenic fluids shall meet the requirements of **Chapter 11**.

8.2.2.6. Electrical ground systems used in laser systems shall meet the requirement of **Chapter 14**.

8.2.3. Laser System Test Requirements.

8.2.3.1. The Range User shall contact Wing Safety and the Installation Laser Safety Officer (ILSO) for hazard area verification before first operation and test.

8.2.3.2. Safety features shall be verified before coming to the ranges.

8.2.3.3. Test plans and test results shall be submitted to Wing Safety for review and approval.

8.2.4. Laser System Data Requirements.

8.2.4.1. Laser system data requirements shall be submitted IAW Attachment 2, **A2.2.4.10.3**.

8.2.4.2. Hazard Evaluation Data. Analysis and supporting data outlining possible laser system failures for all phases of laser system uses shall be submitted IAW Attachment 2, **A2.2.4.10.3.7**.

8.2.4.3. Biophysiological Data. Biophysiological data requirements shall be submitted IAW Attachment 2, **A2.2.4.10.3.8**.

Chapter 9

RADIOACTIVE (IONIZING) RADIATION SOURCES.

9.1. Radioactive Source Design Standards and Controls.

9.1.1. Radioactive systems shall conform to the requirements specified in 10 CFR, *Energy*, 49 CFR, *Transportation*, AFI 40-201, and AFMAN 91-110, *Nuclear Safety Review and Launch Approval for Space or Missile Use of Radioactive Material and Nuclear Systems*.

9.1.2. Radioactive sources shall be designed to prevent the release of radioactive material..

9.1.3. Radioactive sources shall incorporate shielding in the design to ensure minimum exposure to personnel. Where total protection from radiation exposure by use of shielding is not feasible, access controls shall be used.

9.1.4. Radiation hazard warning signs and/or labels shall be fixed to the container or housing as directed by the IRSO.

9.1.5. High voltage sources shall be evaluated to determine their capability of producing X-rays.

9.1.6. High voltage sources shall be properly shielded and shall use interlocks on cabinet doors to interrupt power when a door is open.

9.1.7. Control measures for flight systems shall be handled on a case-by-case basis.

9.1.8. Range Users shall comply with requirements in Air Force Environmental Policy and the National Environmental Policy Act, and provide compliance documentation to the IRSO on the ER and/or the Radiation Safety Committee on the WR.

9.1.9. Application for USAF permits shall be submitted in accordance with AFI 40-201 and any Wing Supplements/Instructions.

9.1.10. The Nuclear Regulatory Commission (NRC) license holder or Range User shall submit 3 copies of the NRC license with the USAF permit to the IRSO and Wing Safety at least 90 calendar days before planned entry to the range. **Note**: Licensing and permitting requirements and procedures are specified in 10 CFR, AFI 40-201, and any Wing Supplements/Instructions.

9.1.11. Radioactive sources shall be handled under the supervision of the designated Range User or the Radiation Protection Officer named on the NRC license, state license, or USAF permit as described in AFI 40-201.

9.1.12. Written approval for use of radioactive materials on AFSPC ranges is provided by the Wing Radiation Safety Committee. Range Users shall brief the Radiation Safety Committee on the hazards and procedures concerning the handling of radioactive sources and shall comply with any unique requirements of AFI 40-201, and any Wing Supplements/Instructions.

9.1.13. The Safety Analysis Summary (SAS) and Radiation Protection Plan shall be submitted at least 180 calendar days before launch.

9.2. Radioactive Sources Carried on Launch Vehicles and Payloads. In addition to the design requirements noted above in **9.1.1**., radioactive materials carried on launch vehicles and payloads shall meet the following requirements:

9.2.1. Radioactive Sources Carried on Launch Vehicles and Payloads General Design Requirements.

9.2.1.1. Radioactive materials carried aboard launch vehicles and payloads shall comply with AFMAN 91-110 public safety launch risk constraints.

9.2.1.2. Radioactive materials carried aboard launch vehicles and payloads shall be compatible with and have no adverse safety effects on ordnance items, propellants, high pressure systems, critical structural components, or FTSs.

9.2.1.3. Radioactive materials carried aboard launch vehicles and payloads shall be designed so that they may be installed as late in the countdown as possible, particularly if personnel will be required to work within the system controlled radiation area (as defined in AFI 40-201, and any Wing Supplements/Instructions) while performing other tasks on the launch vehicle and/or payload.

9.2.2. Radioactive Sources Carried on Launch Vehicles and Payloads Test Requirements.

9.2.2.1. To launch radioactive materials from AFSPC ranges, adequate tests shall be performed to characterize the survivability of the radioactive materials and any containment system, in the launch, abort, and destruct environments. Range Users shall also describe the risk of any release of radioactive materials and potential contamination from these environments and provide the information to Wing Safety. **Note**: Abort and destruct environments may induce damaging effects due to reentry, ground impact, explosion and fragment impact, fire, or mechanical crushing.

9.2.2.2. Test Plans, Test Analyses, and Test Results.

9.2.2.2.1. Wing Safety shall approve test plans, analyses, and results in accordance with MSPSP timelines described in sections **4.1** and **4.2**, thereby providing support to required environmental impact assessments at L-3 years, with periodic updates as agreed upon by Wing Safety and the program.

9.2.2.2.2. Range Users shall perform and document the results of radiation surveys of their radioactive sources before coming to the ranges.

9.2.2.2.3. Range Users shall coordinate and allow an initial radiation survey to be performed by the IRSO the first time the source is delivered to the ranges. Follow-on surveys may be required by the IRSO and shall be coordinated and allowed.

9.2.2.2.4. Safeguards, such as interlocks and leak tests, shall be tested and verified by the Range User before bringing a radiation source to the ranges.

9.2.3. Radioactive Sources Carried on Launch Vehicles and Payloads Launch Approval Requirements.

9.2.3.1. Range Users contemplating launch of any radioactive source shall comply with AFMAN 91-110, and any Wing Supplements/Instructions.

9.2.3.2. Certification of compliance with an equivalent government agency safety review and launch approval process is required for all non-Air Force Range Users

9.2.3.3. All Range Users proposing to use major radioactive sources shall comply with Presidential Directive/National Security Council (NSC) 25, dated 08 May 1996, *Scientific or Technological Experiments with Possible Large-Scale Adverse Environmental Effects and Launch of Nuclear Systems into Space*.

Table 9.1. Wing Safety Support to Interagency Nuclear Safety Review Panels.

PD/NSC-25 established an Interagency Nuclear Safety Review Panel (INSRP) for major sources. Wing Safety is a member to provide launch abort data and evaluation; therefore, some failure mode, breakup, and blast data may be obtained from the Program Office or Wing Safety. In some situations, such as using a new launch vehicle, the data may not be available from the sources and shall be obtained by analysis and test following the requirements described in Volume 2 of this publication and through discussions with Wing Safety.

9.2.4. Radioactive Sources Launch Approval Data Requirements. Radioactive sources launch approval data requirements shall be submitted IAW Attachment 2, **A2.2.4.11**.

9.2.5. Radiation Producing Equipment, Devices, and/or Reactors Data Requirements. Radiation producing equipment, devices, and/or reactor data requirements shall be submitted IAW Attachment 2, **A2.2.5.13**.

Chapter 10

HAZARDOUS MATERIALS.

10.1. Hazardous Materials Selection Criteria. The requirements for preventing or minimizing the consequences of catastrophic releases of toxic, reactive, flammable, or explosive materials that may result in toxic, fire, or explosion hazards are described in this chapter. The requirements apply to all of the chemicals included in, but not limited to, those specified in 29 CFR 1910.119, *Process Safety Management of Highly Hazardous Chemicals*. These requirements also apply to explosives and pyrotechnics as defined in 29 CFR 1910.109, *Explosives and Blasting Agents*.

10.1.1. Hazardous Materials Flammability and Combustibility. The least flammable material that meets design requirements while minimizing potential ignition sources and fire propagation paths shall be used.

10.1.2. Hazardous Materials Toxicity.

10.1.2.1. If more than one material satisfies the performance requirement, the least toxic material shall be used.

10.1.2.2. Materials that will not give off a toxic gas if ignited shall be used wherever/whenever possible.

10.1.3. Hazardous Materials Compatibility. If contact of material with a non-compatible material can cause a critical or catastrophic hazard, the hazard shall be mitigated to a level acceptable to Wing Safety.

10.1.4. Hazardous Materials Electrostatic Buildup. Hazardous materials shall not retain a static charge that presents an ignition source to ordnance or propellants or a shock hazard to personnel.

10.2. Hazardous Materials Test Requirements.

10.2.1. Materials Test Requirements and Databases. Material properties shall be determined by test processes defined in this section or be selected from Wing Safety approved material databases.

Table 10.1. Potential Sources of Hazardous Material Information.

The following is a list of Wing Safety approved sources for material information:
a. NASA-MSFC Material and Process Technical Information System (MAPTIS) for rating of materials, standard and commercial parts, and components.
b. Kennedy Technical Instruction (KTI) 5211, *Material Selection List for Reactive Fluid Services*.
c. Kennedy Technical Instruction (KTI) 5212, *Material Selection List for Plastic Foams and Adhesive Tapes*.

10.2.1.1. Plastic materials that may pose a hazard because of compatibility or toxicity shall be tested IAW the requirements described in Kennedy Documented Procedure (KDP)-KSC-P-6001, *KSC Materials and Processes Control Program*.

10.2.1.2. Plastic materials that may pose a hazard because of flammability shall be tested IAW requirements described in NASA-STD-6001, *Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion*.

10.2.1.3. Plastic materials that may pose a hazard because of electrostatic discharge shall be tested IAW the requirements described in KSC/Report MMA-1985-79, *Standard Test Method for Evaluating Triboelectric Charge Generation and Decay*.

10.2.1.4. Plastic materials that may pose a hazard because of hypergolic ignition/breakthrough shall be tested IAW the procedures described in KSC/MTB-175-88, *Procedure for Casual Exposure of Materials to Hypergolic Fluids*.

10.2.1.5. The results of these tests shall be submitted to Wing Safety for review and approval, based on use.

10.2.2. Other Material Test Requirements.

10.2.2.1. Wing Safety may require the testing of materials whose properties are not well defined.

10.2.2.2. Toxicity, reactivity, compatibility, flammability and/or combustibility testing requirements shall be determined by Wing Safety on a case-by-case basis.

10.2.2.3. Testing shall consider the following material characteristics:

10.2.2.3.1. Ability to build up a charge (triboelectric test).

10.2.2.3.2. Ability of that charge to decay (triboelectric test). **Note**: A material is considered to have good electrostatic dissipation properties if it can dissipate voltage down to 350 volts in 5 seconds using the triboelectric test.

10.2.2.3.3. Flammability.

10.2.2.3.4. Compatibility with other materials and liquids the material may come into contact with. **Note**: Issues with material compatibility may result in operational restrictions.

10.2.2.4. Material restrictions may also arise from other limitations such as being humidity dependent (for charge dissipation) or degradable in sunlight (ultraviolet).

10.3. Hazardous Materials Environmental Requirements. Range User business plans shall comply with the range Hazardous Materials (HAZMAT) Plan.

10.4. Hazardous Material Data Requirements . Hazardous material data requirements shall be submitted IAW Attachment 2, **A2.2.4.13**.

10.5. Process Safety Management and Risk Management Plan.

10.5.1. Range Users shall comply with 29 CFR 1910.119, *Process Safety Management (PSM) of Highly Hazardous Chemicals*, 40 CFR 68, *Chemical Accident Prevention Provisions*, AFMAN 91-203 for process safety management and risk management planning requirements, and any Wing Supplements/Instructions.

10.5.2. Additional ER Requirements. Tenant organizations and commercial companies that have operational control over a PSM covered process shall provide representation on the 45 SW PSM team.

Chapter 11

GROUND SUPPORT PRESSURE, VACUUM, AND HAZARDOUS STORAGE SYSTEMS.

11.1. Overview.

11.1.1. These requirements establish minimum safety design, fabrication, installation, testing, inspection, recertification, and data requirements for fixed, portable, or mobile ground support hazardous pressure systems. Ground support systems include aerospace ground equipment (AGE), ground support equipment (GSE), missile support systems, real property installed equipment (RPIE), and industrial property. Ground support hazardous pressure systems:

11.1.1.1. Store and transfer hazardous fluids such as cryogens, flammables, combustibles, and hypergols;

11.1.1.2. Operate at pressures that exceed 250 psig;

11.1.1.3. Store energy at levels exceeding 14,240 foot pounds; and

11.1.1.4. May be identified by Wing Safety as safety critical.

11.2. Ground Support Pressure, Vacuum, and Storage Systems Requirements.

11.2.1. Pressure and vacuum systems shall be designed IAW accepted national industry standards such as NFPA, Underwriters Laboratory (UL), American Petroleum Institute (API), ASME, Department of Transportation (DOT), T.O. 00-25-223, *Integrated Pressure Systems and Components (Portable and Installed)*, and federal, state, and local environmental regulations. **Note**: Vacuum systems should be designed using T.O. 00-25-223 as guidance.

11.2.2. Pressure systems used to store and transfer fuels such as kerosene, RP-1, and heating oils are not generally considered hazardous when designed and operated IAW the following requirements:

11.2.2.1. Pressure shall not exceed 15 psig.

11.2.2.2. The system shall be designed, maintained, and operated in accordance with API 620, *Recommended Rules for Design and Construction of Large, Welded Low Pressure Storage Tanks*, and applicable Environmental Protection Agency (EPA) and OSHA requirements.

11.2.3. The requirements for operating hazardous pressure systems found in Volume 6 of this document shall be taken into consideration in the design and testing of these systems.

11.3. Ground Support Pressure Systems Requirements.

11.3.1. Generic Ground Support Pressure System Requirements.

11.3.1.1. Generic Ground Support Pressure System Service Life. All pressure system components shall operate safely and reliably during their intended period of service (service life). Components shall not fail at operating conditions in a time period that is four times the service life of the components. Minimum service life requirements are as follows:

11.3.1.1.1. Permanently installed pressure vessels shall be designed to have a service life of at least 20 years.

11.3.1.1.2. Other components shall be designed to have a service life of not less than 5,000 cycles. **Note**: Normal preventive maintenance and calibration may be performed to maintain the service life. The source document for the service life is the ASME Boiler and Pressure Vessel Code.

11.3.1.2. Generic Ground Support Pressure System Safety Factor. Safety factor for pressure systems is the ratio of design burst pressure over the maximum allowable working pressure or design pressure, whichever is greater. The safety factor can also be expressed as the ratio of tensile strength over the maximum allowable stress for the material. ASME or DOT codes are specified as compliance documents for various components such as pressure vessels and piping throughout this part. Acceptable safety factors have already been incorporated into accepted and relevant National Industry standards, such as ASME or DOT codes, for various components such as pressure vessels and piping. If an ASME or DOT code cannot be specified as a compliance document for a component (i.e., applicable code does not exist), the minimum safety factor for the component shall be 4, or burst shall be 4 times maximum allowable working pressure (MAWP).

11.3.1.3. Generic Ground Support Pressure System Fault Tolerance.

11.3.1.3.1. Ground support pressure systems shall be designed to ensure that no single failure (component fails to function or human operator error) can result in serious injury and/or loss of life.

11.3.1.3.2. Single-fault (failure) tolerant systems shall have at least two, Wing Safety approved, independent and verifiable inhibits in place during all periods when the potential for serious injury and/or death exists. Structural failure of tubing, piping, or pressure vessels is not to be considered single failure.

11.3.1.3.3. Wing Safety may require that a pressure system be dual-fault tolerant if the failure of two components could result in multiple injuries or deaths.

11.3.1.4. Generic Ground Support Pressure System Material Selection and Compatibility.

11.3.1.4.1. Materials shall be compatible throughout their intended service life with the service fluids and the materials such as supports, anchors, and clamps used in construction and installation of tankage, piping, and components as well as nonmetallic items such as gaskets, seals, packing, seats, and lubricants.

11.3.1.4.2. At a minimum, material compatibility shall be determined in regard to the following criteria: permeability, flammability, ignition and combustion, functional and material degradation, contamination, toxicity, pressure and temperature extremes, shock, oxidation, and corrosion.

11.3.1.4.3. Brittle materials shall not be used for pressure system components. The nil-ductility transition temperature of materials shall be below the service temperatures.

Table 11.1. Material Selection and Testing.

Material properties should be selected IAW reputable government and industry sources or material test results when testing was done IAW Wing Safety approved testing methods. Reliable sources include the Department of Transportation, Federal Aviation Administration, Office of Aviation Research (DOT/FAA/AR) *Metallic Materials Properties Development and Standardization (MMPDS) Handbook*; Composite Materials Handbook (CMH)-17; American Society for Testing Materials (ASTM) standards; and the *Air Force Damage Tolerant Design Handbook* should be used to verify material is not crack sensitive.

11.3.1.4.4. Materials that could come in contact with fluid from a ruptured or leaky tank, pipe, or other components that store or transfer hazardous fluids shall be compatible with the fluid so that they do not create a flammable, combustible, or toxic hazard.

11.3.1.4.5. Compatible materials selection shall be obtained from one of the following sources:

11.3.1.4.5.1. T.O. 00-25-223.

11.3.1.4.5.2. Chemical Propulsion Information Agency (CPIA) 394, *Hazards of Chemical Rockets and Propellants*.

11.3.1.4.5.3. Marshall Space Flight Center Handbook (MSFC-HDBK)-527, *Material Selection for Space Hardware, Volume 1*.

11.3.1.4.5.4. KTI-5210, *NASA/KSC Material Selection List for Oxygen and Air Services*.

11.3.1.4.5.5. KTI-5211, *NASA/KSC Material Selection List for Reactive Fluid Service*.

11.3.1.4.5.6. KTI-5212, *NASA/KSC Material Selection List for Plastic Films, Foams, and Adhesive Tapes*.

11.3.1.4.5.7. MSFC-STD-3029, *NASA/MSFC Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments*.

11.3.1.4.5.8. Other sources and documents approved by Wing Safety.

11.3.1.4.6. Compatibility Testing.

11.3.1.4.6.1. Materials shall be tested for compatibility if data does not exist.

11.3.1.4.6.2. If compatibility testing is performed, the test plan shall be submitted to Wing Safety for review and approval.

11.3.1.4.7. Compatibility Analysis. A compatibility analysis containing the following information shall be prepared:

11.3.1.4.7.1. List of all materials used in system.

11.3.1.4.7.2. Service fluid in contact with each material.

11.3.1.4.7.3. Materials that may come in contact with leaking fluid.

11.3.1.4.7.4. Source document or test results showing material compatibility in regard to permeability, flammability, ignition and combustion, functional and material degradation, contamination, toxicity, pressure and temperature extremes, shock, oxidation, corrosion, and environmental conditions.

11.3.1.4.8. Metallic components for pressure vessels, pipes, valves, and fittings shall be fabricated from low carbon stainless steel or other alloys that provide adequate strength, corrosion resistance, and material compatibility. Materials shall be traceable to an industry standard such as ASME, ANSI, Society of Automotive Engineers (SAE), DOT/FAA/AR-MMPDS, *Metallic Materials Properties Development and Standardization (MMPDS) Handbook*, etc. **Note**: Wing Safety approved materials that provide adequate strength, corrosion resistance to the environment, and material compatibility may be used for metallic components of pressure vessels, pipes, valves, and fittings.

11.3.1.5. Generic Ground Support Pressure System Corrosion Control. Although corrosion control is primarily the responsibility of the maintainer of the equipment, the designer is responsible for providing hardware that cannot present safety problems caused by corrosion. As a minimum, the following potentially critical areas shall be evaluated and appropriately protected:

Table 11.2. Corrosion Control Guidance.

A Wing Safety approved corrosion control standard, such as NASA-STD-5008A, *Protective Coating Of Carbon Steel, Stainless Steel, And Aluminum On Launch Structures, Facilities, And Ground Support Equipment*, or NACE RP0285, *Corrosion Control of Underground Storage Tank Systems by Cathodic Protection* (published by the National Association of Corrosion Engineers), should be used as guidance for corrosion control. Corrosion protection of fixed outdoor pressure systems includes supports, anchors, and clamps. Avoid use of 17-4PH stainless steel wherever possible due to its susceptibility to stress corrosion cracking at low heat treatment levels. Any 17-4PH stainless steel specified should be heat treated to condition H1025 or higher. Avoid use of type 303 stainless steel wherever possible due to its susceptibility to stress corrosion cracking.

11.3.1.5.1. Carbon steel surfaces exposed to atmospheric corrosion shall be protected by the application of zinc coatings (inorganic zinc or hot dip galvanizing) or equivalent means.

11.3.1.5.2. Stainless steel surfaces exposed to rocket engine exhaust impingement or acid deposits from solid rocket motor exhaust shall be coated with inhibitive polyamide epoxy primer and aliphatic polyurethane topcoat in accordance with NASA-STD-5008A. **Note**: Nitrile, rubber-based, aluminum-pigmented coating (AR-7) is no longer recommended for coating stainless steel surfaces because it has a high volatile organic compound content and is generally unavailable through commercial suppliers.

11.3.1.5.3. No protective coatings are normally required for the stainless steel surfaces located in a neutral pH corrosive marine environment. Exterior stainless steel surfaces in the launch environment exposed to rocket engine exhaust, elevated temperatures, hypergolic propellant, or acid deposition from solid booster exhaust shall be coated with inhibitive polyamide epoxy primer and aliphatic polyurethane topcoat in accordance with NASA-STD-5008A.

11.3.1.5.4. Underground vessels and piping shall be coated with a coal-tar epoxy coating (or equivalent) and galvanically protected.

11.3.1.5.5. All underground systems shall be cathodically protected and designed so that periodic checks of the protection can be obtained.

11.3.1.5.6. Dissimilar metals shall be protected through mutual isolation.

11.3.1.5.7. All underground metallic systems shall be protected against corrosion by cathodic protection. Cathodic protection systems (sacrificial or DC power) shall be designed so that a periodic check of the system can be obtained.

11.3.1.6. Generic Ground Support Pressure System Contamination Control.

11.3.1.6.1. To avoid a hazardous failure, adequate levels of contamination control shall be established by relating the cleanliness requirements to the actual needs and nature of the system and components. **Note**: KSC-C-123, *Surface Cleanliness of Fluid Systems*, *Specifications for* or T.O. 42C-11, *Cleaning and Inspection Procedures for Ballistic Missile Systems*, should be used as guidance in relating cleanliness requirements to the actual needs and nature of the system and components.

11.3.1.6.2. Materials and fluids used in the design shall be selected to reduce internally generated contamination caused by rate of wear, friction, and fluid decomposition.

11.3.1.6.3. Systems shall have acceptable contamination tolerance levels. The tolerance level of the system and/or components shall be based on considerations of the overall functional requirements and service life.

11.3.1.6.4. The system shall be designed to verify, through sampling, that the lines and components are clean after flushing and purging of the system.

11.3.1.6.5. Each component or section of a system shall be cleaned to the appropriate level before installation. Immediately following cleaning, all components or sections of a system shall be protected to prevent contamination.

11.3.1.6.6. Equipment designed to be cleaned or re-cleaned in place without significant disassembly shall be provided with high point bleeds and low point drains to facilitate introduction and removal of cleaning fluid.

11.3.1.6.7. Filters shall be installed immediately downstream of all interfaces where control of particulate matter is critical and at other appropriate points as required to control particulate migration.

11.3.1.6.8. Filter design shall permit easy servicing and ready accessibility.

11.3.1.7. Generic Ground Support Pressure System Identification and Marking. All hazardous pressure system components shall be identified as to function, content, applicable hazard, and, if applicable, direction of flow. The marking and identification shall be accomplished by some means that cannot cause “stress concentration” or otherwise reduce the integrity of the system. Minimum identification and marking requirements are as follows:

11.3.1.7.1. Fixed Pressure Vessels.

11.3.1.7.1.1. Fixed pressure vessels shall be code stamped IAW the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, *Rules for Construction of Pressure Vessels,* or ASME Boiler and Pressure Vessel Code, Section VIII, Division 2*, Alternative Rules – Rules for Construction of Pressure Vessels.*

11.3.1.7.1.2. The maximum pressure at which fixed pressure vessels shall be normally operated and the name of the working fluid shall be painted in a conspicuous location on the vessel facing the roadway approach, if possible. This additional labeling shall be legible at a distance of 50 feet under clear daytime conditions.

11.3.1.7.2. Portable and mobile pressure vessels shall be marked IAW the applicable DOT specifications.

11.3.1.7.3. Individual lengths or fabricated assemblies of pipe and tubing shall be identified with part number and/or contractor tracking number, pipe or tube size, schedule number or wall thickness, test pressure, and the date of hydrostatic and/or pneumatic test. Identification data shall be affixed to fabricated assemblies by means of an attached stainless steel band or “dog tag” that has been stamped or electrochemically etched.

11.3.1.7.4. Fixed ground support piping and tubing runs external to regulation and control panels and consoles shall be identified and marked with commodity, maximum operating pressure (MOP), flow direction, and applicable hazards, warnings and symbols.

11.3.1.7.5. All RPIE shall be identified in accordance with MIL-STD-101C, *Color Code for Pipelines and for Compressed Gas Cylinders* or equivalent.

11.3.1.7.6. Shutoff and metering valves, pressure relief valves, regulators, gauges, quick disconnect ground half couplings, and filters shall have the following information permanently attached to the body by stamping, engraving, tagging, or other means:

11.3.1.7.6.1. Manufacturer and/or contractor name.

11.3.1.7.6.2. Manufacturer part number.

11.3.1.7.6.3. Applicable design pressure rating.

11.3.1.7.6.4. Service media.

11.3.1.7.6.5. Month and year of most recent calibration for gauges and transducers.

11.3.1.7.6.6. Flow direction arrow, if applicable.

11.3.1.7.6.7. System reference designation for the component, such as CV1, CV2.

11.3.1.7.6.8. Unique serial number.

11.3.1.7.7. All manual pressure system regulation and control panels and consoles shall be clearly marked with a flow schematic, operating parameters, and component identification.

11.3.1.7.8. The system shall be designed or marked to prevent incorrect installation of filters.

11.3.1.7.9. Flexible hoses shall be provided with an identification tag that is permanently and legibly marked with the following information:

11.3.1.7.9.1. Manufacturer name.

11.3.1.7.9.2. Manufacturer and/or contractor part number.

11.3.1.7.9.3. Hose size.

11.3.1.7.9.4. MAWP or manufacturer rated working pressure.

11.3.1.7.9.5. Service media.

11.3.1.7.9.6. Month and year of most recent hydrostatic test and test pressure.

11.3.1.7.9.7. System reference designation for the hose, such as FH1, FH2.

11.3.1.7.9.8. Unique serial number.

11.3.1.7.10. An identification tag that is permanently and legibly marked with the month and year of the most recent set pressure calibration shall be attached to the relief valve.

11.3.1.8. Generic Ground Support Pressure System Bonding and Grounding. All pressure systems shall be properly bonded and grounded to provide the following. **Note**: See KSC-STD-E-0012, *Bonding and Grounding*, and NFPA 77, *Recommended Practices on Static Electricity*, for additional guidance.

11.3.1.8.1. Any single joint measurement shall exhibit a DC resistance of 1 ohm or less.

11.3.1.8.2. DC resistance from any point in the piping and tubing system to the nearest earth electrode ground plate shall be 1 ohm or less.

11.3.1.8.3. A low-impedance path to earth shall be provided for electrical currents resulting from lightning discharges or electrical power system faults to minimize abnormal voltage rises that might injure personnel or damage equipment.

11.3.1.8.4. A discharge path shall be provided between distribution piping and tubing and earth to prevent the buildup of static electricity.

11.3.1.8.5. For flammable or combustible commodities, piping and tubing shall be bonded to ground at the end termination and at intervals of not more than 100 feet.

11.3.1.8.6. Non-flammable and non-combustible pressure system piping and tubing shall be bonded to ground at the end terminations and at intervals of not more than 300 feet.

11.3.1.8.7. Flanged joints are acceptable if the flanges are stainless steel or the flanged areas in contact with the bolt heads and washers are clean and bright. In addition, the bolts and nuts shall be equipped with serrated or spring washers to maintain tightness.

11.3.1.8.8. Tubing sections joined with fittings that seat metal-to-metal are considered adequately bonded.

11.3.1.8.9. All mobile equipment shall be equipped for connection to bonding and grounding stations at fixed facility transfer apron areas.

11.3.1.8.10. Grounds shall be provided for propellant loading systems (flight propulsion systems or ground propellant tanks) to allow for common grounding and bonding during propellant transfer operations. Loading systems include portable vessels and units.

11.3.1.8.11. The use of interconnecting dissimilar ground metals that could lead to increased resistance due to galvanic corrosion over a relatively short time period shall be avoided.

11.3.1.9. Generic Ground Support Pressure System Physical Arrangement and Human Factors. Pressure systems shall be designed to provide adequate accessibility, clearance, and operating safety. **Note**: MIL-STD-1472 or the equivalent should be used as guidance in designing pressure system operating consoles.

11.3.1.9.1. Hypergolic system design shall take into consideration the limitations imposed on individuals dressed in Self-Contained Atmospheric Protective Ensemble (SCAPE) suits or Propellant Handlers Ensemble (PHE).

11.3.1.9.2. All components and piping shall be located so they are readily accessible for maintenance, inspection, and calibration. All piping shall be located to preclude a hazard to personnel (tripping or head injury).

11.3.1.9.3. Tubing shall be located and protected so that damage cannot occur due to being stepped on, used as handholds, or by manipulation of tools during maintenance.

11.3.1.9.4. Pressure lines shall clear all structures, components, and other lines by not less than 1/4 inch under the most adverse conditions of service to ensure that abrasive chafing does not occur.

11.3.1.9.5. Piping, tubing, and other components shall be routed or located to provide protection from other operational hazards, including moveable equipment. Where such exposure is unavoidable, safeguards that minimize the effects of such exposure shall be incorporated in the design.

11.3.1.9.6. Maximum spacing shall be provided between oxidizer and fuel lines to preclude mixing and combustion. A minimum of 24 inches shall be provided.

11.3.1.9.7. Pipes containing liquids shall not be attached or secured to electrical lines or conduit.

11.3.1.9.8. A 2-inch space shall be maintained between electrical conduits and pressure lines.

11.3.1.9.9. Vent outlets shall be located far enough away from incompatible propellant systems and incompatible materials to ensure that no contact is made during vent operations.

11.3.1.9.10. System connections for incompatible propellants shall be keyed, sized, or located so that it is physically impossible to interconnect them.

11.3.1.9.11. Safety relief valves and burst diaphragms shall be located so that their discharge is directed away from personnel or safety critical equipment to prevent injury to personnel or damage to safety critical equipment. If this requirement cannot be met, safety valves and burst diaphragms shall be equipped with deflection devices. Consideration shall be given to minimizing the noise hazard of high pressure venting.

11.3.1.9.12. Vent lines for flammable and combustible vapors, toxic gases, and gas streams that may be contaminated with toxic vapors shall be extended away from work areas to prevent accidental ignition of vapors and/or injury to personnel.

11.3.1.9.13. Pipe routing shall not block personnel egress routes.

11.3.1.9.14. Pressure systems shall be designed so that the operator is not required to leave the operating control station to monitor the hazard level of that system.

11.3.1.9.15. Valves carrying hazardous liquids shall not be located overhead in the area of an operating station.

11.3.1.9.16. Manually operated liquid valves shall be located to permit operation from the side or above to prevent spillage of service fluid on the operator due to leak or failure of the valve seals.

11.3.1.9.17. For systems with failure modes that could result in a time-critical emergency, provision shall be made for automatic switching to a safe mode of operation. Caution and warning signals shall be provided for these time-critical functions.

11.3.1.9.18. Pressure systems shall be designed so that removal and replacement of tubing can be accomplished with minimal removal of other system components.

11.3.1.9.19. Systems shall be designed with accessibility to perform end-to-end static ground system checks.

11.3.1.9.20. Pipes containing hazardous liquids shall be routed with a continuous downward slope to prevent the accumulation of trapped liquid fluids and allow draining of the lines.

11.3.1.9.21. Where possible, pipes carrying hazardous liquids shall be mounted so that the liquid cannot be trapped in internal cavities when it is drained.

11.3.1.9.22. High pressure lines and components shall be protected from damage due to leakage, servicing, or other operational hazards created by other systems.

11.3.1.9.23. Redundant legs (branches) of a safety pressure system shall be physically separated and protected so that a single event such as damage, fire, or an explosion cannot cause both redundant legs to fail.

11.3.1.9.24. Components shall be located and lines routed to minimize the risk of ignition should a leak or rupture occur.

11.3.1.9.25. Pressure lines shall not be installed inside conduit, large pipe, or tubing for protective support. **Exception**: Lines may be enclosed in protective conduit, pipes, or tubing when routed under roadways, obstructions, and through thick walls.

11.3.1.9.26. System components such as a hand regulator and gauge that are closely related shall be arranged to allow operation and surveillance from a common point.

11.3.2. Ground Support Pressure System Hardware Design Requirements.

11.3.2.1. Ground support pressure systems shall be designed in accordance with applicable national consensus standards and the requirements contained in this chapter.

11.3.2.2. Propellant systems shall be designed to ensure separation of fuels and oxidizers to prevent the inadvertent mixing of propellants during operations.

11.3.2.3. All calibration adjustments shall be designed so that the setting, position, or adjustment cannot be inadvertently altered.

11.3.2.4. Permanently Installed Pressure Vessels.

11.3.2.4.1. All permanently installed pressure vessels shall be designed, constructed, tested, certified, and code stamped IAW the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or Division 2.

11.3.2.4.2. All ASME code stamped vessels shall be registered with the National Board of Boiler and Pressure Vessel inspectors.

11.3.2.4.3. The following additional design, fabrication, and inspection requirements shall also be met:

11.3.2.4.3.1. Pressure vessels shall be designed with an opening for inspection purposes.

11.3.2.4.3.2. Pressure retaining welds, including all shell, head nozzle, and nozzle-to-head or shell welds, shall be inspected using volumetric and surface NDE techniques.

11.3.2.4.3.3. At a minimum, all attachment welds such as supports, lugs, pads, and nameplates shall be inspected using surface NDE techniques.

11.3.2.4.3.4. Welded attachments such as stiffening rings or supports shall be welded with a continuous weld bead.

11.3.2.4.3.5. Welded and bolted attachments such as piping, gussets, ladders, and platforms to the pressure vessel should be minimized and the design shall be approved by Wing Safety.

11.3.2.4.3.6. External and internal surfaces of vessels shall be free of crevices and other areas that can trap moisture or contaminants.

11.3.2.4.3.7. All attachments shall be positioned so that no attachment weld will overlap any category A or B weld as defined by ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or Division 2.

11.3.2.4.3.8. SA514, SA517, or other alloys with substantially the same properties as T-1 steel shall not be used for pressure vessels that are fabricated by welding.

11.3.2.4.4. Fixed pressure vessels exposed to the atmosphere and wind shall be designed to withstand the maximum expected external loading as determined by analysis. The analysis shall be conducted IAW American Society of Civil Engineers (ASCE)/Structural Engineering Institute (SEI) 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, and L.P. Zick, “Stresses in Large Cylindrical Pressure Vessels on Two Saddle Supports" (originally published in *The Welding Journal Research Supplement* (1951) and modified by the ASME in Volume 2 of *Pressure Vessel and Piping: Design and Analysis, A Decade of Progress* (1972)). **Note**: An additional reference is ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix G, *Suggested Good Practice Regarding Piping Reactions and Design of Supports and Attachments.*

Table 11.3. Additional Analysis Lessons Learned.

Pressure vessels near launch pads may need to take into consideration additional possible launch plume overpressure.

11.3.2.4.5. Pressure vessel supports shall be designed IAW good structural practice and local requirements for wind or seismic loads. Accepted guidelines such as the ASME Boiler and Pressure Vessel Code, Section VIII, or those developed by L.P. Zick, may be utilized, and a detailed finite element structural analysis may be required.

11.3.2.4.6. Consideration shall be given to anchor bolt design capability for hold down in the event of a deluge water filled bay (buoyant force of vessel), if applicable.

11.3.2.4.7. One of the two supports of a fixed vessel shall be capable of providing for expansion and contraction of the vessel.

11.3.2.4.8. All underground hazardous waste tanks and ancillary piping shall comply with the requirements in 40 CFR 264.193, *Containment and Detection of Releases*, and 40 CFR 280, *Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks*, and shall have secondary containment systems with leak detection capability.

11.3.2.4.9. Vessel installation design shall meet range-peculiar conditions such as severe wind and seismic loads.

11.3.2.4.10. Vessels, tanks, and systems shall be inventoried and records maintained in a Range Pressure System Database Management Program or by the Range User responsible for operating the facility.

11.3.2.4.11. Pressure vessels designed and fabricated according to DOT codes are not normally specified for permanent installation in high pressure systems. If such vessels are installed on a permanent basis, the installation shall meet ASME design requirements or be installed to permit easy access to hydrostat the vessel periodically in compliance with DOT regulations.

11.3.2.4.12. All pressure vessels shall be designed to allow for a minimum 10% ullage space at full-load conditions.

11.3.2.5. Portable or Mobile Pressure Vessels.

11.3.2.5.1. Mobile equipment for public and range highway use shall be designed, fabricated, inspected, and tested to meet the requirements in 49 CFR, Subpart 6, Parts 1000 through 1199, *Surface Transportation Board, Department of Transportation*. A copy of any DOT-approved exemptions shall be provided to Wing Safety.

11.3.2.5.2. DOT pressure vessels shall be protected against overpressure in accordance with 49 CFR.

11.3.2.5.3. DOT pressure vessels used and approved for use in a fixed ground-based system shall be provided overpressure protection in accordance with ASME code.

11.3.2.6. Ground Support Pressure System Piping. At a minimum, all piping installations shall be designed in accordance with ASME B31.3, *Process Piping*, in addition to the following:

11.3.2.6.1. Pipe material shall be in accordance with ASTM A312/A312M, *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*, and ASME B36.10M, *Welded and Seamless Wrought Steel Pipe* or B36.19M, *Stainless Steel Pipe*. **Note**: Recommended material for piping is cold-drawn seamless ASTM A312 grade TP304L or TP316L stainless steel.

11.3.2.6.2. Weld fittings such as tees, crosses, elbows, and reducers shall be of the butt-weld type in accordance with ASME B16.9, *Factory Made Wrought Steel Butt Welding Fittings*. **Note**: Butt-weld fittings should be constructed of ASTM A403, grade WP-316L or WP-304L wrought stainless steel.

11.3.2.6.3. Mechanical joints shall be made of ASTM A182, *Forged or Rolled Alloy-Steel Pipe Flanges, Forged*, F316 butt-weld hubs, ASTM A182 F304 clamp assemblies, and type 17-4PH teflon-coated seal rings. Where system design dictates the use of industrial flanged-type mechanical joints, they shall be in accordance with ASME B16.5, *Pipe Flanges and Flanged Fittings*. Flange serrations shall be of concentric design. Flange gaskets shall conform to ASME B16.21, *Nonmetallic Flat Gaskets for Pipe Flange*, and be compatible with the media.

11.3.2.6.4. Threaded National Pipe Thread (NPT) connectors shall not be used in hazardous pressure systems unless specifically approved by Wing Safety. **Exception**: With prior approval from Wing Safety, NPT connectors may be used for selected supply components in some compressed nitrogen (GN2) or helium (GHe) gas pipeline metering and letdown stations. The following guidelines will apply:

11.3.2.6.4.1. Maximum Operating Pressure shall not exceed 6,000 psig.

11.3.2.6.4.2. NPT connection size shall not exceed 1-inch nominal pipe size.

11.3.2.6.4.3. Selected components are sample ports, vent/blowdown valves, pressure indicators, thermowells, and pressure regulation sensors.

11.3.2.6.4.4. NPT connectors used for connections that do not require repeated demating/mating shall have effective corrosion control applied to the exposed threads to prevent external corrosion from weakening the high stress points.

11.3.2.6.4.5. All of the selected components installed with NPT connections shall face away from high traffic areas and be anchored or shielded to mitigate projectile risk if an NPT connector does fail.

11.3.2.6.4.6. Signs shall be placed in the metering and letdown stations warning personnel not to step on or grab the pipe or components protruding from the pipe due to use of NPT connectors in the pressure system.

11.3.2.6.4.7. All connections that require periodic demating/mating for periodic maintenance purposes (such as relief valve functional testing) shall use MS or equal straight thread connectors; NPT connectors shall not be used.

11.3.2.6.4.8. Pressure reducing regulators and control valves shall not be installed in the pipeline using NPT (tapered thread) fittings. Connections such as hub and seal ring connectors or flanged connections are recommended. Pipe hubs are specifically designed for large, high-pressure connections.

11.3.2.6.5. Socket welded flanges shall not be used in hazardous pressure system piping.

11.3.2.6.6. All piping welds shall be of the full penetration butt-weld type.

11.3.2.6.7. All piping and fitting butt welds used to fabricate hazardous pressure systems shall be 100% visually and radiographically inspected. Accept/reject criteria shall be in accordance with ASME B31.3, Table 341.3.2 or Table K341.3.2 for pressure systems with MOP equal to or greater than 6,000 psig.

11.3.2.6.8. Cryogenic piping systems shall provide for thermal expansion and contraction without imposing excessive loads on the system. **Note**: Offset bends and loops rather than bellows should be used for this purpose wherever possible.

11.3.2.6.9. All welded pipe fabricated in place shall be installed with adequate weld-repair clearance from buildings and other structures. **Note**: An adequate weld-repair clearance from buildings and other structures is typically a minimum of 6 inches.

11.3.2.6.10. All piping shall be located so that it is not hazardous to working personnel.

11.3.2.6.11. Cryogenic Pipe Weld Inspection.

11.3.2.6.11.1. All inner pipe welds shall be 100% radiographically inspected.

11.3.2.6.11.2. The accept/reject criteria shall be IAW Table 341.3.2 of ASME B31.3.

11.3.2.7. Ground Support Pressure System Tubing. Tubing connections can be of a butt-weld type or by use of precision 37-degree fittings. **Note**: For welded connections, pneumatic distribution tubing should be annealed seamless, stainless steel type 304/304L or 316/316L.

11.3.2.7.1. If 37-degree flared end fittings are used, they shall be designed IAW precision type AN, MS, or KSC-GP-425, *Engineering Standards*, standards. **Note**: The material used to join 37-degree flared end fittings should be type 316 stainless steel.

11.3.2.7.2. If butt-weld fittings are used to join tubing, they shall be designed in accordance with KSC-GP-425 or equivalent. **Note**: The material should be type 304L or 316L stainless steel.

11.3.2.7.3. All tubing and butt-weld fitting welds shall be 100% radiographically inspected. Acceptance and rejection criteria shall be IAW Table 341.3.2 of ASME B31.3.

11.3.2.7.4. Tubing used with AN or MS fittings shall be flared per MS33584, *Tubing End, Standard Dimensions for Flared*, and tubing used with KSC-GP-425 fittings shall be flared per KSC-GP-425. "Crush" washers are prohibited.

11.3.2.7.5. Since flared tubing is not designed for service above 6,000 psig, Wing Safety approved super pressure tubing shall be used for service above 6,000 psig.

11.3.2.7.6. Fabrication and installation of tubing using KSC-GP-425 fittings shall be in accordance with KSC-SPEC-Z-0008, *Specification for Fabrication and Installation of Flared Tube Assemblies and Installation of Fittings and Fitting Assemblies*.

11.3.2.7.7. Tube fittings with NPT connectors shall not be used in hazardous pressure systems.

11.3.2.7.8. The number of mechanical joints in tubing systems shall be kept to a minimum.

Table 11.4. Steel Types for Pressure System Tubing.

All pressure gauge material that normally contacts the service fluid should be type 316 stainless steel. **Exception**: Bourdon-tube bleed screws may be constructed of any 300 series stainless steel.

11.3.2.7.9. Tubing shall be seamless, stainless steel conforming to ASTM A269, *Seamless and Welded Austenitic Stainless Steel Tubing*, or KSC-SPEC-Z-0007, *Specification for Tubing, Steel Corrosion Resistance Type 304 and 316, Seamless, Annealed*.

11.3.2.8. Ground Support Pressure System Regulators.

11.3.2.8.1. Regulators shall be sized to accurately control the pressure to be used in the system.

11.3.2.8.2. Manually operated regulators shall be selected so that overtorquing the regulator cannot damage soft seats to the extent that seat failure occurs.

11.3.2.8.3. Regulators shall be designed so that a functional failure cannot create a hazard to personnel.

11.3.2.8.4. Dome loaded pressure regulators shall be designed to withstand a differential pressure across the diaphragm and/or piston equal to the maximum rated inlet pressure without damage. A means of venting the dome loading circuit shall be provided.

11.3.2.8.5. Pressure regulator actuators shall be capable of shutting off the fluid when the system is at the maximum possible flow and pressure.

11.3.2.8.6. A regulator shall not be used as a safety critical component or be required to function to prevent a failure that might injure personnel.

11.3.2.8.7. For each stage of regulation, the ratio of upstream-to-downstream pressure shall be considered by the designer to allow the operator accuracy and control appropriate for the system being designed. A maximum ratio of 10:1 is recommended.

11.3.2.8.8. Regulators shall be selected so their working pressure falls within the center 50% of the total pressure range if it is susceptible to inaccuracies or creep at either end of the pressure range.

11.3.2.8.9. Regulator design using uncontained seats shall not be used.

11.3.2.8.10. The use of a sheathed flexible actuator such as push-pull wires and torque wires for regulator control is prohibited.

11.3.2.9. Ground Support Pressure System Valves.

11.3.2.9.1. Both manual and automatic valve actuators shall be operable under maximum design flow and pressure for complete opening and closing the respective valve.

11.3.2.9.2. Remotely operated valves shall be designed to be fail-safe if pneumatic or electric control power is lost.

11.3.2.9.3. Designs using uncontained seats shall not be used.

11.3.2.9.4. Use of metal-to-metal seats without Wing Safety concurrence is prohibited. **Note**: Metal-to-metal seats are not suited for frequent mate/demate activities, as the seats are subject to scratching and damage when demated, which leads to increased leakage. They are suitable for permanent or rarely demated connections.

11.3.2.9.5. Inlet and outlet isolation valves (shutoff valves) and appropriate intermediate vent valves shall be provided for shutdown and maintenance.

11.3.2.9.6. Valve stem travel shall be limited by a positive stop at each extreme position.

11.3.2.9.7. The application or removal of force to the stem positioning device shall not cause disassembly of the pressure containing structure of the valve.

11.3.2.9.8. Manually operated valves used in hazardous pressure systems shall be designed so that overtorquing the valve stem cannot damage soft seats to the extent that seat failure occurs.

11.3.2.9.9. Inlet and outlet isolation valves shall be capable of isolating the maximum allowable working pressure in both directions without seat failure.

11.3.2.9.10. Fast opening valves that can produce high velocity kinetic effects or heating effects due to rapid pressurization shall not be used.

11.3.2.9.11. Systems shall have shutoff valves located as close to the supply vessel as practical and be readily accessible.

11.3.2.9.12. Remotely controlled valves shall provide for remote monitoring of open and closed positions.

11.3.2.9.13. Local or remote stem position indicators shall sense the position of the stem directly, not the position of the actuating device.

11.3.2.9.14. For remotely controlled valves, positive indication of actual valve position shall be displayed at the control station. Indication of valve stem position or flow measurement is an acceptable indication. Indication of a remote command being initiated is not a positive indication of valve position.

11.3.2.9.15. Valves used in flared tubing system applications shall be designed for panel or other rigid mounting.

11.3.2.9.16. All pressure system valves that are required to be in a closed or open position during system operation shall be protected against inadvertent actuation by physical means. **Note**: Examples of physical means to protect against inadvertent actuation are mechanical stops, lock wires, or access control.

11.3.2.9.17. Valves that are not intended to be reversible shall be designed or marked so that they cannot be connected in a reverse mode.

11.3.2.9.17.1. Check valves shall be provided where back flow of fluids would create a hazard.

11.3.2.9.17.2. Check valves shall be the spring-loaded type with soft seats.

11.3.2.9.18. The use of sheathed flexible actuators, such as push/pull wires and cables, for valve control is prohibited.

11.3.2.9.19. All electrical control circuits for remote activation shall be shielded or otherwise protected from hazardous stray energy.

11.3.2.9.20. Balanced manual valves that use external balancing ports or vents open to the atmosphere shall not be used.

11.3.2.9.21. Remotely operated flow control valves shall be operated pneumatically, electrically, or hydraulically and shall be capable of fail-safe operation to either the open or closed position. Determination of fail-safe mode (the open or closed position) shall depend on the system characteristics.

11.3.2.10. Ground Support Pressure System Vents, Drains, Low Points, Bleeds, Test Ports, and Sampling Ports. All pressure and propellant systems shall have a low-point drain capability unless prohibited by the DOT, as well as a high-point bleed capability with easy accessibility.

11.3.2.10.1. Pressure and propellant systems shall be designed so that commodities cannot be trapped in any part of the system without vent capability. **Exception**: Loosening of fittings to vent trapped pressure is allowed when the fluid under pressure is non-hazardous and only for the purpose of calibrating or replacing pressure gauges or transducers that are provided with an upstream isolation valve where the total trapped volume does not exceed 1and 1/2 cubic inches.

11.3.2.10.2. Vent system outlets shall be in a location normally inaccessible to personnel and shall be conspicuously identified.

11.3.2.10.3. Vent outlets shall be protected against rain intrusion and entry of birds, insects, and animals.

11.3.2.10.4. Oxidizer and fuel vent outlets to the atmosphere shall be separated sufficiently to prevent mixing of vented fluids/gases.

11.3.2.10.5. All vent outlets shall be designed to preclude accumulation of vented fluid in dangerous concentrations in areas frequented by unprotected personnel or motor vehicles.

11.3.2.10.6. Vent line supports shall be designed to withstand reaction loads due to the actuation of safety relief devices in accordance with ASME B31.3, Paragraph 322.6.2.

11.3.2.10.7. Each line venting into a multiple-use vent system shall be protected against back pressurization by a check valve if the upstream system cannot withstand the back pressure or where contamination of the upstream system cannot be tolerated.

11.3.2.10.8. Incompatible fluids shall not be discharged into the same vent or drain system.

11.3.2.10.9. Fuel and oxidizer vent systems shall be equipped with a means of purging the system with an inert gas to prevent explosive mixtures.

11.3.2.10.10. Vent systems shall be sized to provide minimum back pressures consistent with required venting flow rates. In no case shall back pressures interfere with proper operation of relief devices.

11.3.2.10.11. Personnel and critical equipment shall be protected from potential venting hazards.

11.3.2.10.12. Bleed ports shall be located so that they can be operated with minimal removal of other components and permit the attachment of a hose to direct the bleed-off material into a container, away from the positions of the operators.

11.3.2.10.13. Test points shall be provided on pressure systems so that disassembly for test is not required.

11.3.2.10.14. Test points shall be easily accessible for attachment of ground test equipment.

11.3.2.10.15. A sampling port shall be provided upstream and downstream of each regulator in any pneumatic branch line that interfaces with a hypergolic propellant system to permit periodic sampling and analysis of the medium for contamination.

11.3.2.10.16. Sample ports shall be provided at cryogenic system low points.

11.3.2.10.17. A single pressure gauge shall be provided at some point downstream either in the pneumatic system or the propellant system to indicate the pressure in the propellant system.

11.3.2.10.18. Gauge calibration ports shall be designed to limit potential impingement of contaminated gas on personnel.

11.3.2.10.19. The drain system shall include a sump or basin where the fluid can safely collect. This sump or basin shall be designed so that it can be easily cleaned and drainage easily removed.

11.3.2.11. Ground Support Pressure System Indicating Devices.

11.3.2.11.1. All pressure gauges shall conform to the requirements of ASME B40.1, *Gauges, Pressure Indicating Dial Type*. **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 as are gauges associated with pneumatic controllers, positioners, and other standard process control equipment.

11.3.2.11.2. A pressure indicating device shall be connected downstream of each pressure regulator, on each storage system, and on any section of the system where pressure can be trapped.

11.3.2.11.3. Gauges shall be sized to accurately display the pressure to be used in the system.

11.3.2.11.4. All pressure gauges shall be equipped with a full diameter pressure release back that shall be sized for maximum flow without case rupture.

11.3.2.11.5. Gauges shall be securely attached to a panel or other rigid mounting. **Exception**: With a documented hazard assessment, self-supporting gauges may be allowed for applications where damage to the gauge connection will not result in a hazard to personnel, damage to high value hardware, or loss of valuable commodities. Self-supporting gauges may also be allowed in applications where the gauge is not susceptible to impact or rotation.

11.3.2.11.6. If pressure gauge isolation valves are used, they shall be designed so that they can be secured in the open position. **Note**: Lock wiring is an acceptable means of securing pressure gauge isolation valves in the open position.

11.3.2.11.7. Gauge installations shall be designed to have a minimum of 1-inch clearance to allow unrestricted venting in the event the gauge vents. Personnel and equipment shall be protected from the vent area.

11.3.2.11.8. Gauges shall be selected so that the normal operating pressure falls between 25% and 75% of the scale range, except for gauges used in applications that require a wide range of operating pressure, which shall not exceed 95% of scale range of the gauge.

11.3.2.11.9. Remote sensing devices shall be required when it is necessary to monitor hazardous operations from a remote location.

11.3.2.11.10. Pressure gauges shall be of one-piece, solid-front, using an optically clear shatterproof window made of high-impact, non-cracking plastic, heat-treated glass, or laminated glass.

11.3.2.11.11. For systems containing liquid, such as propellant loading tanks and hazardous waste tanks, a method for indicating the presence or absence of liquid shall be provided. **Note**: Metals that could come in contact with the service medium should be compatible, such as type 304 or 316 stainless steel.

11.3.2.11.12. Liquid system liquid level indicators that contain welded portions (typically magnetic float type) shall be constructed from stainless steel. **Note**: Stainless steels such as type 304L or 316L should be used.

11.3.2.11.13. Liquid system sight glasses used for liquid level indicators shall be protected from physical damage.

11.3.2.11.14. As required, pressure gauges shall allow for precision cleaning and verification of cleanliness by particle analysis and non-volatile residue analysis; for example, a bourdon tube tip bleeder or equivalent.

11.3.2.11.15. Each pressure-indicating device shall be provided with an isolation valve and should have a test connection (test port) between the isolation valve and the pressure-indicating device. Trapped volume between the isolation valve and the pressure-indicating device shall be minimized.

11.3.2.11.16. The operating range-of-pressure transducers used for monitoring pressures during hazardous operations shall not be less than 1.2 and not more than 2.0 times the system MOP.

11.3.2.12. Ground Support Pressure System Flexible Hoses.

11.3.2.12.1. Flexible hoses shall be used only when required for hookup of portable equipment or to provide for movement between interconnecting fluid lines when no other feasible means is available.

11.3.2.12.2. Flexible hoses shall consist of a flexible inner pressure carrier tube (compatible with the service fluid) constructed of elastomeric (typically poly-tetrafluoroethylene [PTFE] for hypergolic fluid) or corrugated metal (typically 300 series stainless steel) material reinforced by one or more layers of 300 series stainless steel wire and/or fabric braid. **Note**: In applications where stringent permeability and leakage requirements apply, hoses with a metal inner pressure carrier tube should be used. Where these hoses are used in a highly corrosive environment, consideration should be given to the use of Hastalloy C-22 in accordance with ASTM B575 for the inner pressure carrier tube and C-276 material for the reinforcing braid.

11.3.2.12.3. Hoses shall be provided with 300-series stainless steel end fittings of the coupling nut, 37-degree flared type or with fittings to mate with the appropriately sized ASME B16.5 flange or KC159 hub. Other end fittings may be used for unique applications, subject to Wing Safety approval.

11.3.2.12.4. Interchanging of flexible hoses used in incompatible service media such as hypergolics shall be avoided. Permeation is not totally negated by any cleaning process. Hoses shall be dedicated to a service media.

11.3.2.12.5. Hoses over 2 feet long, pressurized to 250 psig or greater, shall meet the following restraint requirements:

11.3.2.12.5.1. Flexible hoses shall have safety chains or cables securely attached across each union or splice and at intervals not to exceed 6 feet. Flexible hose installations that are 6 feet long or longer shall be included so that restraint is provided on both the hose and adjacent structure at no greater than 6-foot intervals and at each end to prevent whiplash in the event of a burst.

11.3.2.12.5.2. Hose end restraints shall be securely attached to the structure in a manner that in no way interferes with the hose flexibility.

11.3.2.12.5.3. Restraining devices shall be designed and demonstrated to contain a force not less than 1.5 times the open line pressure force. A thrust equation using pressure, area, and momentum is the approach best founded in physics and shall be used for calculating the open force line pressure.

11.3.2.12.5.4. The design safety factor for restraint devices shall not be less than 3 on material yield strength.

11.3.2.12.5.5. Temporary flexible hose installations may be weighted with 50-pound sand bags, lead ingots, or other suitable weights at intervals not to exceed 6 feet.

11.3.2.12.5.6. Hose clamp-type restraining devices shall not be used.

11.3.2.12.6. Flexible hose installation shall be designed to avoid abrasive contact with adjacent structures or moving parts.

11.3.2.12.7. Flexible hose assemblies shall not be installed in a manner that will place a mechanical load on the hose or hose fittings to an extent that will degrade hose strength or cause the hose fitting to loosen.

11.3.2.12.8. Flexible hose shall not be supported by rigid lines or components if excessive loads from flexible hose motion can occur.

11.3.2.12.9. Flexible hose between two components may have excessive motion restrained where necessary, but shall never be rigidly supported by a tight rigid clamp around the flexible hose.

11.3.2.12.10. Flexible hoses shall not be exposed to temperatures that exceed the rated temperature of the hose.

11.3.2.12.11. Flexible hoses that are permitted to pass close to a heat source shall be protected with a fireproof boot metal baffle.

11.3.2.12.12. Designs using convoluted, unlined bellows or flexible metal hoses shall be analyzed to verify premature failure caused by flow-induced vibration is precluded.

11.3.2.12.13. Acoustic coupling that can intensify the stresses caused by flow-induced vibration shall be avoided by ensuring that normal fluid flow requirements do not exceed a velocity of Mach 0.2. **Note**: A guidance document for performing the flow-induced vibration analysis is MSFC 20MO2540, *Assessment of Flexible Line and Flow-Induced Vibration*.

11.3.2.12.14. The bend radius of flexible hoses shall be designed to be no less than the safe minimum bend radius recommended in authoritative specifications for the particular hose and in no case less than five times the outside diameter of the hose.

11.3.2.12.15. A means of plugging or capping flexible hoses shall be provided when the hose is not in use.

11.3.2.12.16. Ground Support Cryogenic System Flexible Hoses.

11.3.2.12.16.1. Flexible hoses shall be used only when required to isolate vibration and piping movement and for hookup of portable and mobile equipment.

11.3.2.12.16.2. Flexible hoses shall be of the single-wall, double-wall, or double-wall vacuum-jacketed type.

11.3.2.12.16.3. All convoluted portions of flexible hoses shall be covered with stainless steel wire braid.

11.3.2.13. Ground Support Pressure System Relief Devices.

11.3.2.13.1. All fixed pressure vessels shall be protected against overpressure by means of at least one conventional safety relief valve or pilot-operated pressure relief valve in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1. Rupture disks alone shall not be used to protect against overpressure.

11.3.2.13.2. A rupture disc may be installed between the pressure relief valve and the vessel provided that the limitations of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Paragraphs UG-127(a)(3)(-b) and UG 127(a)(3)(-c) are met.

11.3.2.13.3. Particular care shall be taken to monitor and/or vent the space between the rupture disc and the relief valve as required. The space between a rupture disc and a relief valve shall be designed to allow annual testing for leakage and/or contamination. **Note**: Providing a screen between the rupture disc and the valve to prevent rupture disc contamination of the relief valve should be considered.

11.3.2.13.4. Installation of the pressure relief devices shall be in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Paragraph UG-135.

11.3.2.13.5. The flow capacity for all relief devices shall be certified in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Paragraph UG-127, UG-129, UG-131, and UG-132, as applicable.

11.3.2.13.6. The total relieving capacity of pressure relief devices shall be determined in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Paragraph UG-133. The required relieving capacity shall be provided by a single valve where possible.

11.3.2.13.7. The set pressure on pressure relief devices shall be set to operate at a pressure not to exceed the MAWP of the vessel (see ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, UG-134).

11.3.2.13.8. The relieving capacity of the relief valve shall be equal to or greater than the maximum flow capability of the upstream pressure reducing device or pressure source and shall prevent the pressure from rising more than 20% above the system MOP or that allowed by ASME B31.3, whichever is less.

11.3.2.13.9. Pressure relief valves shall be set to operate at a set pressure not to exceed 110% of the system MOP or that allowed by ASME B31.3, whichever is less.

11.3.2.13.10. Negative pressure protection shall be provided for vessels not designed to withstand pressures below 1 atmosphere if the pressure vessel feed system or operational use renders it susceptible to negative gauge pressure. **Note**: Negative pressure protection may be accomplished by the use of check valves or negative pressure relief devices.

11.3.2.13.11. Pressure vessel relief devices shall be located so that other components cannot render them inoperative except as specified in ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Paragraph UG-135 and Appendix M, *Installation and Operations,* Paragraphs M-5 and M-6. When a shutoff valve is allowed IAW the ASME Boiler and Pressure Vessel Code, the valve type shall have provisions for being locked in the open or closed position. **Note**: Safety wiring is an acceptable means of locking shutoff valves in the open or closed position.

11.3.2.13.12. The shutoff valve associated with the relief device shall have permanent marking clearly identifying its position (open or closed).

Table 11.5. Steel Types for Pressure Relief Devices.

The body and other pressure containing parts for pressure relief devices should be 300-series stainless steel. **Exception**: DOT cylinders or trailer relief devices may contain parts of brass or bronze.

11.3.2.13.13. A pressure relief valve shall be installed downstream of the last GSE regulator before flight hardware interface and before entering a container and/or black box purge system.

11.3.2.13.14. All relief valves and piping shall be structurally restrained to eliminate any thrust effects from transferring moment forces to the vessel nozzles or lines.

11.3.2.13.15. The effects of the discharge from relief devices shall be assessed and analyzed to ensure that operation of the device cannot be hazardous to personnel or equipment. Items to be analyzed are thrust loads, noise, impingement of high velocity gas or entrained particles, toxicity, oxygen enrichment, flammability, and oxygen deprivation.

11.3.2.13.16. All relief devices shall be vented separately unless the following can be positively demonstrated:

11.3.2.13.16.1. The creation of a hazardous mixture of gases in the vent system and the migration of hazardous gases into an unplanned environment is impossible.

11.3.2.13.16.2. The capacity of the vent system is adequate to prevent a pressure rise more than 20% above MOP or exceed 10% of the set pressure of the valve in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix M, Paragraph M-8. The analysis shall assume that all relief valves connected to the vent system are open and flowing full capacity.

11.3.2.13.17. Both the inlet and discharge sides of a relief valve shall be hydrostatically or pneumatically tested. When the discharge side has a lower pressure rating than the inlet side, they are to be hydrostatically or pneumatically tested independently. Prior approval of the plan for pneumatic testing shall be obtained from Wing Safety.

11.3.2.13.18. Pressure relief valves shall be tested for proper set pressure setting before installation.

11.3.2.13.19. Pressure relief devices shall be marked in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Paragraphs UG-129, UG-130, UG-131, and UG-132 as applicable.

11.3.2.13.20. A pressure relief valve shall be installed as close as is practical downstream of each pressure reducing device (regulator, orifice) or downstream of any source of pressure such as compressors, gas rechargers, and tube bank trailer whenever any portion of the downstream system cannot withstand the full upstream pressure. The criteria for "withstand" is that the upstream pressure shall not exceed the MAWP of any pressure vessel or component downstream of the regulator or pressure source.

11.3.2.13.21. A three-way valve with dual relief valve is required where continuous operation of the system is needed during relief valve calibration.

11.3.2.13.22. Pressure system relief devices shall have no intervening stop valves between piping being protected and the relief devices or between the relief device and the point of discharge except as allowed by ASME B31.3, Paragraph 322.6.1. When a shutoff valve is allowed IAW the ASME code, the valve shall have provisions for being locked in the open or closed position. The valve shall have permanent marking clearly identifying its position (OPEN or CLOSED). **Note**: Safety wiring is an acceptable means of locking shutoff valves in the open or closed position.

11.3.2.14. Ground Support Pressure System Supports, Anchors, Clamps, and Other Restraints.

11.3.2.14.1. All piping supports, anchors, hangers, and other restraints shall conform to the requirements of ASME B31.3, Paragraph 321.

11.3.2.14.2. Line Restraints.

11.3.2.14.2.1. Where line restraint is required, anchors, guides, pivots, or restraints shall be fabricated or purchased and assembled in such a form as to secure the desired points of piping in relatively fixed positions.

11.3.2.14.2.2. Line restraints shall permit the line to expand and contract freely in opposite directions away from the anchored or guided point.

11.3.2.14.2.3. Line restraints shall be designed to withstand the thrust, torsional forces, and load conditions of operation.

11.3.2.14.2.4. Line restraints shall contain the line in case of line failure.

11.3.2.14.2.5. The support shall be capable of withstanding no less than 2 times the available force as a result of thrust generated from component failure under pressure.

11.3.2.14.3. All relief valves and attached vent piping shall be designed to withstand any thrust caused by venting fluids.

11.3.2.14.4. All rigid tubing assemblies shall be supported by rigid structures using cushioned steel clamps or suitable multiple tube, block-type clamps.

11.3.2.14.5. Tubing supports within consoles or modules shall be spaced according to the maximum spacing listed in **Table 11.6**.

Table 11.6. Spacing for Tubing Supports Within Consoles or Modules.

Nominal Tubing Diameter (inches)	**Maximum Distance Between Tubing Support (inches)**
1/8 through 3/8	18
1/2 through 3/4	25
1 and over	30

11.3.2.14.6. Tubing supports between consoles and modules shall be spaced according to the maximum spacing listed in **Table 11.7**.

Table 11.7. Spacing for Tubing Supports Between Consoles or Modules.

Nominal Tubing Diameter (inches)	**Maximum Distance Between Tubing Support (feet)**
1/8 through 3/8	4
1/2 through 3/4	6
1 through 2	9

11.3.2.14.7. Components within a system shall be supported by a firm structure and not the connecting tubing or piping unless it can be shown by analysis that the tubing or piping can safely support the component with a safety factor of 3 against yield.

11.3.2.14.8. Hazardous pressure system piping shall be installed with sufficient flexibility to prevent static or dynamic flow-induced loads and thermal expansion or contraction from causing excessive stresses to be induced in the system, excessive bending moments at joints, or undesirable forces or moments at points of connection to equipment or at anchorage or guide points.

11.3.2.15. Reserved.

11.3.2.16. Ground Support Pressure System Pumps.

11.3.2.16.1. *The Standards of the Hydraulic Institute* should be used as a guide in selecting a safe pump.

11.3.2.16.2. Gear pumps shall not be used for high pressure applications involving flammable and/or hazardous fluids.

11.3.2.16.3. The inlet pressure of hydraulic pumps shall be controlled to prevent cavitation effects in the pump passage or outlets.

11.3.2.16.4. Hydraulic pumps required to provide emergency power shall not be used for any other function.

11.3.2.16.5. Hydraulic pressure systems shall have regulators with a pressure relieving or self-bleeding feature.

11.3.2.16.6. Pumps used in hypergolic propellant systems shall be of the centrifugal type specifically designed for pumping hypergolic propellants.

11.3.2.17. Ground Support Hydraulic System Hardware.

11.3.2.17.1. General Ground Support Hydraulic System Design.

11.3.2.17.1.1. For all power-generating components, pump pulsations shall be controlled to a level that does not adversely affect system tubing, components, and support installation.

11.3.2.17.1.2. When two or more hydraulic actuators are mechanically tied together, only one lock valve shall be used to hydraulically lock all the actuators.

11.3.2.17.1.3. The ambient operating temperature for hydraulic systems shall not exceed 275° F for systems using petroleum-based fluids.

11.3.2.17.1.4. Fluids for systems operating at temperatures higher than 275° F shall be fire resistant or fireproof for the intended service.

11.3.2.17.1.5. Where system leakage can expose hydraulic fluid to potential ignition sources, fire resistant or flameproof hydraulic fluid shall be used.

11.3.2.17.1.6. All hydraulic piping installations shall be designed, installed, and tested in accordance with ASME B31.3.

11.3.2.17.1.7. Pressure snubbers shall be used with all hydraulic pressure transmitters, hydraulic pressure switches, and hydraulic pressure gauges. **Exception**: Pneumatic pressure gauges are excluded from this requirement.

11.3.2.17.1.8. A gauge indicating accumulator gas pressure shall never be used to indicate equivalent hydraulic pressure.

11.3.2.17.1.9. Pressure system relief devices shall have no intervening stop valves between piping being protected and the relief devices or between the relief device and the point of discharge, except as allowed per ASME B31.3.

11.3.2.17.1.10. When a shutoff valve is allowed IAW the ASME Boiler and Pressure Vessel Code, the valve type shall have provisions for being secured in the open or closed position.

11.3.2.17.1.11. The shutoff valve shall have permanent marking clearly identifying its position (OPEN or CLOSED).

11.3.2.17.1.12. Thermal expansion relief valves shall be installed as necessary to prevent system damage from thermal expansion of hydraulic fluid.

11.3.2.17.1.13. The thermal relief valve setting shall not exceed either the system test pressure or 120% of the system MOP.

11.3.2.17.2. Ground Support Hydraulic System Accumulators and Reservoirs.

11.3.2.17.2.1. Accumulators and reservoirs that are pressurized with gas to pressures greater than 250 psig shall be designed, constructed, tested, certified, and code stamped in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or Division 2.

11.3.2.17.2.2. Hydraulic system reservoirs shall be provided with a fluid level indicator. If a sight glass is used for a liquid level indicator, it shall be properly protected from physical damage.

11.3.2.17.2.3. Only inert gases shall be used in pressurization accumulators in systems operating at pressures in excess of 200 psi or temperatures over 160° F unless adequate fire and explosion resistance is demonstrated.

11.3.2.17.2.4. For a gas-pressurized reservoir, the gas pressure shall be controlled by an externally nonadjustable pressure regulating device to control the gas pressure in the reservoir.

11.3.2.17.2.5. Hydraulic systems having reservoir filling caps shall include design provisions that will automatically vent the reservoir opening.

11.3.2.18. Ground Support Hypergolic System Hardware. The minimum design requirements for all fixed, mobile, or portable equipment used to handle hypergolic propellants (nitrogen tetroxide [N2O4], hydrazine [N2H4,] unsymmetrical dimethylhydrazine [UDMH], Aerozine 50 [A-50], and monomethylhydrazine [MMH]) are described below.

11.3.2.18.1. All fixed hypergolic fuel vessels shall be designed with a minimum value of 75 psig MAWP.

11.3.2.18.2. All fixed hypergolic oxidizer vessels shall be designed with a minimum value of 100 psig MAWP.

11.3.2.18.3. Components used in any fuel or oxidizer system shall not be interchanged after exposure to the respective media.

11.3.2.18.4. Lubricants for hypergolic systems shall be approved compatible lubricants only. **Note**: See KSC-STD-Z-0006, *Standard for Design of Hypergolic Propellants Ground Support Equipment*, for guidance on compatible lubricants and design of hypergolic propellants GSE.

11.3.2.18.5. Bi-propellant propellant systems shall have the capability of loading fuel and oxidizer systems one at a time.

11.3.2.18.6. The minimum design requirements for controlling the migration of liquid or gas hypergolic propellant into an associated pneumatic system are as follows:

11.3.2.18.6.1. Each pneumatic branch line that interfaces with a hypergolic propellant system shall be single fault tolerant to permit positive shutoff of the pneumatic supply and prevent back flow through the branch. A pressure gauge shall be provided at some point downstream either in the pneumatic system or the hypergol system of each check valve to indicate the pressure in the hypergolic propellant system. **Note**: A hand-operated, shutoff valve upstream of a regulator and a spring-loaded, poppet-type check valve to permit positive shutoff of the pneumatic supply and prevent back flow through the branch is an acceptable solution.

11.3.2.18.6.2. Each pneumatic branch supply shall interface with only one type of hypergolic propellant (fuel or oxidizer).

11.3.2.18.6.3. Downstream of the pneumatic pressure regulator, the pneumatic system shall be identified and marked as a hypergolic system.

11.3.2.18.6.4. All hypergolic vent effluent resulting from routine operations shall be scrubbed or incinerated, as appropriate, before venting to the atmosphere through vent stacks. **Exception**: Minimal vapor releases are acceptable if the potential for an accidental liquid release is fully mitigated (e.g., liquid separator in vent line).

11.3.2.18.6.5. All scrubber and incinerator designs and qualification tests shall be reviewed and approved by Wing Safety, Bioenvironmental Engineering, and Civil Engineering.

11.3.2.18.6.6. Each line venting into a multiple-use vent system shall be protected against back pressurization by means of a check valve if the upstream system cannot withstand the back pressure or where contamination of the upstream system cannot be tolerated.

11.3.2.18.7. Copper, bronze, or other alloys that might form copper oxides shall be avoided in hydrazine areas. If used, they shall be positively protected by distance, sealing in a compatible material, or use of a splash guard.

11.3.2.18.8. GSE used to handle propellant systems shall be designed to ensure that all incompatible fuels and oxidizers are separated so that operations during the prelaunch phase cannot cause inadvertent mixing of the propellants.

11.3.2.18.9. Downstream of the pneumatic pressure regulator, including the regulator seat, the pneumatic system shall be constructed of materials that are compatible with all of the hypergolic propellants serviced by the pneumatic supply.

11.3.2.18.10. The area in close proximity to the hardware containing and/or transporting hydrazine-based fuels shall be maintained free of surface corrosion and its associated oxidation byproducts.

11.3.2.18.11. All hypergolic fuel and oxidizer transportation and storage containers shall have the capability to be grounded.

11.3.2.19. Ground Support Cryogenic System Hardware. The minimum design requirements for all fixed, mobile, and portable equipment used to handle cryogenic liquids (e.g., liquid oxygen (LO2 or LOX), liquid hydrogen (LH2), liquid helium (LHe), liquid nitrogen (LN2), liquefied natural gas (LNG)) and their respective vent gases are as follows:

Table 11.8. Steel Types for Cryogenic Equipment.

The inner shell and piping in the annular space should be Type 304 or 316 (304L or 316L, if welded) stainless steel. The outer shell and supports may be stainless steel or carbon steel.

11.3.2.19.1. Cryogenic systems shall be insulated with compatible material or be vacuum-jacketed to avoid liquefaction of air. Drip pans or other equivalent means shall be provided under flanges when there exists the possibility of leaking liquefied air.

11.3.2.19.2. Cryogenic fuel and oxidizer systems shall have the capability of loading one commodity at a time.

11.3.2.19.3. Vacuum-jacketed systems shall be capable of having the vacuum verified.

11.3.2.19.4. Purge gas for LH2 and cold gaseous hydrogen (GH2) lines shall be gaseous helium (GHe). Neither GN2 nor LN2 shall be introduced into any LH2 line that interfaces with a liquid storage tank cold port.

11.3.2.19.5. Cryogenic systems shall be designed to ensure the separation of fuels and oxidizers and to prevent inadvertent mixing.

11.3.2.19.6. Precautions shall be taken to prevent cross mixing of media through common purge lines by use of check valves to prevent back flow from a system into a purge distribution manifold.

11.3.2.19.7. Cross connection of GN2 and GHe systems is prohibited.

11.3.2.19.8. All permanently installed cryogenic vessels shall consist of an inner and an outer shell.

11.3.2.19.9. The annular space between the inner and outer shell shall be insulated and may be vacuum-jacketed or purged. **Exception**: LH2 and LHe vessels shall be vacuum-jacketed.

11.3.2.19.10. The inner shell shall be designed, constructed, tested, certified, and code stamped on the exterior of the vessel in compliance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or Division 2.

11.3.2.19.11. In lieu of the code stamp, a nameplate bearing the required inner shell data shall be attached to the outer shell. **Note**: An additional nameplate marked “DUPLICATE” may be attached to the support structure.

11.3.2.19.12. The outer shell shall be designed for 0.0 pounds per square inch absolute (psia) internal pressure and 15.0 psia external pressure.

11.3.2.19.13. For non-vacuum-jacketed vessels, the annular space shall be protected by means of a vacuum breaker.

11.3.2.19.14. Local and remote readout liquid level indicators shall be provided for LH2 and LO2 storage vessels.

11.3.2.19.15. At a minimum, local readout capability shall be provided for all other cryogenic storage vessels.

11.3.2.19.16. Cryogenic piping systems shall provide for thermal expansion and contraction without imposing excessive loads on the system.

11.3.2.19.17. Cryogenic systems shall be designed to ensure icing does not render the valve inoperable.

11.3.2.19.18. Cryogenic valves with extended stems shall be installed with the actuator approximately vertical above the valve.

11.3.2.19.19. GH2 and liquefied natural gas (LNG) vapors shall be vented to the atmosphere through a burner system unless otherwise agreed to by Wing Safety.

11.3.2.19.20. GH2 and LNG vapor burner design and testing requirements shall be approved by Wing Safety.

11.3.2.19.21. Pressure vessels shall be designed with an opening for inspection purposes.

11.3.2.19.22. All inner shell pressure retaining welds including shell, head nozzle, and nozzle-to-head and shell welds shall be 100% inspected by radiographic and/or ultrasonic volumetric NDE.

11.3.2.19.23. All inner shell attachment welds for items such as supports, lugs, and pads shall be 100% inspected by liquid penetrant, ultrasonic, magnetic particle, eddy current, and/ or radiographic surface NDE.

11.3.2.19.24. Welded attachments to the inner vessel such as stiffening rings or supports shall be continuously welded.

11.3.2.19.25. All attachments to the inner shell shall be positioned so that no attachment weld overlaps any Category A or B weld as defined in ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Paragraph UW-3.

11.3.2.19.26. Cryogenic systems shall be provided with readily accessible low-point drain capability to allow draining of tanks and piping systems. Small volumes contained in valves, filters, and other containers that will boil off in a short period of time do not require low-point drain capability.

11.3.2.19.27. Vacuum-jacketed or other types of thermal insulation shall be based on system heat leak rate and failure mode and effect determination.

11.3.2.19.28. Guidelines for oxygen systems design, material selection, operations, storage, and transportation can be found in ASTM Manual 36 (MNL36), *Safe Use of Oxygen and Oxygen Systems: Handbook for Design, Operation, and Maintenance*.

11.3.2.19.29. For failure modes that could result in a time-critical emergency condition, provisions shall be made for automatic switching to a safe mode of operation. Caution and warning signals shall be provided for these time-critical functions.

11.3.2.19.30. Flight propulsion systems and/or propellant tanks and their associated propellant loading system (including portable vessels and units) shall be designed such that propellant transfer operations are commonly bonded and grounded.

11.3.2.19.31. Titanium and titanium alloys shall not be used where there is possible exposure to gaseous oxygen (cryogenic boil-off) or liquid oxygen.

11.3.2.20. Ground Support Cryogenic Piping System Joints, Connections, and Fittings.

11.3.2.20.1. Cryogenic piping design shall be in accordance with ASME B31.3.

11.3.2.20.2. Joints in piping systems shall be of the butt-weld, flanged, bayonet, or hub type in accordance with KSC-GP-425, KC159/KC163, or the commercial equivalent.

11.3.2.20.3. Butt-weld fittings shall conform to ASME B16.9 and shall be constructed of wrought ASTM A403 grade WP304L or WP316L stainless steel.

11.3.2.20.4. Flanged joints shall be either weld neck or lap joint, raised face type conforming to ASME B16.5 and shall be constructed of forged ASTM A182 F304L or F316L stainless steel. The use of slip-on flanges shall be avoided.

11.3.2.20.5. Flange faces or lap-joint stub end faces shall be concentrically serrated conforming to MSS-SP-6, *Standard Finishes for Contact Faces of Pipe Flanges and Connecting End Flanges of Valves and Fittings*.

11.3.2.20.6. LH2 vent system flanged joints shall be metal-to-metal and shall be seal-welded unless otherwise approved by Wing Safety.

11.3.2.20.7. Flange bolting and studs shall conform to ASME B18.2.1, *Square and Hex Bolts and Screws, Inch Series,* recommended dimensions and shall use ASME B1.1, *Unified Inch Screw Threads, Unified (UN) and Unified National Radius (UNR) Thread Form,* threads.

11.3.2.20.8. Bolt materials shall be per ASTM A193 or ASTM A320.

11.3.2.20.9. Nuts for flange bolting and studs shall conform to ASTM A194 and ASME B18.2.2 heavy hex type with ASME B1.1 threads. **Note**: Type 304 or 316 stainless steel are the preferred materials for nuts and studs used for flange bolting.

11.3.2.20.10. Pipe fittings such as tees, elbows, crosses, reducers, and lap joint stub ends shall be full penetration butt weld type only, conforming to ASTM A403 and ASME B16.9. **Note**: ASTM A403 wrought stainless steel grades WP-304L and WP-316L are the preferred materials for butt weld pipe fittings.

11.3.2.20.11. Bayonet fittings shall be used on vacuum-jacketed lines where butt welding is not practical and a mechanical joint is required.

11.3.2.20.12. Metal-to-metal couplings shall be the butt-welded types. The gaskets (not reusable) shall be constructed of stainless steel only. The V-band clamps shall be constructed of stress-corrosion-resistant material.

11.3.2.20.13. Vacuum-jacketed pipe shall not use bellows in the inner pipe. Allowance for differential expansion between inner and outer pipe shall be provided by bellows in the outer pipe.

11.3.2.21. Ground Support Compressed and Breathing Air Systems. The minimum requirements for compressed and breathing air systems are as follows:

11.3.2.21.1. Compressed air systems (shop air) operating at 250 psig or less shall be designed, operated and maintained IAW accepted industry standards such as 29 CFR 1910.169, *Air Receivers*, and ASME B19, *Safety Standard for Air Compressor Systems*. Air Force owned/operated compressed air (shop air) systems shall comply with the requirements of AFI 32-1068.

11.3.2.21.2. Breathing air systems shall be designed to ensure acceptable breathing air is provided to the operator and the following requirements are met. **Note**: At a minimum, breathing gas should meet requirements specified in 42 CFR 84.141, *Breathing Gas, Minimum Requirements*.

11.3.2.21.2.1. PHEs shall be compatible with the commodities expected to be contacted.

11.3.2.21.2.2. PHE has been treated to prevent a static charge buildup.

11.3.2.21.2.3. The breathing air commodity shall meet the requirements of Compressed Gas Association (CGA) G-7.1, *Commodity Specification for Air*, Grade D, for breathing air.

11.3.2.21.2.4. The breathing air piping system and all components shall be cleaned to Level 200A or cleaner.

11.3.2.21.2.5. The breathing air piping system shall be designed to provide a positive pad pressure of 10 psig when in standby condition.

11.3.2.21.2.6. Breathing air connection interfaces shall be sized or oriented so that no interconnection with other commodities is possible. Selection of specific quick disconnects shall be approved by Wing Safety.

11.3.2.21.2.7. Air connect interfaces shall be clearly identified with signs or placards to identify the commodity as “BREATHING AIR” or as “SHOP AIR (NOT TO BE USED AS BREATHING AIR).”

11.3.3. Ground Support Pressure System Testing.

11.3.3.1. Testing Ground Support Pressure Systems Before Assembly.

11.3.3.1.1. All permanently installed pressure vessels, accumulators, and reservoirs except DOT vessels shall be hydrostatically tested in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, or Division 2, as applicable to the year of construction of the vessel.

11.3.3.1.2. All piping and tubing system components shall be pressure tested in accordance with methods and criteria contained in ASME B31.3.

11.3.3.1.3. Pressure vessels designed to meet DOT specifications shall undergo qualification and hydrostatic testing in accordance with DOT requirements.

11.3.3.1.4. Hydrostatic or pneumatic testing shall demonstrate that there is no distortion, damage, or leakage of components at the appropriate test level pressure.

11.3.3.1.5. The following inspections shall be performed after hydrostatic testing:

11.3.3.1.5.1. Mechanical components such as valves, regulators, piping, and fittings shall be inspected for distortion or other evidence of physical damage. Damaged components shall be rejected.

11.3.3.1.5.2. A component functional and leak test shall be performed at the MAWP of the component.

11.3.3.1.6. Pressure relief devices, gauges and transducers shall be calibrated before installation and yearly thereafter.

11.3.3.1.7. For pressure gauges, transducers, or rupture discs and other components not covered by ASME B31.3, pneumatic testing to 1.25 times maximum expected operating pressure (MEOP) (not to exceed MAWP), in lieu of hydrostatic testing is permissible if hydrostatic testing is impractical, impossible, or jeopardizes the integrity of the component or system. Pneumatic testing to 1.1 times MAWP for components covered by ASME B31.3 in lieu of hydrostatic testing, is permissible if hydrostatic testing is impractical, impossible, or jeopardizes the integrity of the component or system. Prior approval for pneumatic proof testing at the ranges shall be obtained from Wing Safety.

11.3.3.1.8. Certain critical system components may require further testing (helium mass spectrometer tests) in accordance with ASME Boiler and Pressure Vessel Code, Section V, *Nondestructive Examination,* Article 10, Leak Testing.

11.3.3.1.9. All valves used for hypergolic systems shall be tested for both external and internal leakage at MAWP using an inert gas (helium/nitrogen) consisting of at least 10% helium. The use of argon as a testing medium is prohibited.

11.3.3.1.9.1. No external leakage is allowed (bubble-tight).

11.3.3.1.9.2. Internal leakage of valves shall not exceed limits specified in the valve performance specification.

11.3.3.1.9.3. Where no valve specification exists, the leak rate shall not exceed 1 x 10^{-6} cc/sec at standard temperature and pressure.

11.3.3.2. Testing Ground Support Pressure Systems After Assembly.

11.3.3.2.1. Ground Support Pressure System Hydrostatic Tests.

11.3.3.2.1.1. All newly assembled pressure systems shall be hydrostatically tested to 1.5 times MOP before use. Where this is not possible, Wing Safety shall determine the adequacy of component testing and alternate means of testing the assembled system. Pneumatic testing at 1.1 times the MOP is acceptable in lieu of hydrostatic testing at 1.5 times the MOP. Prior approval of the plan for pneumatic testing shall be obtained from Wing Safety.

11.3.3.2.1.2. All cryogenic systems shall be hydrostatically tested to at least 1.25 times system MOP using an inert cryogenic fluid at or below the expected lowest temperature.

11.3.3.2.1.3. Cryogenic systems that cannot be chilled and hydrostatically tested with an inert fluid at or below the lowest expected temperature shall require a cold shock demonstration test, a hazard analysis, and a fracture mechanics safe-life analysis. The test and analysis methodology is subject to review and approval by Wing Safety.

11.3.3.2.1.4. The hydrostatic test or cold shock/soak test (for at least 1 hour) shall demonstrate that the system or components shall sustain test pressure level and temperature gradient without distortion, damage, or leakage.

11.3.3.2.1.5. The following inspections shall be performed on vacuum-jacketed systems:

11.3.3.2.1.5.1. An examination for cold spots on vacuum jackets. Cold spots in the outer line shall not be more than 5° C colder than the surrounding area, except in cases where system heat-leak requirements permit colder temperatures, such as around low-point drain valves, relief valves, or other areas where a direct thermal path is available.

11.3.3.2.1.5.2. Vacuum readings for all vacuum volumes shall be taken and recorded. These readings shall be taken before, during, and after the test.

11.3.3.2.1.5.3. The vacuum readings after the hydrostatic or cold shock/soak using a cryogenic fluid shall be taken when the system returns to ambient temperature.

11.3.3.2.2. Ground Support Pressure System Leak Tests.

11.3.3.2.2.1. For systems with a hazardous fluid, after hydrostatic testing and before the introduction of propellant, a pneumatic leak test of completely assembled systems shall be conducted at the system MOP using an inert gas (helium/nitrogen) consisting of at least 10% helium. The use of argon as a testing medium is prohibited.

11.3.3.2.2.2. After successful completion of the hydrostatic test using a cryogenic fluid, a pneumatic leak test of the complete system shall be performed at the system MOP using helium or a mixture of nitrogen with a minimum of 25% helium. There shall be no leakage into the vacuum volume in excess of 1.0E-06 cc/sec. The sensitivity of the instrumentation used to measure leak rate shall be a minimum of 1 times 1.0E-09 std cm3/sec/div IAW Article 10 of the ASME Boiler and Pressure Vessel Code.

11.3.3.2.2.3. All newly assembled pressure systems, except systems designed, fabricated, inspected, and tested in accordance with DOT requirements, shall be leak tested at the system MOP before first use at the ranges.

11.3.3.2.2.4. This test shall be conducted at the ranges unless prior approval from Wing Safety has been obtained.

11.3.3.2.2.5. Minimum test requirements are as follows:

11.3.3.2.2.5.1. The gas or fluid used during the leak test shall be the same as the system fluid media except those used for hazardous gas systems. A system-compatible, non-hazardous gas may be used that has a density as near as possible to the system fluid (for example, helium should be used to leak test a gaseous hydrogen system).

11.3.3.2.2.5.2. Mechanical connections, gasketed joints, seals, valve bonnets, and weld seams shall pass a mass spectrometer helium leak check or shall be visually bubble tight for a minimum of 1 minute when leak tested with MIL-PRF-25567E, *Leak Detection Compound, Oxygen Systems*, Type 1 or equivalent leak test solution. **Note**: Alternate methods of leak testing may be approved on a case-by-case basis.

11.3.3.2.2.5.3. Non-hazardous liquid systems may be leak tested using the normal system service.

11.3.3.2.3. Ground Support Pressure System Validation and Functional Tests.

11.3.3.2.3.1. All newly assembled pressure systems shall have a system validation test and a functional test of each component at system MOP before first operational use at the ranges.

11.3.3.2.3.2. These tests shall be conducted at the ranges unless prior approval from Wing Safety has been obtained.

11.3.3.2.3.3. Minimum test requirements are as follows:

11.3.3.2.3.3.1. Tests shall demonstrate the functional capability of all components such as valves, regulators, orifices, pumps, and gauges.

11.3.3.2.3.3.2. All operational sequences for the system shall be executed including emergency shutdown and safing procedures.

11.3.3.2.3.3.3. All shutoff and block valves shall be leak checked downstream to verify their shutoff capability in the closed position.

11.3.3.2.3.3.4. The intended service fluid shall be used as the test fluid where practical. Wing Safety approved inert service fluid may be used in place of the service fluid if the intent of the test (equivalent effect on the system) is demonstrated.

11.3.3.2.3.3.5. Systems shall be tested to verify bonding and grounding.

11.3.3.3. Testing Modified and Repaired Ground Support Pressure Systems.

11.3.3.3.1. After repairs and/or modifications to existing tankage, piping, and other system components, tests shall be performed to the same standards, codes, and requirements for which a new system would be designed, fabricated, and tested. Minor refurbishment, such as replacement of gaskets, seals, and valve seats that does not affect structural integrity, does not require a retest.

11.3.3.3.2. Any pressure system component, covered by ASME B31.3, including piping, tubing, fittings, or welds, that has been repaired, modified, or possibly damaged, before having been hydrostatically or pneumatically tested, shall be retested hydrostatically to 1.5 times MAWP or pneumatically to 1.1 times MAWP before reuse. Any pressure system component not covered by ASME B31.3, including pressure gauges, transducers, or rupture discs and other components shall be retested hydrostatically to 1.5 times MOP (not to exceed MAWP) before reuse. Pneumatic testing at the ranges requires prior approval by Wing Safety.

11.3.3.3.3. After hydrostatic testing, modified or repaired systems shall be leak tested at the system MOP before placing them back in service. This test shall be conducted at the ranges unless prior approval has been obtained from Wing Safety.

11.3.3.3.4. After hydrostatic testing, modified or repaired systems shall be functionally tested at the system MOP before reuse.

11.3.3.3.5. All system mechanical joints affected in the disconnection, connection, or replacement of components shall be leak tested at the system MOP before being placed back in service.

11.3.3.3.6. Gaskets shall not be reused.

11.3.4. Ground Support Pressure System Analysis and Documentation Requirements.

11.3.4.1. Ground Support Pressure System Hazard Analysis.

11.3.4.1.1. As applicable, a hazard analysis, shall be performed on all hazardous systems hardware and software IAW a jointly tailored SSPP. (See Volume 1, Attachment 3.)

11.3.4.1.2. At a minimum, the hazard analysis shall include the analysis requirements in AFI 10-2501, *Air Force Emergency Management Program*, and AFMAN 32-4013, *Hazardous Materials Emergency Planning and Response Program*, for toxic, reactive, flammable, and explosive fluids and AFMAN 91-203 and 29 CFR 1910.119 for highly hazardous chemicals, as applicable.

11.3.4.2. Engineering Assessment, Data, and Analysis Requirements.

11.3.4.2.1. An engineering assessment and analysis shall be performed before the start of the first recertification period.

11.3.4.2.2. The engineering assessment of the design, fabrication, material, service, inspection, and testing shall be evaluated against the latest codes, standards, regulations, and requirements identified in this volume.

11.3.4.2.3. Discrepancies with the latest requirements shall be resolved by repair, modification, analysis, inspection, or test.

11.3.4.2.4. Design, Fabrication, and Installation Deficiencies. At a minimum, the following potential design, fabrication, and installation type deficiencies shall be assessed:

11.3.4.2.4.1. Design deficiencies such as design notches, weld joint design, and reinforcements.

11.3.4.2.4.2. Material deficiencies such as laminations, laps, seams, cracks, hardness variations, and notch brittleness.

11.3.4.2.4.3. Welding deficiencies such as cracks, incomplete fusion, lack of penetration, overlap, undercut, arc strikes, porosity, slag inclusions, weld spatter, residual stresses, and distortion.

11.3.4.2.4.4. Installation deficiencies such as fit up, alignment, attachments, and supports.

11.3.4.2.4.5. Operation and Maintenance Deficiencies. At a minimum, the following potential operation and maintenance deficiencies shall be assessed:

11.3.4.2.4.5.1. Refurbishment damage.

11.3.4.2.4.5.2. Modification and/or repair deficiencies.

11.3.4.2.4.5.3. Operation beyond allowable limits or improper sequence.

11.3.4.2.4.5.4. Maintenance deficiencies.

11.3.4.3. In-service Operating, Maintenance, and Inspection Plan. The Range User responsible for the design of hazardous pressure systems shall prepare an in-service operating, maintenance, and inspection plan. This plan shall be referred to as the In-service Inspection (ISI) Plan. The ISI Plan shall address and provide the following:

Table 11.9. In-service Operating, Maintenance and Inspection Plan Guidance.

Guidance for preparing an ISI Plan can be found in ASME Post Construction Committee (PCC)-3, *Inspection Planning Using Risk-Based Methods*. Petroleum storage systems designed, operated and maintained in accordance with OSHA and/or other identified standards are not generally considered hazardous and thus do not require ISI plans. Compressed air (shop air) systems designed, operated and maintained in accordance with 29 CFR 1910.169 also do not require an ISI Plan.

11.3.4.3.1. Credible failure mechanisms that may cause service-related failures of the system during its service life shall be analyzed.

11.3.4.3.2. Methods such as “eliminated,” “controlled by design,” “controlled by procedure,” or “controlled by corrosion protection” used to eliminate and control these failure mechanisms shall be identified. **Note**: Failure mechanisms to be evaluated include corrosion, stress, fatigue, creep, design fabrication, installation, operation, and maintenance deficiencies.

11.3.4.3.3. Using the results of the above failure mechanism analysis, the following minimum requirements for an operating, maintenance, and inspection plan shall be defined:

11.3.4.3.3.1. Operating plans shall address operating constraints such as maximum pressure, MAWP, MOP, minimum and maximum temperature, vibration, and maximum cycles.

11.3.4.3.3.2. Maintenance plans shall address corrosion protection, maintenance schedule, soft-good replacement program, refurbishment, calibration, and other maintenance requirements. **Note**: Hazardous pressure systems intended for one-time use can usually be exempted from the cited maintenance plan requirements. Typically, a Launch Site Requirements Relief Request (LSRRR) provides the basis for this exemption.

11.3.4.3.3.3. Inspection plans shall identify the type and frequency of inspections such as visual, surface, and volumetric NDE required for each vessel and system to detect the types of failure mechanisms identified in paragraph **11.3.4.3.1**.

11.3.4.4. Ground Support Pressure System Data Requirements. The minimum data required to certify compliance with the design, analysis, and test requirements of ground support pressure systems are listed below. The data required shall be incorporated into the MSPSP or submitted as a separate package when appropriate. Certification data shall be placed in a certification file to be maintained by the hazardous pressure system operator. Wing Safety shall review and approve this data before first operational use of new, modified, or repaired hazardous pressure systems at the ranges.

11.3.4.4.1. Ground Support Pressure System General Data Requirements. The following general ground support equipment data shall be submitted as part of the MSPSP.

11.3.4.4.1.1. Hazard analysis of hazardous pressure systems IAW a jointly tailored SSPP (Volume 1, Attachment 2).

11.3.4.4.1.2. A compliance checklist of all design, test, analysis, and data submittal requirements in this volume.

11.3.4.4.1.3. The material compatibility analysis IAW section **11.3.1.4**.

11.3.4.4.1.4. In-service operating, maintenance, and inspection plan IAW section **11.3.4.3**.

11.3.4.4.1.5. Physical and chemical properties and general characteristics of propellants, test fluids, and gases data.

11.3.4.4.1.6. For hazardous propellants, fluids, and gases, data shall be submitted IAW Attachment 2, **A2.2.4.13** and **A2.2.4.7.1.3**.

11.3.4.4.2. Ground Support Pressure System Design Data Requirements. Ground support pressure systems design data shall be submitted IAW Attachment 2, **A2.2.5.9**.

11.3.4.4.3. Ground Support Pressure System Component Design Data Requirements. Ground support pressure systems component design data shall be submitted IAW Attachment 2, **A2.2.5.9.3**.

11.3.4.4.4. Ground Support Pressure System Test Procedures and Reports.

11.3.4.4.4.1. All test plans, test procedures and test reports required in this chapter shall be submitted to Wing Safety for review and approval.

11.3.4.4.4.2. A list and synopsis of all hazardous pressure system operational procedures to be performed at the ranges shall be provided to Wing Safety.

11.4. Ground Support Pressure Systems Certification Data.

11.4.1. The certification file for each hazardous pressure system shall contain all the data required to justify system certification.

11.4.2. The data shall include, but not be limited to, the following:

11.4.2.1. Design calculations for stress, fatigue, and other items that verify compliance with applicable code requirements such as ASME, ANSI, and DOT.

11.4.2.2. In-process fabrication and construction inspection plans and results.

11.4.2.3. Pressure vessel manufacturer data reports (ASME Form U-1 or Form U-1A).

11.4.2.4. Specification drawings and documents for all components.

11.4.2.5. If available, maintenance manuals for all components.

11.4.2.6. If available, component operating manual.

11.4.2.7. As required, a cross-sectional assembly drawing of the component to assess the safety aspects of the internal elements.

11.4.2.8. System operating and maintenance plans and procedures.

11.4.2.9. Certification that welding and weld NDE meet applicable standards such as ASME and ANSI.

11.4.2.10. Unique qualification and acceptance test plans and test reports.

11.4.2.11. Certification documentation showing that vessels are designed, fabricated, and tested in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1/Division 2 or 49 CFR.

11.4.2.12. Certification that all components, including pipe and tube fittings have successfully passed a hydrostatic or pneumatic pressure test.

11.4.3. Ground Support Pressure System Analyses. An engineering analysis shall be performed as follows:

11.4.3.1. A stress analysis of all vessels and piping shall be available for evaluation or performed to verify that stresses are within allowable limits of current codes, standards, and regulations as identified in this volume.

11.4.3.2. The number of stress cycles experienced by the vessel during the certification period shall be determined.

11.4.3.3. Using fracture mechanics analysis, the cyclic limits for vessels with pressures greater than 2,500 psig, burst-before-leak failure mode, or corrosive and/or toxic fluids shall be determined.

11.4.3.4. The safe-life analysis shall be performed under the assumption of pre-existing cracks. This does not imply that cracks are allowed. All unacceptable indications shall be repaired. The safe-life analysis shall be conducted IAW the following requirements:

11.4.3.4.1. The analysis shall show that the vessel will service at least 4 times the cycles expected during the recertification period.

11.4.3.4.2. The analysis shall calculate and evaluate the results from the worst combination of crack sizes (refer to MSFC-STD-1249, *Standard NDE Guidelines and Requirements for Fracture Control Program*, for guidance) and locations such as boss transition area, heat affected area, weld joint, and membrane section within the vessel.

11.4.3.4.3. The appropriate stress component in the vessel shall be used in the analysis.

11.4.3.4.4. The initial flaw size used in the safe-life analysis shall be based on either the hydrostatic test pressure or the detection limits of the appropriate NDE techniques. Flaw shapes (a/2c) ranging from 0.1 to 0.5 shall be considered. **Note**: Refer to MSFC-STD-1249 for guidance.

11.4.3.4.5. Calculated cycles to failure shall be based on the maximum and minimum operating pressure.

11.4.3.4.6. A liner elastic fracture mechanic parameter (stress-intensity factors) shall be used to determine critical crack sizes. The most conservative deformation mode shall be used to determine the appropriate stress-intensity factors (fracture toughness) as appropriate for the parent, weld, and joint materials.

11.4.3.4.7. Fracture mechanics shall only be used to predict the subcritical crack propagation life before unstable crack growth.

11.4.3.4.8. The safe-life analysis results shall be reduced by a factor of 4 in conjunction with assuming the most conservative bounds on material properties and crack growth data for the vessel environment.

11.4.3.4.9. Failure mode determination shall be in accordance with API-579/ASME-FFS-1, *Fitness for Service*, or equivalent standard.

11.4.3.4.10. Vessels subject to stress corrosion (sustained stress) shall show that the corresponding applied stress intensity during operation is less than the threshold stress intensity in the intended environment.

11.4.3.4.11. Corrosion allowance and the remaining wall shall be determined based on MIL-HDBK-729, *Corrosion and Corrosion Prevention Metals*.

Chapter 12

FLIGHT HARDWARE PRESSURE SYSTEMS AND PRESSURIZED STRUCTURES.

12.1. Overview.

12.1.1. This chapter establishes minimum design, fabrication, installation, testing, inspection, certification, and data requirements for flight aerospace vehicle equipment pressure systems, pressure vessels, and pressurized structures. Hazardous flight hardware pressure systems:

12.1.1.1. Contain hazardous fluids such as cryogens, flammables, combustibles, and toxics;

12.1.1.2. Transfer hazardous fluids such as cryogens, flammables, combustibles, and hypergols;

12.1.1.3. Operate at pressures that exceed 250 psig;

12.1.1.4. Store energy at levels exceeding 14,240 foot pounds; and

12.1.1.5. May be identified by Wing Safety as safety critical.

12.2. Flight Hardware Pressure System and Pressurized Structure General Requirements.

12.2.1. Flight Hardware Pressure System and Pressurized Structure General Design Requirements.

12.2.1.1. The structural design of all pressure vessels and pressurized structures shall use industry or government standard processes and procedures for manufacture and repair.

12.2.1.2. The design shall provide for access, inspection, service, repair, and refurbishment.

12.2.1.3. For all reusable pressure vessels and pressurized structures, the design shall permit these hardware to be maintained in and refurbished to a flightworthy condition. To be considered flightworthy, repaired or refurbished hardware items shall pass all the applicable acceptance tests and inspections required for new flight hardware.

12.2.1.4. Repaired and refurbished hardware shall meet the same conditions of flightworthiness as new hardware.

12.2.2. Flight Hardware Pressure System and Pressurized Structure Fault Tolerance.

12.2.2.1. Airborne hazardous pressure systems shall be designed to be single fault tolerant against inadvertent actuations (including leakage) or component failure that could result in a critical hazard during prelaunch operations.

12.2.2.2. Airborne hazardous pressure systems shall be designed to be dual fault tolerant against inadvertent actuations (including leakage) or component failure that could result in a catastrophic hazard during prelaunch operations. **Exception**: Structural failure (i.e., rupture or leakage) of tubing, piping, vessels and normally closed pyrovalves with machined parent metal shear sections shall not be considered single failures provided they meet the applicable requirements of this volume. Normally closed pyrovalves used in propellant/pressurization systems without additional barriers to leakage shall be considered hazardous ordnance devices per **Chapter 13** of this volume and shall meet the tubing and fitting requirements of this volume.

12.2.3. Flight Hardware Pressure System Offloading.

12.2.3.1. For contingency safing operations, hazardous pressure systems shall be designed so that depressurization and drain fittings are accessible and do not create a personnel or equipment hazard for offloading hazardous fluids at the launch complex.

12.2.3.2. The design goal is to be able to offload these pressure systems at any point after pressurization or loading, including the ability to offload all systems at the launch pad without demating of the spacecraft from the launch vehicle or any other disassembly of vehicle systems.

12.2.3.3. If the Range User and Wing Safety decide that depressurizing and/or offloading the pressure systems of a mated spacecraft is prohibited at the launch pad, spacecraft offload procedures shall be approved by Wing Safety prior to use.

12.2.4. Flight Hardware Pressure System Operations. The requirements for operating hazardous pressure systems found in Volume 6 of this publication shall be taken into consideration in the design and testing of these systems in addition to the general requirements identified in section **12.6**.

12.2.5. Flight Hardware Pressure System and Pressurized Structure Analyses.

12.2.5.1. Flight Hardware Pressure System and Pressurized Structure Hazard Analysis.

12.2.5.1.1. A hazard analysis shall be performed on all hazardous systems hardware and software (if applicable) IAW a jointly tailored SSPP (Volume 1, Attachment 3).

12.2.5.1.2. Prelaunch and launch hazards shall be analyzed.

12.2.5.2. Flight Hardware Pressure System and Pressurized Structure Functional Analysis.

12.2.5.2.1. A detailed system functional analysis shall be performed to determine that the operation, interaction, or sequencing of components shall not lead to damage to the launch vehicle, payload, or associated ground support equipment.

12.2.5.2.2. The analysis shall identify all possible malfunctions or personnel errors in the operation of any component that may create conditions leading to an unacceptable risk to personnel or equipment.

12.2.5.2.3. The analysis shall also evaluate any credible secondary or subsequent occurrence, failure, or component malfunction that, initiated by a primary failure, could result in personnel injury.

12.2.5.2.4. Items identified by the hazard analyses shall be designated safety critical and shall require the following considerations:

12.2.5.2.4.1. Hazard identification and proposed corrective action.

12.2.5.2.4.2. Design action.

12.2.5.2.4.3. Safety procedures and operating requirements.

12.2.5.2.4.4. Safety supervision.

12.2.5.2.5. Systems analysis data shall show that:

12.2.5.2.5.1. The system provides the capability of maintaining all pressure levels in a safe condition in the event of the interruption of any process or control sequence at any time during test or countdown.

12.2.5.2.5.2. Redundant pressure relief devices have mutually independent pressure escape routes.

12.2.5.2.5.3. In systems where pressure regulator failure may result in a critical hazard to personnel or hardware safety systems, regulation is redundant and, where passive redundant systems are specified, includes automatic switchover.

12.2.5.2.5.4. When the hazardous effects of safety critical failures or malfunctions are prevented through the use of redundant components or systems, all such redundant components or systems shall be operational before the initiation of irreversible portions of safety critical operations or events.

12.2.5.3. Flight Hardware Pressure System and Pressurized Structure Stress Analysis.

12.2.5.3.1. General Requirements.

12.2.5.3.1.1. A detailed and comprehensive stress analysis of each pressure vessel and pressurized structure shall be conducted under the assumption of no crack-like flaws in the structure.

12.2.5.3.1.2. The analysis shall determine stresses resulting from the combined effects of internal pressure, ground or flight loads, and thermal gradients.

12.2.5.3.1.3. Both membrane stresses and bending stresses resulting from internal pressure and external loads shall be calculated to account for the effects of geometrical discontinuities, design configuration, and structural support attachments.

12.2.5.3.1.4. Loads shall be combined by using the appropriate design limit or ultimate safety factors on the individual loads and comparing the results to material allowables.

12.2.5.3.1.5. Safety factors shall be as determined in section **12.3**.

12.2.5.3.1.6. Safety factors on external (support) loads shall be as assigned to the primary structure supporting the pressurized system.

12.2.5.3.2. Metallic Pressure Vessels and Pressurized Structures Stress Analysis.

12.2.5.3.2.1. For metallic pressure vessels and pressurized structures, classical solutions are acceptable if the design geometries and loading conditions are simple and the results are sufficiently accurate (as determined by Wing Safety) to warrant their application.

12.2.5.3.2.2. Finite element or other equivalent structural analysis techniques shall be used to calculate the stresses, strains and displacements for complex geometries and loading conditions.

12.2.5.3.2.3. As necessary, local structural models shall be constructed to augment the overall structural model in areas of rapidly varying stresses.

12.2.5.3.2.4. Minimum material gauge as specified in the design drawings shall be used in calculating stresses.

12.2.5.3.2.5. The allowable material strengths shall reflect the effects of temperature, thermal cycling and gradients, processing variables, and time associated with the design environments.

12.2.5.3.2.6. Minimum margins of safety associated with the parent materials, weldments, and heat-affected zones shall be calculated and tabulated for all pressure vessels and pressurized structures along with their locations and stress levels.

12.2.5.3.2.7. The margins of safety shall be positive against the strength and stiffness requirements of section **12.2.7** and **12.2.8**.

12.2.5.3.3. Composite Hardware Stress Analysis.

12.2.5.3.3.1. For composite overwrapped pressure vessels (COPVs) and pressurized structures made of composite materials, the state-of-the-art methodology using composite laminate theory shall be used. See ANSI/American Institute of Aeronautics and Astronautics (AIAA) S-081B-2018, *Space Systems – Composite Overwrapped Pressure Vessels (COPVs)* for additional stress analysis methodologies.

12.2.5.3.3.2. Interlamination normal and shear stresses as well as in-plane stress components shall be calculated.

12.2.5.3.3.3. Effects of ply orientation, stacking sequence, and geometrical discontinuities shall be accounted for.

12.2.5.4. Flight Hardware Pressure System and Pressurized Structure Fatigue Analysis. When conventional fatigue analysis is used to demonstrate the fatigue-life of an unflawed pressure vessel or pressurized structure, nominal values of fatigue-life characteristics, including stress-life (S-N) and strain-life (Se-N) data of the structural materials, shall be used.

12.2.5.4.1. These data shall be taken from reliable sources or other sources approved by the procuring agency. **Note**: Fatigue-life characteristics data are available from reliable sources such as MIL-HDBK-5.

12.2.5.4.2. The analysis shall account for the spectra of expected operating loads, pressure, and environments.

12.2.5.4.3. Fatigue damage cumulative technique such as Miner's rule is an acceptable method for handling variable amplitude fatigue cyclic loadings.

12.2.5.5. Flight Hardware Pressure System and Pressurized Structure Safe-Life Analysis.

12.2.5.5.1. When crack growth safe-life analysis is used to demonstrate the safe-life of a pressure vessel or a pressurized structure, undetected flaws shall be assumed to be in the critical locations and in the most unfavorable orientation with respect to the applied stress and material properties.

12.2.5.5.2. The size of the flaws (cracks) shall be based on the appropriate NDE techniques and flaw detection capabilities. Proof test logic shall not be used to determine the initial flaw size for fracture analysis.

12.2.5.5.3. The crack growth safe-life analysis shall be based on fracture mechanics methodology that has been submitted to and approved by Wing Safety.

12.2.5.5.4. Nominal values of fracture toughness and fatigue crack growth rate data associated with each alloy, temper, product form, and thermal and chemical environments shall be used in the safe-life analysis.

12.2.5.5.5. Pressure vessels or pressurized structures that experience sustained stresses shall also show that the corresponding maximum stress intensity factor (K_{max}) during sustained load in operation is less than the stress-corrosion cracking threshold (K_{ISCC}) data in the appropriate environment, $K_{max} < K_{ISCC}$.

12.2.5.5.6. A Wing Safety approved crack growth software package shall be used to conduct the safe-life analysis.

12.2.5.5.7. Aspect ratio (a/2c) changes shall be accounted for in the analysis.

12.2.5.5.8. Retardation effects on crack growth rates from variable amplitude loading shall not be considered without approval by the procuring agency.

12.2.5.5.9. Tensile residual stresses shall be included in the analysis.

12.2.5.5.10. The safe-life analysis shall be included in the stress analysis report. In particular, loading spectra, environments, assumed initial flaw sizes, crack-growth models, fatigue crack growth rate, and fracture data shall be delineated. A summary of significant results shall be clearly presented.

12.2.6. Flight Hardware Pressure Vessel and Pressurized Structure Loads, Pressures, and Environments.

12.2.6.1. The entire anticipated load-pressure-temperature history and associated environments throughout the service life shall be determined IAW specified mission requirements.

12.2.6.2. At a minimum, the following factors and their statistical variations shall be considered:

12.2.6.2.1. The environmentally induced loads and pressures.

12.2.6.2.2. The environments acting simultaneously with these loads and pressures with their proper relationships.

12.2.6.2.3. The frequency of application of these loads, pressures, environments, and their levels and duration.

12.2.7. Flight Hardware Pressure Vessel and Pressurized Structure Strength Requirements.

12.2.7.1. All pressure vessels and pressurized structures shall possess sufficient strength to withstand limit loads and MEOP in the expected operating environments throughout their respective service lives without experiencing detrimental deformation.

12.2.7.2. All pressure vessels and pressurized structures shall also withstand ultimate loads and design burst pressure in the expected operating environments without experiencing rupture or collapse.

12.2.7.3. Pressure vessels and pressurized structures shall be capable of withstanding ultimate external loads and ultimate external pressure (destabilizing) without collapse or rupture when internally pressurized to the minimum anticipated operating pressure.

12.2.7.4. All pressure vessels and pressurized structures shall sustain proof pressure without incurring gross yielding or detrimental deformation and shall sustain design burst pressure without rupture.

12.2.7.5. When proof tests are conducted at temperatures other than design temperatures, the change in material properties at the proof temperature shall be accounted for in determining proof pressure.

12.2.7.6. Pressurized structures subject to instability modes of failure shall not collapse under ultimate loads nor degrade the functioning of any system due to elastic buckling deformation under limit loads.

12.2.7.7. Evaluation of buckling strength shall consider the combined action of primary and secondary stresses and their effects on general instability, local or panel instability, and crippling.

12.2.7.8. Design loads for buckling shall be ultimate loads, except that any load component that tends to alleviate buckling shall not be increased by the ultimate design safety factor.

12.2.7.9. Destabilizing pressures shall be increased by the ultimate design factor, but internal stabilizing pressures shall not be increased unless they reduce structural capability.

12.2.7.10. The margin of safety shall be positive and shall be determined by analysis or test at design ultimate and design limit levels, when appropriate, at the temperatures expected for all critical conditions.

12.2.8. Flight Hardware Pressure Vessel and Pressurized Structure Stiffness Requirements.

12.2.8.1. Pressure vessels and pressurized structures shall possess adequate stiffness to preclude detrimental deformation at limit loads and pressures in the expected operating environments throughout their respective service lives.

12.2.8.2. The stiffness properties of pressure vessels and pressurized structures shall be such as to prevent all detrimental instabilities of coupled vibration modes, minimize detrimental effects of the loads and dynamics response that are associated with structural flexibility, and avoid adverse contact with other vehicle systems.

12.2.9. Flight Hardware Pressure Vessel and Pressurized Structure Thermal Requirements.

12.2.9.1. Thermal effects, including heating rates, temperatures, thermal gradient, thermal stresses and deformations, and changes in the physical and mechanical properties of the material of construction shall be considered in the design of all pressure vessels and pressurized structures.

12.2.9.2. These effects shall be based on temperature extremes that simulate those predicted for the operating environment plus a design margin as specified in Space and Missile Systems Center (SMC) Standard, SMC-S-016, *Test Requirements for Launch, Upper-stage, and Space Vehicles*, or equivalent.

12.2.10. Physical Arrangement of Flight Hardware Pressure Systems and System Components.

12.2.10.1. Flight Hardware Pressure System and System Component General Requirements.

12.2.10.1.1. The design of hypergolic systems shall take into consideration limitations imposed on individuals dressed in SCAPE during fill and drain operations.

12.2.10.1.2. Sufficient clearances are needed for the insertion of assembly tools.

12.2.10.1.3. Redundant pressure components and systems shall be separated from main systems to decrease the chance of total system failure in case of damage, fire, or malfunction.

12.2.10.1.4. Pressure systems shall be shielded from other systems to protect against hazards caused by proximity to combustible gases, heat sources, and electrical equipment.

12.2.10.1.5. Any failure in any such adjacent system shall not result in combustion, explosion, or release of pressure fluids.

12.2.10.1.6. Safety critical pressure systems shall be designed so that special tools shall not be required for removal and replacement of components unless it can be shown that the use of special tools is unavoidable.

12.2.10.2. Flight Hardware Pressure System Components and Fixtures.

12.2.10.2.1. Fixtures for safe handling and hoisting with coordinated attachment points in the system structure shall be provided for equipment that cannot be hand carried and attached.

12.2.10.2.2. Components shall be designed so that, during the assembly of parts, sufficient clearance exists to permit assembly of the components without damage to seals, O-rings, or backup rings where they pass over threaded parts or sharp corners.

12.2.10.2.3. Handling and hoisting loads shall be IAW the requirements in 29 CFR 1910, **Chapter 6** of this volume, and Chapter 6 of Volume 6.

12.2.10.2.4. All incompatible propellant system connections shall be designed to be physically impossible to interconnect. **Note**: Incompatible propellant system connections should be keyed, sized, or located so that it is physically impossible to interconnect them.

12.2.10.2.5. Quick Disconnect Couplings.

12.2.10.2.5.1. All quick disconnect couplings shall be designed with a factor of safety of not less than 2.5. **Note**: The quick disconnect assembly consists of both the ground-half and air-half couplings.

12.2.10.2.5.2. Quick disconnect coupling bodies and appropriate parts shall be constructed of 304, 304L, 316, or 316L series stainless steel. All parts that contact the fluid shall be compatible with the fluid.

12.2.10.2.5.3. The quick disconnect ground-half coupling shall withstand being dropped from a height of 6 feet on to a metal deck/grating or concrete floor without leaking or becoming disassembled.

12.2.10.2.5.4. When uncoupled, the quick disconnect shall seal the air-half and ground-half couplings and shall not permit external leakage. Both halves of the coupling shall seal under both low and high pressure. In cryogenic systems only, quick disconnects used in vent coupling assemblies shall allow gaseous cryogenic flow through the coupling whether connected or disconnected.

12.2.10.2.5.5. When coupled, the quick disconnect shall permit fluid flow in either direction.

12.2.10.2.5.6. The quick disconnect shall not permit external leakage during any phase of coupling or uncoupling.

12.2.10.2.5.7. The quick disconnect shall be designed so that coupling and uncoupling can be performed with simple motions.

12.2.10.2.5.8. The quick disconnect coupling shall contain a positive locking device that will automatically lock the connection of the coupling halves. It shall be possible by visual inspection to determine that the quick disconnect is completely coupled and locked. The quick disconnect shall not have any partially coupled unlocked position in which the coupling can remain stable and permit fluid flow.

12.2.10.2.5.9. Special care shall be taken in the quick disconnect design to ensure that the possibility of inadvertent uncoupling and/or coupling external leakage due to side and axial loads is minimized.

12.2.10.2.5.10. The quick disconnect shall be designed to couple/uncouple without imparting adverse loads on the vehicle fluid lines that could cause flight hardware damage.

12.2.10.2.5.11. Quick disconnects shall be designed to ensure that all incompatible fuel and oxidizer couplings cannot be inadvertently connected, causing mixing of propellants.

12.2.10.2.5.12. All quick disconnect ground half couplings shall be identified IAW the requirements of section **11.3.1.7.6**.

12.2.10.2.6. Pressure fluid reservoirs shall be shielded or isolated from combustion apparatus or other heat sources.

12.2.10.3. Flight Hardware Pressure System Tubing and Piping.

12.2.10.3.1. In general, tubing and piping shall be located so that damage cannot occur due to being stepped on, used as handholds, or by manipulation of tools during installation.

12.2.10.3.2. Straight tubing and piping runs shall be avoided between two rigid connection points.

12.2.10.3.3. Where such straight runs are necessary, provisions shall be made for expansion joints, motion of the units, or similar compensation to ensure that no excessive strain is applied to the tubing and fittings.

12.2.10.3.4. Line bends shall be used to ease stresses induced in tubing by alignment tolerances and vibration.

12.2.10.4. Flight Hardware Pressure System Flexible Hose Requirements.

Table 12.1. Flexible Hose Guidance.

Guidance for the handling and installation of flexible hoses can be found in KSC specification 80K51846, *Flex Hose Handling and Installation Requirements*.

12.2.10.4.1. Flexible hoses shall be used only when required to provide movement between interconnecting fluid lines when no other means are available.

12.2.10.4.2. Flexible hose systems shall be designed to prevent kinking, avoid abrasive chafing from the restraining device, and avoid abrasive contact with adjacent structure or moving parts that may cause reduction in strength.

12.2.10.4.3. Flexible hoses shall not be supported by rigid lines or components if excessive loads from flexible hose motion can occur.

12.2.10.4.4. Flexible hose assemblies shall not be installed in a manner that will place a mechanical load on the hose or hose fittings to an extent that will degrade hose strength or cause the hose fitting to loosen.

12.2.10.4.5. Flexible hoses shall be designed such that the bend radius is no less safe than the minimum bend radius recommended in authoritative specifications for the particular hose.

12.2.10.4.6. Flexible hoses shall not be exposed to internal temperatures that exceed the rated temperature of the hose.

12.2.10.4.7. Flexible hoses that Wing Safety permits to pass close to a heat source shall be protected.

12.2.10.4.8. All flexible hoses that are not lined shall be subjected to a flow-induced vibration analysis. **Note**: MSFC 20MO2540 provides guidance for performing flow-induced vibration analysis.

12.2.10.4.9. Flexible hoses shall consist of a flexible inner pressure carrier tube (compatible with the service fluid) constructed of elastomeric (typically poly-tetrafluoroethylene [PTFE]) for hypergolic fluid) or corrugated metal (typically 300 series stainless steel) material reinforced by one or more layers of 300 series stainless steel wire and/or fabric braid. **Note**: In applications where stringent permeability and leakage requirements apply, hoses with a metal inner pressure carrier tube should be used. If these hoses will be used in a highly errosive environment, consideration should be given to the use of Hastalloy C-22 in accordance with ASTM B575 for the inner pressure carrier tube and C-276 material for the reinforcing braid.

12.2.10.4.10. Flexible hose restraining devices shall be designed and demonstrated to contain a force not less than 1.5 times the open line pressure force. A thrust equation using pressure, area, and momentum is the approach best founded in physics and shall be used for calculating the open force line pressure.

12.2.10.4.10.1. The restraint design safety factor shall not be less than 3 on material yield strength.

12.2.10.4.10.2. Hose clamp-type restraining devices shall not be used.

12.2.10.4.11. Flexible hose installations shall be designed to produce no stress or strain in the hard lines or components. Stresses induced because of dimensional changes caused by pressure or temperature variations or torque forces induced in the flexible hose shall be included.

12.2.10.5. Flight Hardware Pressure System Valves, Vents, Vent Lines, and Drains.

12.2.10.5.1. Manually operated valves shall be located to permit operation from the side or above to prevent spillage of "hazardous" service fluid on the operator due to leak or failure of the valve seals.

12.2.10.5.2. For remotely controlled non-pyrotechnically actuated valves, positive indication of actual valve position shall be displayed at the control station. **Note**: Indication of valve stem position or flow measurement is an acceptable indication. Indication of an electrical control circuit actuation is not a positive indication of valve position.

12.2.10.5.3. Vent lines for flammable and combustible vapors shall be extended away from work areas to prevent accidental ignition of vapors and/or injury to personnel.

12.2.10.5.4. Vent outlets shall be located far enough away from incompatible propellant systems and incompatible materials to ensure no contact is made during vent operations.

12.2.10.5.5. Safety valves and burst diaphragms shall be located so that their operation cannot cause injury to personnel standing close by or damage to the installation or equipment, or they shall be equipped with deflection devices to protect personnel and equipment.

12.2.10.5.6. Lines, drains, and vents shall be separated or shielded from other high-energy systems; for example, heat, high voltage, combustible gases, and chemicals.

12.2.10.5.7. Drain and vent lines shall not be connected to any other lines in any way that could generate a hazardous mixture in the drain/vent line or allow feedback of hazardous substances to the components being drained or vented.

12.2.10.5.8. Systems containing liquid explosives, flammable liquids, or explosive waste shall be designed so that a complete offload/drainage of the system is achievable by gravity or pneumatics.

12.2.10.5.9. For systems designed for gravity drainage, the pipe/tube slope shall be not less than 1/4 inch per foot at any point. Drain lines designed for positive pressure purges do not have a slope requirement.

12.2.10.5.10. The drain system shall include a sump or basin where the fluid can safely collect. This sump or basin shall be designed so that it can be easily cleaned, and drainage easily removed.

12.2.10.6. Flight Hardware Pressure System Test Points.

12.2.10.6.1. If required, test points shall be provided so that disassembly for test is not required.

12.2.10.6.2. The test points shall be easily accessible for attachment of ground test equipment.

12.2.10.6.3. Common-plug test connectors for pressure and return sections shall be designed to require positive removal of the pressure connection before unsealing the return connections.

12.2.10.6.4. Individual pressure and return test connectors shall be designed to positively prevent inadvertent cross-connections.

12.2.11. Flight Hardware Pressure System and Pressurized Structure Supports and Clamps.

12.2.11.1. All rigid pipe and tubing assemblies shall be supported by a firm structure to restrain destructive vibration, shock, and acceleration.

12.2.11.2. Components within a system shall be supported by a firm structure and not the connecting tubing or piping unless it can be shown by analysis that the tubing or piping can safely support the component.

12.2.11.3. Pipe and tube accessories such as supports, anchors, and braces shall be compatible with hypergolic vapors when installed in a hypergolic propellant system.

12.2.11.4. All threaded parts in safety critical components shall be securely locked to resist uncoupling forces by acceptable safe design methods. **Note**: Safety wiring and self-locking nuts are examples of acceptable safe design.

12.2.11.5. Torque for threaded parts in safety critical components shall be specified.

12.2.11.6. Friction-type locking devices shall be avoided in safety critical applications.

12.2.11.7. Star washers and jam nuts shall not be used as locking devices.

12.2.11.8. The design of internally threaded bosses shall preclude the possibility of damage to the component or the boss threads because of screwing universal fittings to excessive depths in the bosses.

12.2.11.9. Retainers or snap rings shall not be used in pressure systems where failure of the ring would allow connection failures or blow-outs caused by internal pressure.

12.2.11.10. Snubbers shall be used with all bourdon-type pressure transmitters, pressure switches, and pressure gauges, except air pressure gauges.

12.2.12. Flight Hardware Pressure System Bonding and Grounding.

12.2.12.1. Hazardous pressure systems shall be designed so that the flight system being loaded or unloaded and the ground support loading system can be commonly grounded and bonded during transfer operations. When the flight system and the ground system are connected, maximum DC resistance from any flight system tubing or tanks to the nearest earth electrode plate shall be 1 ohm or less. See section **11.3.1.8**.

12.2.12.2. Propellant system components and lines shall be grounded to metallic structures.

12.2.12.3. All hazardous pressure systems shall be electrically bonded to the flight vehicle to minimize the DC resistance between the hazardous pressure system and the flight vehicle.

12.2.13. Flight Hardware Pressure System and Pressurized Structure Material Compatibility and Selection.

12.2.13.1. Compatibility.

12.2.13.1.1. Materials shall be compatible throughout their intended service life with the service fluids and the materials used in the construction and installation of tankage, piping, and components as well as with nonmetallic items such as gaskets, seals, packing, seats, and lubricants.

12.2.13.1.2. At a minimum, material compatibility shall be determined in regard to flammability, ignition and combustion, toxicity, and corrosion.

12.2.13.1.3. Materials that could come in contact with fluid from a ruptured or leaky tank, pipe, or other components that contain hazardous fluids shall be nonflammable and non-combustible.

12.2.13.1.4. Compatible materials selection shall be obtained from one of the following sources:

12.2.13.1.4.1. T.O. 00-25-223.

12.2.13.1.4.2. CPIA 394.

12.2.13.1.4.3. MSFC-HDBK-527.

12.2.13.1.4.4. KTI-5210, *NASA/KSC Material Selection List for Oxygen and Air Services*.

12.2.13.1.4.5. KTI-5211, *NASA/KSC Material Selection List for Reactive Fluid Service*.

12.2.13.1.4.6. KTI-5212, *NASA/KSC Material Selection List for Plastic Films, Foams, and Adhesive Tapes*.

12.2.13.1.4.7. MSFC-STD-3029, *NASA/MSFC Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments*.

12.2.13.1.4.8. Other sources and documents approved by Wing Safety.

12.2.13.1.5. Compatibility Testing. When compatibility data cannot be obtained from Wing Safety approved source, compatibility tests shall be performed. Test procedures, pass/fail criteria, and test results shall be submitted to Wing Safety for review and approval.

12.2.13.1.6. Compatibility Analysis. The Range User shall prepare a compatibility analysis containing the following information:

12.2.13.1.6.1. List of all materials used in system.

12.2.13.1.6.2. Service fluid in contact with each material.

12.2.13.1.6.3. Source document or test results showing material compatibility in regard to flammability, toxicity, corrosion, and ignition and combustion.

12.2.13.2. Selection.

12.2.13.2.1. Material "A" allowable values shall be used for pressure vessels and pressurized structures where failure of a single load path would result in loss of structural integrity.

12.2.13.2.2. For redundant pressurized structures where failure of a structural element would result in a safe redistribution of applied loads to other load-carrying members, material "B" allowables may be used.

12.2.13.2.3. The fracture toughness shall be as high as practical within the context of structural efficiency and fracture resistance.

12.2.13.2.4. For pressure vessels and pressurized structures to be analyzed with linear elastic fracture mechanics, fracture properties shall be accounted for in material selection. These properties include fracture toughness; threshold values of stress intensity under sustained loading; subcritical crack-growth characteristics under sustained and cyclic loadings; the effects of fabrication and joining processes; the effects of cleaning agents, dye penetrants, coatings, and proof test fluids; and the effects of temperature, load spectra, and other environmental conditions.

12.2.13.2.5. Materials that have a low K_{ISCC} in the expected operating environments shall not be used in pressure vessels and pressurized structures unless adequate protection from the operating environments can be demonstrated by tests and reviewed and approved by Wing Safety.

12.2.13.2.6. If the material has a K_{ISCC} less than 60% of the plane-strain fracture toughness, K_{IC} under the conditions of its application, it shall be mandatory to show, by a “worst case” fracture mechanics analysis, that the low threshold stress intensity factor cannot precipitate premature structural failure.

12.2.14. Flight Hardware Pressure System Contamination and Cleanliness Requirements.

12.2.14.1. Adequate levels of contamination control shall be established by relating the cleanliness requirements to the actual needs and nature of the system and components.

12.2.14.2. General contamination control requirements are as follows:

12.2.14.2.1. Components and systems shall be protected from contaminants by filtration, sealed modules, clean fluids, and clean environment during assembly, storage installation, and use.

12.2.14.2.2. Systems shall be designed to allow verification that the lines and components are clean after flushing and purging the system.

12.2.14.2.3. Systems shall be designed to ensure that contaminants or waste fluids can be flushed and purged after fill and drain operations.

12.2.15. Flight Hardware Pressure System Components Service Life and Safe-Life.

12.2.15.1. All hazardous pressure system components shall be designed for safe endurance against hazardous failure modes for not less than 400% of the total number of expected prelaunch cycles.

12.2.15.2. The safe-life for pressure vessels and pressurized structures shall be established assuming the existence of pre-existing initial flaws or cracks in the vessel and shall cover the maximum expected operating loads and environments. The safe-life shall be at least 4 times the specified life for those pressure vessels not accessible for periodic inspection and repair.

12.2.15.3. For those pressure vessels and pressurized structures that are readily accessible for periodic inspection and repair, the safe-life, as determined by analysis and test, shall be at least four times the interval between scheduled inspection and/or refurbishment.

12.2.16. Flight Hardware Metallic Materials.

12.2.16.1. Selection. Metallic materials shall be selected on the basis of proven environmental compatibility, material strengths, fracture properties, fatigue-life, and crack growth characteristics consistent with the overall program requirements.

12.2.16.2. Evaluation. Metallic material evaluation shall be conducted based on the following considerations:

12.2.16.2.1. The metallic materials selected for design shall be evaluated with respect to material processing, fabrication methods, manufacturing operations, refurbishment procedures and processes, and other pertinent factors that affect the resulting strength and fracture properties of the material in the fabricated as well as the refurbished configurations.

12.2.16.2.2. The evaluation shall ascertain that the mechanical properties, strengths, and fracture properties used in design and analyses shall be realized in the actual hardware and that these properties are compatible with the fluid contents and the expected operating environments.

12.2.16.2.3. Materials that are susceptible to stress-corrosion cracking or hydrogen embrittlement shall be evaluated by performing sustained threshold-stress-intensity tests when applicable data are not available

12.2.16.3. Characterization. Metallic material characterization shall be based on the following considerations:

12.2.16.3.1. The allowable mechanical properties, strength and fracture properties of all metallic materials selected for pressure vessels and pressurized structures shall be characterized in sufficient detail to permit reliable and high confidence predictions of their structural performance in the expected operating environments unless these properties are available from reliable or other sources approved by the procuring agency. **Note**: Strength and fracture properties of metallic materials selected for pressure vessels and pressurized structures are available from references such as DOT/FAA/AR-MMPDS, ASTM Standards, the *Air Force Damage Tolerant Design Handbook*, military specifications, and the *Aerospace Structural Metals Handbook*.

12.2.16.3.2. Where material properties are not available, they shall be determined by test methods approved by the procuring agency.

12.2.16.3.3. The characterization shall produce the following strength and fracture properties for the parent metals, weldments, and heat-affected zones as a function of the fluid contents, loading spectra, and the expected operating environments, including proof test environments, as appropriate:

12.2.16.3.3.1. Tensile yield strength, F_y, and ultimate tensile strength, F_u.

12.2.16.3.3.2. Fracture toughness, K_{Ic}, K_{Ie}, K_c, K_{ISCC}.

12.2.16.3.3.3. Sustained-stress crack-growth data, da/dt versus K_{max}.

12.2.16.3.3.4. Fatigue crack growth data, da/dn versus K_I and load ratio, R.

12.2.16.3.4. Proven test procedures shall be used for determining material fracture properties as required. These procedures shall conform to recognized standards. **Note**: Recognized standards include those developed by the ASTM.

12.2.16.3.5. The test specimens and procedures used shall provide valid test data for the intended application.

12.2.16.3.6. Enough tests shall be conducted so that meaningful nominal values of fracture toughness and crack growth rate data corresponding to each alloy system, temper, product form, thermal and chemical environments, and loading spectra can be established to evaluate compliance with safe-life requirements.

12.2.16.3.7. If the conventional fatigue analysis is to be performed, the stress-life (S-N) or the strain-life (Se-N) fatigue data shall be generated IAW the standard test methods developed by ASTM.

12.2.16.4. Fabrication and Process Control.

12.2.16.4.1. Proven processes and procedures for fabrication and repair shall be used to preclude damage or material degradation during material processing, manufacturing operations, and refurbishment.

12.2.16.4.2. In particular, the melt process, thermal treatment, welding process, forming, joining, machining, drilling, grinding, repair and rewelding operations, and other operations shall be within the state-of-the-art and have been used on currently approved hardware.

12.2.16.4.3. The fracture toughness, mechanical and physical properties of the parent materials, weldments and heat-affected zones shall be within established design limits after exposure to the intended fabrication processes.

12.2.16.4.4. The machining, forming, joining, welding, dimensional stability during thermal treatments, and through-thickness hardening characteristics of the material shall be compatible with the fabrication processes to be encountered.

12.2.16.4.5. Fracture control requirements and precautions shall be defined in applicable drawings and process specifications.

12.2.16.4.6. Detailed fabrication instructions and controls shall be provided to ensure proper implementation of the fracture control requirements.

12.2.16.4.7. Special precautions shall be exercised throughout the manufacturing operations to guard against processing damage or other structural degradation. In addition, procurement requirements and controls shall be implemented to ensure that suppliers and subcontractors use fracture control procedures and precautions consistent with the fabrication and inspection processes intended for use during actual hardware fabrication.

12.2.17. Flight Hardware Pressure Vessel and Pressurized Structure Quality Assurance Program Requirements.

12.2.17.1. A quality assurance (QA) program shall be established to ensure that the necessary NDE and acceptance tests are effectively performed to verify that the product meets the requirements of this publication. The QA program shall be based on a comprehensive study of the product and engineering requirements, drawings, material specifications, process specifications, workmanship standards, design review records, stress analysis, failure mode analysis, safe-life analysis, and the results from development and qualification tests.

12.2.17.2. The program shall ensure that materials, parts, subassemblies, assemblies, and all completed and refurbished hardware conform to applicable drawings and process specifications; that no damage or degradation has occurred during material processing, fabrication, inspection, acceptance tests, shipping, storage, operational use and refurbishment; and that defects that could cause failure are detected or evaluated and corrected.

12.2.17.3. QA program Inspection Plan. At a minimum, the following considerations shall be included in structuring the quality assurance program:

12.2.17.3.1. An inspection master plan shall be established before the start of fabrication.

12.2.17.3.2. The plan shall specify appropriate inspection points and inspection techniques for use throughout the program, beginning with material procurement and continuing through fabrication, assembly, acceptance proof test, operation, and refurbishment, as appropriate.

12.2.17.3.3. In establishing inspection points and inspection techniques, consideration shall be given to the material characteristics, fabrication processes, design concepts, structural configuration, and accessibility for inspection of flaw.

12.2.17.3.4. For metallic hardware, the flaw geometries shall encompass defects commonly encountered, including surface crack at the open surface, corner crack or through-the-thickness crack at the edge of fastener hole, and surface crack at the root of intersecting prismatic structural elements.

12.2.17.3.5. Acceptance and rejection standards shall be established for each phase of inspection and for each type of inspection technique.

12.2.17.3.6. For COPVs and other composite hardware, laminate defects, such as delamination, fiber breakage, surface cuts, porosity, air bubbles, cracks, dents, and abrasions, shall be considered.

12.2.17.3.7. All inspections shall be performed by inspectors qualified and certified in inspection techniques according to the ASNT recommended practices (SNT-TC-1A) or Wing Safety approved equivalent.

12.2.17.3.8. For COPVs, inspectors shall also be certified to ASNT Level II (or Wing Safety approved equivalent) and shall be familiar with laminate production processes and composite shell defects. Inspectors shall be certified to inspect specific types of COPVs using specific inspection techniques in accordance with ASNT standards.

12.2.17.4. Inspection Techniques. At a minimum, the following considerations shall be included in determining the appropriate inspection techniques:

12.2.17.4.1. The selected NDE inspection techniques shall have the capability to determine the size, geometry, location, and orientation of a flaw or defect; to obtain, where multiple flaws exist, the location of each with respect to the other and the distance between them; and to differentiate among defect shapes, from tight cracks to spherical voids.

12.2.17.4.2. Two or more NDE methods shall be used for a part or assembly that cannot be adequately examined by only one method.

12.2.17.4.3. The flaw detection capability of each selected NDE technique shall be based on past experience on similar hardware.

12.2.17.4.4. Where this experience is not available or is not sufficiently extensive to provide reliable results, the capability, under production or operational inspection conditions, shall be determined experimentally and demonstrated by tests approved by the procuring agency on representative material product form, thickness, and design configuration.

12.2.17.4.5. The flaw detection capability shall be expressed in terms of detectable crack length, crack depth, and crack area. For COPVs, the detection of laminate defects, such as delamination, fiber breakage, and air bubbles, shall also be addressed.

12.2.17.4.6. The selected NDE should be capable of detecting allowable initial flaw size corresponding to a 90% probability of detection at a 95% confidence level.

12.2.17.4.7. The most appropriate NDE technique(s) for detecting commonly encountered flaw types shall be used for all metallic pressure vessels, COPVs, pressurized structures, and other hardware based on their flaw detection capabilities.

12.2.17.5. Inspection Data. At a minimum, inspection data shall be dispositioned as follows:

12.2.17.5.1. Inspection data in the form of flaw histories shall be maintained throughout the life of the pressure vessel or pressurized structure. The inspection data shall be stored in the system certification file.

12.2.17.5.2. The result of this assessment shall form the basis of any required corrective action.

12.2.17.5.3. For suspect COPVs, a Material Review Board (MRB) shall be initiated to evaluate the NDE results and disposition. The MRB shall consist of the procuring agency (Range User), the COPV manufacturer, and Wing Safety. The MRB shall use NDE comparison, past experience, additional NDE, and other qualitative and quantitative methods to determine the acceptability of a suspect vessel. Data collected from the MRB process shall be input into the inspection database and system certification file.

12.2.17.6. Acceptance Proof Test.

12.2.17.6.1. All pressure vessels, pressurized structures, and pressure components shall be proof pressure tested IAW the requirements of sections **12.3** through **12.6**, as applicable, to verify that the hardware has sufficient structural integrity to sustain the subsequent service loads, pressure, temperatures, and environments.

12.2.17.6.2. For pressure vessels, pressurized structures, and other pressurized components, the temperature shall be consistent with the critical use temperature; or, as an alternative, tests may be conducted at an alternate temperature if the test pressures are suitably adjusted to account for temperature effects on strength and fracture toughness.

12.2.17.6.3. Proof test fluids shall be compatible with the structural materials in the pressure vessels and pressurized structures.

12.2.17.6.4. Proof test fluids shall not pose a hazard to test personnel.

12.2.17.6.5. If such compatibility data is not available, required testing shall be conducted to demonstrate that the proposed test fluid does not deteriorate the test article.

12.2.17.6.6. Accept/reject criteria shall be formulated before the acceptance proof test.

12.2.17.6.7. Every pressure vessel and pressurized structure shall not leak, rupture, or experience gross yielding during acceptance testing.

12.2.18. Flight Hardware Pressure System and Pressurized Structure Operations.

12.2.18.1. Flight Hardware Pressure System and Pressurized Structure Safe Operating Limits.

12.2.18.1.1. Safe operating limits shall be established for each pressure vessel and each pressurized structure based on the appropriate analysis and testing used in its design and qualification IAW sections **12.3**, **12.4**, and **12.5**.

12.2.18.1.2. These safe operating limits shall be summarized in a format that provides rapid visibility of the important structural characteristics and capability.

12.2.18.2. Flight Hardware Pressure System and Pressurized Structure Operating Procedures.

12.2.18.2.1. Operating procedures shall be established for each pressure vessel and pressurized structure.

12.2.18.2.2. These procedures shall be compatible with the safety requirements and personnel control requirements at the facility where the operations are conducted.

12.2.18.2.3. Step-by-step directions shall be written with sufficient detail to allow a qualified technician or mechanic to accomplish the operations.

12.2.18.2.4. Schematics that identify the location and pressure limits of relief valves and burst discs shall be provided when applicable, and procedures to ensure compatibility of the pressurizing system with the structural capability of the pressurized hardware shall be established.

12.2.18.2.5. Before initiating or performing a procedure involving hazardous operations with pressure systems, practice runs shall be conducted on non-pressurized systems until the operating procedures are well rehearsed.

12.2.18.2.6. Initial tests shall then be conducted at pressure levels not to exceed 50% of the normal operating pressures until operating characteristics can be established and stabilized.

12.2.18.2.7. Only qualified and trained personnel shall be assigned to work on or with high pressure systems.

12.2.18.2.8. Warning signs with the hazard(s) identified shall be posted at the operations facility before pressurization.

12.2.18.3. Flight Hardware Pressure System and Pressurized Structure Inspection.

12.2.18.3.1. The results of the appropriate stress and safe-life analyses shall be used in conjunction with the appropriate results from the structural development and qualification tests to develop a quantitative approach to inspection and repair.

12.2.18.3.2. Allowable damage limits shall be established for each pressure vessel and pressurized structure so that the required inspection interval and repair schedule can be established to maintain hardware to the requirements of this volume.

12.2.18.3.3. NDE technique(s) and inspection procedures to reliably detect defects and determine flaw size under the condition of use shall be developed for use in the field and depot levels.

12.2.18.3.4. Procedures shall be established for recording, tracking, and analyzing operational data as it is accumulated to identify critical areas requiring corrective actions.

12.2.18.3.5. Analyses shall include prediction of remaining life and reassessment of required inspection intervals.

12.2.18.4. Flight Hardware Pressure System and Pressurized Structure Repair and Refurbishment.

12.2.18.4.1. When inspections reveal structural damage or defects exceeding the permissible levels, the damaged hardware shall be repaired, refurbished, or replaced, as appropriate.

12.2.18.5. Flight Hardware Pressure System and Pressurized Structure Storage Requirements.

12.2.18.5.1. When pressure vessels and pressurized structures are put into storage, they shall be protected against exposure to adverse environments that could cause corrosion or other forms of material degradation.

12.2.18.5.2. Pressure vessels and pressurized structures shall be protected against mechanical degradation resulting from scratches, dents, or accidental dropping of the hardware.

12.2.18.5.3. Induced stresses due to storage fixture constraints shall be minimized by suitable storage fixture design.

12.2.18.5.4. In the event storage requirements are violated, recertification shall be required before acceptance for use.

12.2.18.6. Flight Hardware Pressure System and Pressurized Structure Reactivation.

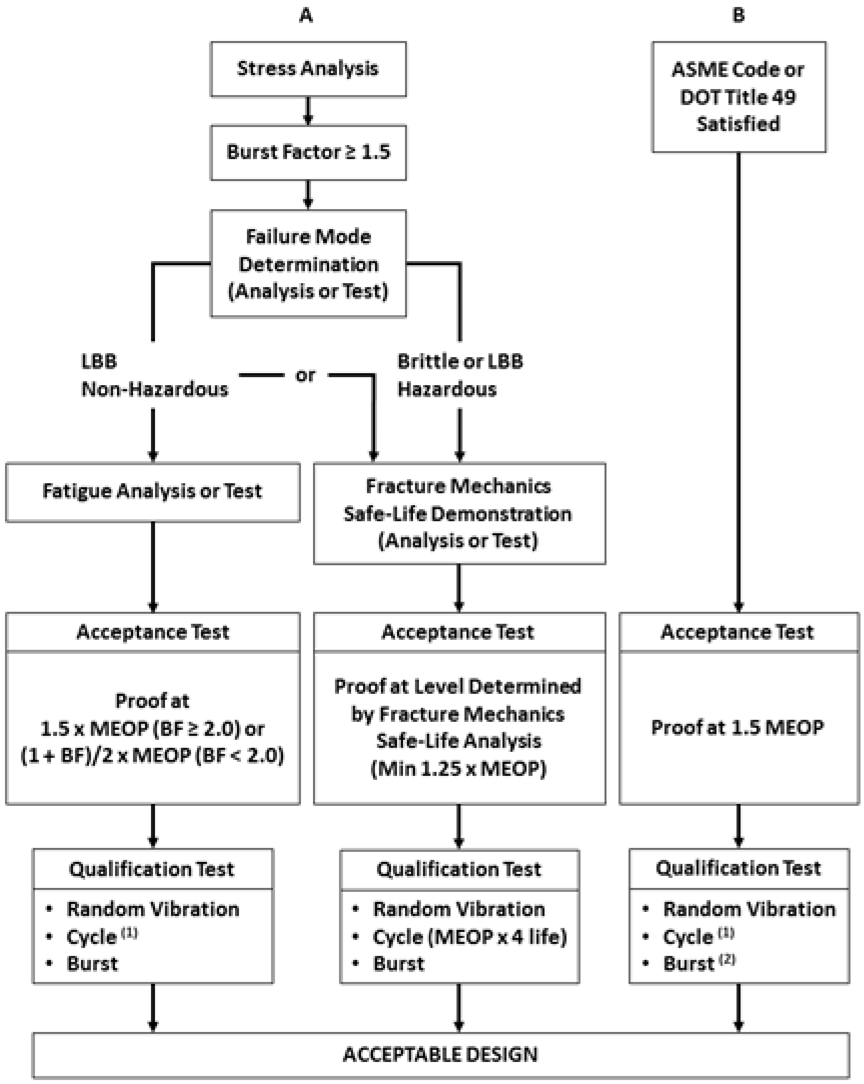
12.2.18.6.1. Pressure vessels and pressurized structures that are reactivated for use after an extensive period in either an unknown, unprotected, or unregulated storage environment shall be recertified to ascertain their structural integrity and suitability for continued service before commitment to flight.

12.2.18.6.2. Recertification tests for pressurized hardware shall be IAW the appropriate Recertification Test Requirement. (See paragraph **12.3.2.8**).

12.3. Flight Hardware Pressure Vessel Design, Analysis, and Test Requirements.

12.3.1. Flight Hardware Metallic Pressure Vessel General Design, Analysis, and Verification Requirements. Two approaches for the design, analysis and verification of metallic pressure vessels can be selected as shown in **Figure 12.1**. Selection of the approach to be used depends on the desired efficiency of design coupled with the level of analysis and verification testing required.

Figure 12.1. Pressure Vessel Design Verification Approach.



NOTES: (1) Cycle test at either MEOP x 4-life or 1.5 MEOP x 2 life
(2) Burst or disposition vessel with approval of the procuring agency

12.3.1.1. Approach A. Approach A in **Figure 12.1** shows the steps required for verification of a metallic pressure vessel designed with a burst factor equal to 1.5 or greater.

12.3.1.1.1. Based on the results of the failure mode determination, one of two distinct verification paths shall be satisfied:

12.3.1.1.1.1. Path 1: Leak-before-burst (LBB), in which leakage of the contents will not create a hazard, or

12.3.1.1.1.2. Path 2: Brittle fracture or hazardous LBB in which leakage of the contents will create a hazard (such as release of toxic gas, damage to nearby safety critical components, or overpressurization of a closed compartment).

12.3.1.1.2. The verification requirements for path 1 are delineated in section **12.3.2** and the verification requirements for path 2 in section **12.3.3**.

12.3.1.2. Approach B. Approach B, **Figure 12.1** shows the steps required for verification of a metallic pressure vessel designed using the ASME Boiler and Pressure Vessel Code or the DOT Pressure Vessel Codes.

12.3.2. Flight Hardware Metallic Pressure Vessels with Non-Hazardous LBB Failure Mode.

12.3.2.1. The LBB failure mode shall be demonstrated analytically or by test showing that an initial surface flaw with a shape (a/2c) ranging from 0.05 to 0.5 will propagate through the vessel thickness to become a through-the-thickness crack with a length less than or equal to 10 times the vessel thickness and still be stable at MEOP.

12.3.2.2. Fracture mechanics shall be used if the failure mode is determined by analysis.

12.3.2.3. A pressure vessel that contains non-hazardous fluid and exhibits LBB failure mode is considered a non-hazardous LBB pressure vessel.

12.3.2.4. Flight Hardware Metallic Pressure Vessels with Non-Hazardous LBB Failure Mode Factor of Safety Requirements.

12.3.2.4.1. Metallic pressure vessels that satisfy the non-hazardous LBB failure mode criterion may be designed conventionally, wherein the design factors of safety and proof test factors are selected on the basis of successful past experience.

12.3.2.4.2. Unless otherwise specified, the minimum burst factor shall be 1.5.

12.3.2.5. Flight Hardware Metallic Pressure Vessels with Non-Hazardous LBB Failure Mode Fatigue-Life Demonstration.

12.3.2.5.1. After completion of the stress analysis conducted IAW the requirements of section **12.2.5.3**, conventional fatigue-life analysis shall be performed, as appropriate, on the unflawed structure to ascertain that the pressure vessel, acted upon by the spectra of operating loads, pressures, and environments meets the life requirements.

12.3.2.5.2. A life factor of 4 shall be used in the analysis.

12.3.2.5.3. Testing of unflawed specimens to demonstrate fatigue-life of a specific pressure vessel together with stress analysis is an acceptable alternative to fatigue test of the vessel.

12.3.2.5.4. Fatigue-life requirements are considered demonstrated when the unflawed specimens that represent critical areas such as membrane section, weld joints, heat-affected zone, and boss transition section successfully sustain the limit loads and MEOP in the expected operating environments for the specified test duration without rupture.

12.3.2.5.5. The required test duration is 4 times the specified service life.

12.3.2.6. Flight Hardware Metallic Pressure Vessels with Non-Hazardous LBB Failure Mode Qualification Test Requirements.

12.3.2.6.1. Qualification tests shall be conducted on flight quality hardware to demonstrate structural adequacy of the design.

12.3.2.6.2. The test fixtures, support structures, and methods of environmental application shall not induce erroneous test conditions.

12.3.2.6.3. The types of instrumentation and their locations in qualification tests shall be based on the results of the stress analysis of section **12.2.5.3**.

12.3.2.6.4. The instrumentation shall provide sufficient data to ensure proper application of the accept/reject criteria, which shall be established before test.

12.3.2.6.5. The sequences, combinations, levels, and duration of loads, pressure, and environments shall demonstrate that design requirements have been met.

12.3.2.6.6. Qualification testing shall include random vibration testing and pressure testing. The following delineates the required tests:

12.3.2.6.6.1. Random Vibration Testing. Random vibration qualification testing shall be performed IAW the requirements of SMC-S-016 or equivalent unless it can be shown that the vibration requirement is enveloped by other qualification testing performed.

12.3.2.6.6.2. Pressure Testing. Required qualification pressure testing levels are shown in **Table 12.2**. Requirements for application of external loads in combination with internal pressures during testing shall be evaluated based on the relative magnitude and/or destabilizing effect of stresses due to the external load. If limit-combined tensile stresses are enveloped by test pressure stresses, the application of external loads shall not be required. If the application of external loads is required, the load shall be cycled to limit for 4 times the predicted number of operating cycles of the most severe design condition (for example, destabilizing load with constant minimum internal pressure or maximum additive load with a constant maximum expected operating pressure). Qualification test procedures shall be approved by the procuring agency and the appropriate range approval authority.

Table 12.2. Qualification Pressure Test Requirements.

Test Item	No Yield After	No Burst At [1]
Vessel #1 [2]		Burst Factor x MEOP
Vessel #2	Cycle at 1.5 x MEOP for 2x predicted number of service life. (50 cycles minimum) Or Cycle at 1.0 x MEOP for 4x predicted number of service life. (50 cycles minimum)	Burst Factor x MEOP
[1] Unless otherwise specified, after demonstrating no burst at the design burst pressure test level, increase pressure to actual burst of vessel. Record actual burst pressure. [2] Test may be deleted at discretion of the Range User.		

12.3.2.7. Flight Hardware Metallic Pressure Vessels with Non-Hazardous LBB Failure Mode Acceptance Test Requirements. Every pressurized system element shall be proof tested to verify that the materials, manufacturing processes, and workmanship meet design specifications and that the hardware is suitable for flight.

12.3.2.7.1. Acceptance tests shall be conducted on every pressure system element before commitment to flight. Accept/reject criteria shall be formulated before tests.

12.3.2.7.2. The test fixtures and support structures shall be designed to permit application of all test loads without jeopardizing the flightworthiness of the test article.

12.3.2.7.3. At a minimum, the following are required:

12.3.2.7.3.1. Nondestructive Examination. A complete inspection by the selected nondestructive examination (NDE) technique(s) shall be performed before the proof pressure test to establish the initial condition of the hardware.

12.3.2.7.3.2. Proof Pressure Test. Every pressure vessel shall be proof pressure tested to verify that the item has sufficient structural integrity to sustain the subsequent service loads, pressure, temperatures, and environments. The proof test fixture shall simulate the structural response or reaction loads of the flight mounting configuration when vessel mounting induces axial or radial restrictions on the pressure driven expansion of the vessel. Test temperature shall be consistent with the critical use temperature, or the test pressure shall be adjusted to account for temperature effects on material properties.

Table 12.3. Minimum Proof Pressure

The minimum proof pressure shall be: P = (1 + Burst Factor)/2) x MEOP for a burst factor less than 2.0, or P = 1.5 x MEOP for a burst factor equal to or greater than 2.0. The minimum hold time at proof pressure shall be five minutes.

12.3.2.8. Flight Hardware Metallic Pressure Vessels with Non-Hazardous LBB Failure Mode Recertification Test Requirements. All refurbished pressure system elements shall be recertified after each refurbishment by the acceptance test requirements for new hardware to verify their structural integrity and to establish their suitability for continued service before commitment to flight. Pressure vessels that have exceeded the approved storage environment (temperature, humidity, time, and others) shall also be recertified by the acceptance test requirements for new hardware.

12.3.2.9. Special Provisions. For one-of-a-kind applications, a proof test of each flight unit to a minimum of 1.5 times MEOP and a conventional fatigue analysis showing a minimum of 10 design lifetimes may be used in lieu of the required pressure testing as defined in section **12.3.2.6**. The implementation of this option needs prior approval by the procuring agency and the appropriate range approval authority.

12.3.3. Flight Hardware Metallic Pressure Vessels with Brittle Fracture or Hazardous LBB Failure Mode.

12.3.3.1. Flight Hardware Metallic Pressure Vessels with Brittle Fracture or Hazardous LBB Failure Mode Factor of Safety Requirements.

12.3.3.1.1. Safe-life design methodology based on fracture mechanics techniques shall be used to establish the appropriate design factor of safety and the associated proof factor for metallic pressure vessels that exhibit brittle fracture or hazardous LBB failure mode.

12.3.3.1.2. The loading spectra, material strengths, fracture toughness, and flaw growth rates of the parent material and weldments, test program requirements, stress levels, and the compatibility of the structural materials with the thermal and chemical environments expected in service shall be taken into consideration.

12.3.3.1.3. Nominal values of fracture toughness and flaw growth rate data corresponding to each alloy system, temper, and product form shall be used along with a life factor of 4 on specified service life in establishing the design factor of safety and the associated proof factor.

12.3.3.1.4. Unless otherwise specified, the minimum burst factor shall be 1.5.

12.3.3.2. Flight Hardware Metallic Pressure Vessels with Brittle Fracture or Hazardous LBB Failure Mode Safe-Life Demonstration Requirements.

12.3.3.2.1. After completion of the stress analysis conducted IAW the requirements of section **12.2.5.3**, a safe-life analysis of each pressure vessel covering the maximum expected operating loads and environments shall be performed under the assumption of pre-existing initial flaws or cracks in the vessel.

12.3.3.2.2. The analysis shall show that the metallic pressure vessel with flaws placed in the most unfavorable orientation with respect to the applied stress and material properties, of sizes defined by the acceptance proof test or NDE and acted upon by the spectra of expected operating loads and environments, meets the safe-life requirements of section **12.2.15**.

12.3.3.2.3. Nominal values of fracture toughness and flaw growth rate data associated with each alloy system, temper, product form, thermal and chemical environments, and loading spectra shall be used along with a life factor of 4 on specified service life in all safe-life analyses.

12.3.3.2.4. Pressure vessels that experience sustained stress shall also show that the corresponding applied stress intensity (K_I) during operation is less than K_{ISCC} in the appropriate environment.

12.3.3.2.5. Testing of metallic pressure vessels under fracture control in lieu of safe-life analysis is an acceptable alternative, provided that, in addition to following a quality assurance program (12.1.17) for each flight article, a qualification test program is implemented on pre-flawed specimens representative of the structure design.

12.3.3.2.6. These flaws shall not be less than the minimum detectable flaw sizes established by the selected NDE method(s). Proof test logic shall not be used to determine minimum flaw size.

12.3.3.2.7. Safe-life requirements of section **12.2.15** are considered demonstrated when the pre-flawed test specimens successfully sustain the limit loads and pressure cycles in the expected operating environments without rupture.

12.3.3.2.8. A life factor of 4 on specified service life shall be applied in the safe-life demonstration testing.

12.3.3.2.9. A report that documents the fracture mechanics safe-life analysis or safe-life testing shall be prepared to delineate the following:

12.3.3.2.9.1. Fracture mechanics data (fracture toughness and fatigue crack growth rates).

12.3.3.2.9.2. Loading spectrum and environments.

12.3.3.2.9.3. Initial flaw sizes.

12.3.3.2.9.4. Analysis assumptions and rationales.

12.3.3.2.9.5. Calculation methodology.

12.3.3.2.9.6. Summary of significant results.

12.3.3.2.9.7. References.

12.3.3.2.10. This report shall be closely coordinated with the stress analysis report.

12.3.3.3. Flight Hardware Metallic Pressure Vessels with Brittle Fracture or Hazardous LBB Failure Mode Qualification Test Requirements. Qualification testing shall meet requirements of section **12.3.2.6**.

12.3.3.4. Flight Hardware Metallic Pressure Vessels with Brittle Fracture or Hazardous LBB Failure Mode Acceptance Test Requirements. Acceptance test requirements for pressure vessels that exhibit brittle fracture or hazardous LBB failure mode are identical to those with ductile fracture failure mode as defined in section **12.3.2.7** except that the test level shall be that defined by the fracture mechanics analysis. Surface and volume NDE shall be performed before and after proof test on the weld joints as a minimum. Cryo-proof acceptance test procedures may be required to adequately verify initial flaw size. The pressure vessel shall not rupture or leak at the acceptance test pressure.

12.3.3.5. Flight Hardware Metallic Pressure Vessels with Brittle Fracture or Hazardous LBB Failure Mode Recertification Test Requirements. Recertification testing shall meet the requirements of paragraph **12.3.2.8**.

12.3.3.6. Flight Hardware Metallic Pressure Vessels with Brittle Fracture or Hazardous LBB Failure Mode Special Provisions. For one-of-a-kind applications, a proof test of each flight unit to a minimum of 1.5 times MEOP and a conventional fatigue analysis showing a minimum of 10 design lifetimes may be used in lieu of the required pressure testing as defined in section **12.3.2.6** for qualification. The implementation of this option needs prior approval by Wing Safety.

12.3.4. Flight Hardware Metallic Pressure Vessels Designed Using ASME Boiler and Pressure Vessel Code. Metallic pressure vessels may be designed and manufactured per the rules of the ASME Boiler and Pressure Vessel Code, Section VIII, Divisions 1 or 2.

12.3.4.1. Flight Hardware Metallic Pressure Vessels Designed Using ASME Boiler and Pressure Vessel Code Qualification Test Requirements. Qualification testing shall meet the requirements of section **12.3.2.6**.

12.3.4.2. Flight Hardware Metallic Pressure Vessels Designed Using ASME Boiler and Pressure Vessel Code Acceptance Test Requirements.

12.3.4.2.1. A proof test shall be performed as specified in ASME Boiler and Pressure Vessel Code.

12.3.4.2.2. NDE shall be performed IAW the ASME Boiler and Pressure Vessel Code and RT and/or UT as appropriate to quantify defects in all full penetration welds after the proof test.

12.3.5. Flight Hardware Composite Overwrapped Pressure Vessels. Flight hardware COPVs shall be designed using either Approach A or Approach B shown in **Figure 12.1**. Criteria pertinent to COPVs can also be located in ANSI/AIAA S-081B-2018.

12.3.5.1. Approach A. Flight COPVs designed using Approach A in **Figure 12.1** shall have a design burst pressure equal to 1.5 or greater. The COPV failure mode shall be demonstrated by applicable fracture mechanics analysis, test, or similarity, as approved by Wing Safety.

12.3.5.1.1. Manufacturers of COPVs using non-metallic liners or new composite overwrap materials (other than carbon, aramid, or glass fibers in epoxy resins) and their customers shall conduct the necessary development test program to demonstrate an equivalent level of safety to that of conventional metal-lined COPVs.

12.3.5.1.2. Based on the results of the failure mode determination, one of two distinct paths shall be satisfied:

12.3.5.1.2.1. Path 1: LBB, in which leakage of the contents will not create a hazard, or

12.3.5.1.2.2. Path 2: Brittle fracture or hazardous LBB, in which leakage of the contents will create a hazard (such as release of toxic gas, damage to nearby safety critical components, or overpressurization of a closed compartment).

12.3.5.1.3. The verification requirements for path 1 (LBB) are delineated in section **12.3.6** and the verification requirements for path 2 (brittle fracture/hazardous LBB) are delineated in section **12.3.7**.

12.3.5.1.4. Failure mode and safe-life testing using coupons or subscale vessels shall not be used unless approved by Wing Safety.

12.3.5.1.5. COPVs with metal liners, evaluated by similarity (in other words, comparison with a vessel that has already been tested and documented having similar fiber, epoxy, matrix design, and geometry) may not require a demonstration test, if approved by Wing Safety.

12.3.5.1.6. For COPVs subjected to sustained load conditions, stress rupture life shall be considered. The COPV shall not be susceptible to stress rupture or sustained creep failure mechanisms. The predicted stress rupture life shall be at least 4 times the service life (for the environment and pressure versus time profile history).

12.3.5.2. Approach B. Approach B, in **Figure 12.1**, shows the steps required for verification of a COPV designed using ASME Boiler and Pressure Vessel Code or DOT Title 49 Exemptions with a burst factor equal to 3.0 or greater.

12.3.5.3. Damage Control Plan (DCP). Damage control plan(s) shall be developed to identify and mitigate credible sources of mechanical and other forms of damage to the COPV during manufacturing and throughout service life. The DCP shall be developed in accordance with ANSI/AIAA S-081B-2018, section 5.3, and shall include the use of protective covers. The DCP may include additional protections, as necessary, such as damage indicators.

12.3.5.3.1. Damage Control Test. The ability of the DCP to mitigate credible sources of damage to the COPV during manufacturing and throughout the service life shall be verified by test. Damage control test procedures shall be developed and performed in accordance with ANSI/AIAA S-081B-2018, section 10.3.

12.3.5.3.2. The DCP and damage control test procedures shall be submitted to Wing Safety for review and approval prior to implementation.

12.3.6. COPVs with Non-Hazardous LBB Failure Mode.

12.3.6.1. General.

12.3.6.1.1. The failure mode designation for COPVs shall be based on the liner and the composite overwrap.

12.3.6.1.2. For metal-lined COPVs, the LBB failure mode shall be demonstrated by applicable fracture mechanics analysis and/or test or similarity, as approved by Wing Safety. The effects of the liner sizing operation on the fracture mechanics characteristics of the metal liner shall be accounted for in the LBB evaluation. For non-metallic lined COPVs, the LBB failure mode shall be demonstrated by test.

12.3.6.1.3. The demonstration of the LBB failure mode by test of a COPV shall include a pre-flawed liner (flaw size determined by analysis of the liner material and flaw detection capabilities of the selected NDE techniques). Surface cracks shall be put into the liner at locations and orientations that are most critical to the LBB response. An inert fluid shall be used to pressurize the COPV. Pressure cycles shall be applied to the COPV with the upper pressure limit equal to the MEOP. The LBB failure mode shall be demonstrated if one or more of the cracks leak pressure from the COPV at MEOP before catastrophic failure occurs.

12.3.6.2. COPVs with Non-Hazardous LBB Failure Mode Factor of Safety Requirements. Nonmetallic pressure vessels that satisfy the non-hazardous LBB failure mode criterion may be designed conventionally, wherein the design factors of safety and proof test factors are selected on the basis of successful past experience. The minimum burst factor shall be 1.5.

12.3.6.3. COPVs with Non-Hazardous LBB Failure Mode Fatigue-Life Demonstration.

12.3.6.3.1. After completion of the stress analysis, a fatigue-life demonstration shall be performed for the liner, bosses, and composite shell of an unflawed COPV. Fatigue-life shall be demonstrated either by test or analysis, as approved by Wing Safety. The test or analysis shall account for the spectra of expected loads, pressures, and environments.

12.3.6.3.2. The minimum fatigue life for COPVs shall be 4 times the service life. The planned number of cycles for the COPV service life shall account for a launch base pressure test at 1.0 times the ground MEOP.

12.3.6.4. COPVs with Non-Hazardous LBB Failure Mode Qualification Test Requirements. Qualification testing shall meet the requirements of section **12.3.2.6**.

12.3.6.5. COPVs with Non-Hazardous LBB Failure Mode Acceptance Test Requirements. Acceptance testing shall be IAW section **12.3.2.7** and the additional requirements of paragraphs **12.3.6.5.1** through **12.3.6.5.3**.

12.3.6.5.1. Nondestructive Examination. A complete inspection using visual and other nondestructive examination techniques shall be performed before and after proof testing. All inspections shall be conducted by specially trained COPV inspectors certified IAW section **12.2.17.3**.

12.3.6.5.2. Proof Pressure Test. Every COPV shall be proof tested IAW paragraph **12.3.2.7.3.2**.

12.3.6.5.3. Liner Inspection. Following completion of the autofrettage cycle and the proof pressure test, every COPV shall be inspected internally for liner buckling, debonding, or other gross internal defects.

12.3.6.6. COPV Prelaunch Inspection and Pressure Test. Before a COPV is used in operations at an AFSPC range, a prelaunch inspection and pressure test shall be conducted IAW paragraphs **12.3.6.6.1** and **12.3.6.6.2**.

12.3.6.6.1. Before the first pressurization of a COPV at the range, an inspection of the vessel shall be conducted to determine if there is evidence of damage to the composite shell. The inspection shall be performed by an inspector certified IAW section **12.2.17.3**. If this inspection is not possible at the launch base because the vessel is no longer accessible, then it shall be conducted the last time the vessel is accessible for inspection.

12.3.6.6.2. After arrival at the prelaunch processing facility and completion of the inspection with no evidence of damage to the COPV, but prior to propellant loading or pressurization, COPVs shall be pressure tested to 100% of the maximum ground operating pressure. The minimum hold time for this pressure test shall be 5 minutes. This pressurization shall be conducted remotely or a blast shield shall be used to protect personnel.

12.3.6.7. COPVs with Non-Hazardous LBB Failure Mode Recertification Test Requirements. Recertification testing shall meet the requirements of paragraph **12.3.2.8.**

12.3.7. Flight Hardware COPVs with Brittle Fracture or Hazardous LBB Failure Mode. The requirements described below are applicable only to flight hardware COPVs that exhibit brittle fracture or hazardous LBB failure modes.

12.3.7.1. COPVs with Brittle Fracture or Hazardous LBB Failure Mode Factor of Safety Requirements. The minimum burst factor shall be 1.5.

12.3.7.2. COPVs with Brittle Fracture or Hazardous LBB Failure Mode Safe-Life Demonstration Requirements.

12.3.7.2.1. In addition to performing a stress analysis as specified in section **12.2.5.3**, a safe-life demonstration of each pressure vessel, covering the maximum expected operating loads and environments, shall be performed assuming pre-existing initial flaws or cracks in the vessel. For metal-lined COPVs, safe-life shall be demonstrated either by test, analysis, similarity, or any combination thereof. For non-metallic lined COPVs, the safe-life shall be demonstrated by test, similarity, or both.

12.3.7.2.2. Specifically, the analysis shall show that the metal-lined COPV (with liner flaws placed in the most unfavorable orientation with respect to the applied stress and material properties, of sizes defined by the NDE flaw detection capabilities, and acted upon by the spectra of expected operating loads) will meet the safe-life requirements specified by section **12.2.15**.

12.3.7.2.3. For metallic liners, the nominal values of fracture toughness and flaw growth rate data associated with each alloy system, temper, product form, thermal and chemical environments, and loading spectra shall be used in all safe-life analyses.

12.3.7.2.4. Metal-lined COPVs that experience sustained stress shall also show that the corresponding stress intensity factor (K_I) applied to the metal liner during the operation is less than K_{ISCC} in the appropriate environment. For all liner materials for which data do not exist, the sustained load crack behavior of the liner material shall be determined by test for all fluids that are introduced into the COPV under pressure.

12.3.7.2.5. Testing of metal-lined COPVs under fracture control is an acceptable alternative to safe-life analysis, provided that, in addition to following a quality assurance program (see section **12.2.17**) for each flight article, a qualification test program is implemented on pre-flawed specimens representative of the structure design. For non-metallic lined COPVs, safe-life demonstrations shall be performed by test.

12.3.7.2.6. These flaws shall not be less than the minimum detectable flaw sizes established by the selected NDE method(s). Proof test logic shall not be used to determine minimum flaw size.

12.3.7.2.7. Safe-life requirements of section **12.2.15** are considered demonstrated when the pre-flawed test specimens successfully sustain the limit loads and pressure cycles in the expected operating environments without rupture.

12.3.7.2.8. The safe-life shall be 4 times the service life for all safe-life demonstrations. The planned number of cycles for the COPV service life shall account for a launch base pressure test at 1.1 times the ground MEOP.

12.3.7.2.9. A report that documents the fracture mechanics safe-life analysis (for metal liners only) or safe-life testing shall be prepared to delineate the following:

12.3.7.2.9.1. Fracture mechanics data for metal liners, including fracture toughness and fatigue crack growth on launch vehicles.

12.3.7.2.9.2. Loading spectrum and environments.

12.3.7.2.9.3. Initial flaw sizes.

12.3.7.2.9.4. Analysis assumptions and rationales.

12.3.7.2.9.5. Calculation methodology.

12.3.7.2.9.6. Summary of significant results.

12.3.7.2.9.7. References.

12.3.7.2.10. This report shall be closely coordinated with the stress analysis report.

12.3.7.3. COPVs with Brittle Fracture or Hazardous LBB Failure Mode Fatigue-Life Demonstration. For fatigue-life demonstration requirements, see section **12.3.6.3**.

12.3.7.4. COPVs with Brittle Fracture or Hazardous LBB Failure Mode Qualification Test Requirements. Qualification testing shall meet the requirements of section **12.3.2.6**.

12.3.7.5. COPVs with Brittle Fracture or Hazardous LBB Failure Mode Acceptance Test Requirements.

12.3.7.5.1. Acceptance testing shall meet the requirements of section **12.3.2.7**.

12.3.7.5.2. Additional prelaunch inspection and pressure testing at the launch site shall be IAW section **12.3.6.6**.

12.3.7.5.3. Every COPV shall be proof tested at a pressure 1.1 times the MEOP to verify that the materials, manufacturing processes, and workmanship meet design specifications and the hardware is suitable for flight.

12.3.7.6. COPVs with Brittle Fracture or Hazardous LBB Failure Mode Recertification Test Requirements. Recertification testing shall meet the requirements of paragraph **12.3.2.8**.

12.3.8. COPV Data Requirements. The following data and documentation shall be provided for flight COPVs in addition to the data required in section **12.11** for all flight pressure systems and vessels.

12.3.8.1. COPV Design Data.

12.3.8.1.1. Design specifications.

12.3.8.1.2. Design drawings.

12.3.8.1.3. Design calculations.

12.3.8.1.4. Material manufacturer's specification sheets for resin, fiber reinforcement, promoters, catalyst, and other components used in laminate construction.

12.3.8.1.5. Properly certified documentation for parts of the vessel fabricated by other fabricators.

12.3.8.1.6. Process specifications, giving the fabrication procedures used to fabricate both the prototype vessel(s) and all production vessels.

12.3.8.2. COPV Validation Data. A summary of the design, analysis, and development test data that validates the design burst pressure, failure mode (LBB or brittle fracture), and material (liner and overwrap) compatibility with propellants and other service fluids.

12.3.8.3. COPV Test Data.

12.3.8.3.1. Qualification test report.

12.3.8.3.2. Quality control and production test reports.

12.3.8.3.3. Acceptance test report.

12.3.8.4. Other Required COPV Documentation.

12.3.8.4.1. Ground processing plans and procedures for the launch sites, including all operations and activities involving to the COPV

12.3.8.4.2. A risk assessment of the COPV during ground processing.

12.3.8.4.3. A description and the analysis of the protection system(s) used to prevent impact damage.

12.3.8.4.4. Description of the protective coating/covers or splash shields used to guard against contact with incompatible commodities.

12.3.8.4.5. History of pressure cycles (rate, magnitude, and duration) along with the design limitations.

12.3.8.4.6. Data to verify design limits have not been exceeded for specified storage and transport environmental conditions.

12.3.8.4.7. Reports of inspections or observations that identified COPV exposure to abnormal conditions, such as impacts, chemical exposure, excessive environmental loads (such as vibration, acceleration, temperature).

12.4. Flight Hardware Metallic Pressurized Structure Analysis and Test Requirements.

12.4.1. Flight Hardware Metallic Pressurized Structure General Requirements. For pressurized structures made of metallic materials such as the fuel tanks of a launch or an upper-stage vehicle, the design approach may be based on successful past experience when appropriate. However, the analysis and verification requirements specified in this part shall be met.

12.4.2. Flight Hardware Metallic Pressurized Structures with Non-Hazardous LBB Failure Mode.

12.4.2.1. Flight Hardware Metallic Pressurized Structure Factor of Safety Requirements. Unless otherwise specified, metallic pressurized structures that satisfy the LBB failure mode may be designed with a minimum ultimate safety factor of 1.25 for unmanned systems and 1.40 for manned systems.

12.4.2.2. Flight Hardware Metallic Pressurized Structure Fatigue-Life Demonstration. In addition to the stress analysis conducted IAW section **12.2.5.3**, a conventional fatigue-life analysis shall be performed, as appropriate, on the unflawed structure to ascertain that the pressure vessel, acted upon by the spectra of operating loads, pressures, and environments meet the life requirements. A life factor of 4 shall be used in the analysis.

12.4.2.3. Flight Hardware Metallic Pressurized Structure Qualification Test Requirements.

12.4.2.3.1. Qualification tests shall be conducted on flight quality hardware to demonstrate structural adequacy of the design.

12.4.2.3.2. Because of the potential test facility size limitation, the qualification testing may be conducted at the component level provided that the boundary conditions are correctly simulated.

12.4.2.3.3. The test fixtures, support structures, and methods of environmental application shall not induce erroneous test conditions.

12.4.2.3.4. The sequences, combinations, levels, and duration of loads, pressure and environments shall demonstrate that design requirements have been met.

12.4.2.3.5. Qualification testing shall include pressure cycle testing and burst testing. The following delineates the required tests:

12.4.2.3.5.1. Pressure Cycle Testing.

12.4.2.3.5.1.1. Requirements for application of external loads in combination with internal pressure during testing shall be evaluated based on the relative magnitude and on the destabilizing effect of stresses due to the external loads.

12.4.2.3.5.1.2. If limit-combined tensile stresses are enveloped by the MEOP stress, the application of an external load is not required.

12.4.2.3.5.1.3. Unless otherwise specified, the peak pressure shall be equal to the MEOP during each pressure cycle, and the number of cycles shall be 4 times the predicted number of operating cycles or 50 MEOP cycles, whichever is greater.

12.4.2.3.5.1.4. If the application of external loads is required, the load shall be cycled 4 times the predicted number of operating cycles of the most severe design condition (for example, destabilizing load with constant minimum internal pressure or maximum additive load with MEOP).

12.4.2.3.5.2. Burst Testing.

12.4.2.3.5.2.1. After the pressure cycle testing, the test article shall be pressurized (pneumatically or hydrostatically, as applicable and safe) to the design burst pressure, while simultaneously applying the ultimate external loads, if appropriate.

12.4.2.3.5.2.2. The design burst pressure shall be maintained for a sufficient period of time to ensure that the proper pressure is achieved.

12.4.2.4. Flight Hardware Metallic Pressurized Structure Acceptance Test Requirements. Every pressurized structure shall be proof tested to verify that the materials, manufacturing processes, and workmanship meet design specifications and that the hardware is suitable for flight. Acceptance testing shall meet the requirements of section **12.3.2.7**. **Exception**: If personnel are exposed to the structure when pressurized above 50% of MEOP, the minimum proof factor shall be 1.25. If personnel are not exposed to the structure when pressurized, the proof pressure factor shall be 1.1 times MEOP.

12.4.2.5. Flight Hardware Metallic Pressurized Structure Recertification Test Requirements. Recertification testing shall meet the requirements of paragraph **12.3.2.8**.

12.4.3. Flight Hardware Metallic Pressurized Structures with Hazardous LBB or Brittle Failure Mode.

12.4.3.1. Flight Hardware Metallic Pressurized Structures with Hazardous LBB or Brittle Failure Mode Factor of Safety Requirements. Unless otherwise specified, metallic pressurized structures that satisfy the LBB failure mode may be designed with a minimum ultimate safety factor of 1.25 for unmanned systems and 1.40 for manned systems.

12.4.3.2. Flight Hardware Metallic Pressurized Structures with Hazardous LBB or Brittle Failure Mode Safe-Life Demonstration.

12.4.3.2.1. Safe-life analysis of each pressurized structure shall be performed under the assumption of pre-existing initial flaws or cracks in the structure as specified in section **12.2.5.5**.

12.4.3.2.2. In particular, the analysis shall show that the pressurized structure with flaws placed in the most unfavorable orientation with respect to the applied stress and material properties, of sizes defined by the acceptance proof test or NDE and acted upon by the spectra of expected operating loads, pressure, and environments meets the safe-life requirements of section **12.2.15**.

12.4.3.2.3. Nominal values of fracture toughness and flaw growth rate data associated with each alloy system, temper, product form, thermal and chemical environments, and loading spectra shall be used along with a life factor of 4 on specified service life in all safe-life analysis.

12.4.3.2.4. Safe-life testing in lieu of safe-life analysis is an acceptable alternative, provided that, in addition to following a quality assurance program (see section **12.2.17**) for each flight article, a qualification test program is implemented on pre-flawed specimens representative of the structural design.

12.4.3.2.5. These flaws shall not be smaller than the minimum detectable flaw sizes established by the selected NDE method(s). Proof test logic shall not be used to determine minimum flaw size.

12.4.3.2.6. Safe-life requirements of section **12.2.15** are considered demonstrated when the pre-flawed test specimens successfully sustain the limit loads and pressure cycles in the expected operating environments.

12.4.3.2.7. A life factor of 4 on specified pressure cycles in the service life shall be applied in the safe-life demonstration testing.

12.4.3.3. Flight Hardware Metallic Pressurized Structures with Hazardous LBB or Brittle Failure Mode Qualification Test Requirements. Qualification testing shall include pressure cycle testing and burst testing. The following delineates the required tests:

12.4.3.3.1. Pressure Cycle Testing.

12.4.3.3.1.1. Requirements for application of external loads in combination with internal pressure during testing shall be evaluated based on the relative magnitude and on the destabilizing effect of stresses due to the external loads.

12.4.3.3.1.2. If limit-combined tensile stresses are enveloped by the MEOP stress, the application of external load is not required.

12.4.3.3.1.3. Unless otherwise specified, the peak pressure shall be equal to the MEOP during each pressure cycle, and the number of cycles shall be 4 times the predicted number of operating cycles or 50 MEOP cycles, whichever is greater.

12.4.3.3.1.4. If the application of external loads is required, the load shall be cycled 4 times the predicted number of operating cycles of the most severe design condition; for example, destabilizing load with constant minimum internal pressure or maximum additive load with MEOP.

12.4.3.3.2. Burst Testing.

12.4.3.3.2.1. After the pressure cycle testing, the test article shall be pressurized (pneumatically or hydrostatically, as applicable and safe) to the design burst pressure while simultaneously applying the ultimate external loads, if appropriate.

12.4.3.3.2.2. The design burst pressure shall be maintained for a period of time sufficient to ensure that the proper pressure is achieved.

12.4.3.3.2.3. Unless otherwise specified, the minimum design burst pressure shall be 1.25 times MEOP for unmanned systems, and 1.4 times for manned systems.

12.4.3.4. Flight Hardware Metallic Pressurized Structures with Hazardous LBB or Brittle Failure mode Acceptance Test Requirements.

12.4.3.4.1. The acceptance test requirements for pressurized structures that exhibit brittle fracture failure mode or hazardous LBB failure mode are identical to those with non-hazardous LBB failure mode as defined in section **12.4.2** except that the selected NDE techniques shall be capable of detecting flaws or cracks smaller than the allowable initial flaw size as determined by safe-life analysis.

12.4.3.4.2. Surface and volumetric NDE shall be performed on welds before and after proof testing if personnel are exposed to the structure when pressurized above 50% of MEOP. If personnel will not be exposed to pressures greater than 50%, surface and volumetric NDE shall be performed on welds after the proof test.

12.4.3.5. Flight Hardware Metallic Pressurized Structures with Hazardous LBB or Brittle Failure Mode Recertification Test Requirements. Recertification testing shall meet the requirements of paragraph **12.3.2.8**.

12.5. Flight Hardware Special Pressurized Equipment Design, Analysis, and Test Requirements. The detailed design, analysis, and test requirements for cryostats (or dewars), heat pipes, and sealed containers, which are classified as special pressurized equipment, are described below.

12.5.1. Flight Hardware Cryostats or Dewars with LBB Failure Mode.

12.5.1.1. Flight Hardware Cryostats or Dewars with LBB Failure Mode General Requirements. Pressure containers of the cryostat or dewar shall be demonstrated to exhibit LBB failure mode IAW the following criteria:

12.5.1.1.1. The LBB failure mode shall be demonstrated analytically or by test showing that an initial surface flaw with a shape (a/2c) ranging from 0.05 to 0.5 will propagate through the vessel thickness to become a through-the-thickness crack with a length 10 times the vessel thickness and still remain stable at MEOP.

12.5.1.1.2. Fracture mechanics shall be used if the failure mode is determined by analysis.

12.5.1.1.3. A pressure vessel that contains non-hazardous fluid and exhibits LBB failure mode is considered as a non-hazardous LBB pressure vessel.

12.5.1.2. Flight Hardware Cryostats or Dewars with LBB Failure Mode Factor of Safety Requirements. Unless otherwise specified, the minimum burst factor for the pressure container of a cryostat shall be 1.5.

12.5.1.3. Flight Hardware Cryostats or Dewars with LBB Failure Mode Qualification. Qualification tests shall be conducted on flight quality hardware to demonstrate structural adequacy of the design. The following tests are required:

12.5.1.3.1. Random Vibration Testing. Random vibration testing shall be performed on cryostats per the requirements of SMC-S-016.

12.5.1.3.2. Pressure Testing. The cryostat (dewar) shall be pressurized to the design burst pressure that is 1.5 times MEOP of the pressure container. The design burst pressure shall be maintained for a period of time sufficient to ensure that the proper pressure was achieved.

12.5.1.4. Flight Hardware Cryostats or Dewars with LBB Failure Mode Acceptance Test Requirements.

12.5.1.4.1. Acceptance tests should be conducted on every cryostat (or dewar) before being committed to flight.

12.5.1.4.2. The following tests are required:

12.5.1.4.2.1. Proof-Pressure Test. Cryostats shall be proof-pressure tested to 1.25 times the MEOP of the pressure container.

12.5.1.4.2.2. Nondestructive Examination. Surface and volumetric selected NDE techniques shall be performed after the proof-pressure test.

12.5.1.5. Flight Hardware Cryostats or Dewars with LBB Failure Mode Recertification Test Requirements. Recertification testing shall meet the requirements of paragraph **12.3.2.8**.

12.5.1.6. Flight Hardware Cryostats or Dewars with LBB Failure Mode Special Requirements. Outer shells (vacuum jackets) shall have pressure relief capability to preclude rupture in the event of pressure container leakage. If pressure containers do not vent external to the cryostats (or dewars) but instead vent into the volume contained by outer shells, the relief devices of outer shells shall be capable of venting at a rate to release full flow without outer shells rupturing. Relief devices shall be redundant and individually capable of full flow. Furthermore, pressure relief devices shall be certified to operate at the required condition of use.

12.5.2. Flight Hardware Cryostats or Dewars with Brittle Fracture Failure Mode.

12.5.2.1. Flight Hardware Cryostats or Dewars with Brittle Fracture Failure Mode Factor of Safety Requirements.

12.5.2.1.1. Safe-life design methodology based on fracture mechanics techniques shall be used to establish the appropriate design factor of safety and the associated proof factor for metallic pressure vessels that exhibit brittle fracture or hazardous leak-before-burst failure mode.

12.5.2.1.2. The loading spectra, material strengths, fracture toughness, and flaw growth rates of the parent material and weldments, test program requirements, stress levels, and the compatibility of the structural materials with the thermal and chemical environments expected in service shall be taken into consideration.

12.5.2.1.3. Nominal values of fracture toughness and flaw growth rate data corresponding to each alloy system, temper, and product form shall be used along with a life factor of 4 on specified service life in establishing the design factor of safety and the associated proof factor.

12.5.2.1.4. Unless otherwise specified, the minimum burst factor shall be 1.5.

12.5.2.2. Flight Hardware Cryostats or Dewars with Brittle Fracture Failure Mode Safe-Life Demonstration Requirements.

12.5.2.2.1. After completion of the stress analysis conducted IAW the requirements of section **12.2.5.3.**, safe-life analysis of each pressure container covering the maximum expected operating loads and environments, shall be performed under the assumption of pre-existing initial flaws or cracks in the vessel.

12.5.2.2.2. In particular, the analysis shall show that the metallic cryostat with flaws placed in the most unfavorable orientation with respect to the applied stress and material properties, of sizes defined by the acceptance proof test or NDE and acted upon by the spectra of expected operating loads and environments, meet the safe-life requirements of section **12.2.15**.

12.5.2.2.3. Nominal values of fracture toughness and flaw growth rate data associated with each alloy system, temper, product form, thermal and chemical environments, and loading spectra shall be used along with a life factor of 4 on specified service life in all safe-life analyses.

12.5.2.2.4. Cryostats that experience sustained stress shall also show that the corresponding applied stress intensity (K_I) during operation is less than K_{ISCC} in the appropriate environment.

12.5.2.2.5. Testing of metallic cryostats under fracture control in lieu of safe-life analysis is an acceptable alternative, provided that, in addition to following a quality assurance program (see section **12.2.17**.) for each flight article, a qualification test program is implemented on pre-flawed specimens representative of the structure design.

12.5.2.2.6. These flaws shall not be smaller than the minimum detectable flaw sizes established by the selected NDE method(s). Proof test logic shall not be used to determine minimum flaw size.

12.5.2.2.7. Safe-life requirements of section **12.2.15** are considered demonstrated when the pre-flawed test specimens successfully sustain the limit loads and pressure cycles in the expected operating environments without rupture.

12.5.2.2.8. A life factor of 4 on specified service life shall be applied in the safe-life demonstration testing.

12.5.2.2.9. A report that documents the fracture mechanics safe-life analysis or safe-life testing shall be prepared to delineate the following:

12.5.2.2.9.1. Fracture mechanics data (fracture toughness and fatigue crack growth rates).

12.5.2.2.9.2. Loading spectrum and environments.

12.5.2.2.9.3. Initial flaw sizes.

12.5.2.2.9.4. Analysis assumptions and rationales.

12.5.2.2.9.5. Calculation methodology.

12.5.2.2.9.6. Summary of significant results.

12.5.2.2.9.7. References.

12.5.2.2.10. This report shall be closely coordinated with the stress analysis report.

12.5.2.3. Flight Hardware Cryostats or Dewars with Brittle Fracture Failure Mode Qualification Test Requirements. Qualification testing shall meet the requirements of section **12.3.2.6**.

12.5.2.4. Flight Hardware Cryostats or Dewars with Brittle Fracture Failure Mode Acceptance Test Requirements.

12.5.2.4.1. The acceptance test requirements for cryostats that exhibit brittle fracture or hazardous LBB failure mode are identical to those for metallic pressure vessels with ductile fracture failure mode as defined in section **12.3.2.7** except that test level shall be that defined by the fracture mechanics analysis whenever possible.

12.5.2.4.2. At a minimum, surface and volumetric NDE techniques shall be performed on all weld joints before and after the proof test.

12.5.2.4.3. Cryo-proof acceptance test procedures may be required to adequately verify initial flaw size.

12.5.2.4.4. The pressure container shall not rupture or leak at the acceptance test pressure.

12.5.2.5. Flight Hardware Cryostats or Dewars with Brittle Fracture Failure Mode Recertification Test Requirements. Recertification testing shall meet the requirements of paragraph **12.3.2.8**.

12.5.2.6. Flight Hardware Cryostats or Dewars with Brittle Fracture Failure Mode Special Provisions.

12.5.2.6.1. For one-of-a-kind applications, a proof test of each flight unit to a minimum of 1.5 times MEOP and a conventional fatigue analysis showing a minimum of 10 design lifetimes may be used in lieu of the required pressure testing as defined in section **12.3.4** or **12.3.3.3**, as applicable, for qualification.

12.5.2.6.2. Outer shells (vacuum jackets) shall have pressure relief capability to preclude rupture in the event of pressure container leakage. If pressure containers do not vent external to the cryostats or dewars, but instead vent into the volume contained by outer shells, the relief devices of outer shells shall be capable of venting at a rate to release full flow without the outer shall rupturing. Pressure relief devices shall be certified to operate at the required condition of use.

12.5.2.6.3. The implementation of this option needs prior approval by the procuring agency and the appropriate range approval authority.

12.5.3. Flight Hardware Heat Pipe Requirements.

12.5.3.1. Flight Hardware Heat Pipe Factor of Safety.

12.5.3.1.1. Unless otherwise specified, the minimum burst factors for heat pipes with a diameter greater than 1.5 inches shall be 2.5.

12.5.3.1.2. For heat pipes with a diameter less than or equal to 1.5 inches, the minimum burst factor shall be 4.0.

12.5.3.2. Flight Hardware Heat Pipe Qualification Test Requirements. Pressure testing shall be conducted to demonstrate no failure at the design burst pressure.

12.5.3.3. Flight Hardware Heat Pipe Acceptance Test Requirements.

12.5.3.3.1. All fusion joints or full penetration welds on the heat pipes that contain hazardous fluids shall be inspected using acceptable surface and volumetric NDE techniques.

12.5.3.3.2. A proof pressure test shall be conducted to a minimum level of 1.5 times MEOP on all heat pipes.

12.5.3.4. Flight Hardware Heat Pipe Recertification Test Requirements. Recertification testing shall meet the requirements of paragraph **12.3.2.8**.

12.5.3.5. Flight Hardware Heat Pipe Special Requirements. The heat pipe material shall satisfy the material compatibility requirements defined in section **12.2.16** for the contained fluid at both the proof test temperature and operational temperature.

12.5.4. Flight Hardware Sealed Containers.

12.5.4.1. Sealed Containers with Non-Hazardous LBB Failure Mode. The LBB failure mode shall be demonstrated as defined in section **12.3.2**. **Exception**: Those containers made of aluminum, stainless steel, or titanium sheets that are acceptable as LBB designs do not have to demonstrate LBB failure mode.

12.5.4.1.1. Sealed Containers with Non-Hazardous LBB Failure Mode Factor of Safety. Unless otherwise specified, the minimum burst factor shall be 1.5.

12.5.4.1.2. Sealed Containers with Non-Hazardous LBB Failure Mode Qualification Test Requirements.

12.5.4.1.2.1. Sealed containers containing non-electronic equipment shall only be subjected to pressure testing.

12.5.4.1.2.2. For sealed containers containing safety-related electronic equipment, other qualification tests including functional, thermal vacuum, thermal cycling, random vibration, and pyro shock shall be conducted per SMC-S-016 or equivalent.

12.5.4.1.3. Sealed Containers with Non-Hazardous LBB Failure Mode Acceptance Test Requirements. Sealed containers shall be proof-pressure tested to a minimum level of 1.25 times maximum design pressure differential.

12.5.4.1.4. Sealed Containers with Non-Hazardous LBB Failure Mode Recertification Test Requirements.

12.5.4.1.4.1. All refurbished sealed containers shall be recertified after each refurbishment by the acceptance test requirements for new hardware to verify their structural integrity and to establish their suitability for continued service before commitment to flight.

12.5.4.1.4.2. Sealed containers that have exceeded the approved storage environment (temperature, humidity, time, and others) shall also be recertified by the acceptance test requirements for new hardware.

12.5.4.2. Sealed Containers with Brittle Fracture or Hazardous LBB Failure Mode.

12.5.4.2.1. Sealed containers that exhibit a brittle fracture failure mode or contain hazardous fluid, or both, shall meet the requirements of section **12.3.3**.

12.5.4.2.2. For sealed containers containing safety-related electronic equipment, qualification tests including functional, thermal vacuum, thermal cycling, and pyro shock shall be conducted in addition to random vibration and pressure testing.

12.6. Flight Hardware Pressure System Component Design and Test Requirements . The requirements for the design and testing of flight hardware pressure system components are described below. Included are hydraulic, pneumatic, hypergolic, and cryogenic system components.

12.6.1. Flight Hardware Pneumatic and Hydraulic Pressure System Components.

12.6.1.1. Factor of Safety Requirements. Flight hardware pneumatic and hydraulic pressure system components shall be designed to the minimum factors shown in **Table 12.4**.

Table 12.4. Pressure Components Safety Factors.

Component	**Proof**	**Design Burst**
Lines and fittings diameter < 1.5 inches	1.5	4.0
Lines and fitting diameter > 1.5 inches	1.5	2.5
Fluid Return Sections	1.5	3.0
Fluid Return Hose	1.5	5.0
Other Pressure Components	1.5	2.5
Components subject to low or negative pressures shall be evaluated at 2.5 times maximum external pressure expected during service life.		

12.6.1.2. Flight Hardware Pneumatic and Hydraulic Pressure System Component General Selection and Design Requirements.

12.6.1.2.1. Components shall be selected to ensure that misconnections or reverse installations within the subsystem are not possible. Color codes, labels, and directional arrows shall be used to identify hazards and direction of flow.

12.6.1.2.2. The maximum fluid temperature shall be estimated early in design as part of data for selection of safety critical components, such as system fluid, pressurizing gas, oil coolers, and gaskets.

12.6.1.2.3. Components that are capable of safe actuation under pressure equal to the maximum relief valve setting in the circuit in which they are installed shall be specified.

12.6.1.2.4. Pumps, valves and regulators, hoses, and all such prefabricated components of a pressure system shall have proven pressure service ratings equal to or higher than the limit load (MEOP) and rated life of the system.

12.6.1.2.5. *The Standards of the Hydraulic Institute* shall be used in evaluating safety in pump selection.

12.6.1.2.6. Where leakage or fracture is hazardous to personnel or critical equipment, valves shall be selected so that failure occurs at the outlet threads of valves before the inlet threads or body of the valve fails under pressure.

12.6.1.2.7. Pressure regulators shall be selected to operate in the center 50% of their total pressure range and avoid creep and inaccuracies at either end of the full operating range.

12.6.1.2.8. In all cases, flareless tube fittings shall be properly preset before pressure application.

12.6.1.2.9. Where system leakage can expose hydraulic fluid to potential ignition sources or is adjacent to a potential fire zone and the possibility of flame propagation exists, fire-resistant or flame-proof hydraulic fluid shall be used.

12.6.1.3. Flight Hardware Oxygen System Components.

12.6.1.3.1. For oxygen systems of 3,000 psi or higher, valves and other components that are slow opening and closing types shall be selected to minimize the potential for ignition of contaminants.

12.6.1.3.2. Such systems shall also require electrical grounding to eliminate the possibility of the buildup of static electrical charges.

12.6.1.3.3. Oxygen system components, design, and material selection shall conform to ASTM MNL 36.

12.6.1.4. Flight Hardware Pneumatic and Hydraulic System Manual Valves and Regulators.

12.6.1.4.1. Manually operated valves and regulators shall be selected so that overtorquing of the valve stem of the regulator adjustment cannot damage soft seats to the extent that failure of the seat will result.

12.6.1.4.2. Valve designs that use uncontained seats are unacceptable and shall not be selected.

12.6.1.5. Flight Hardware Pneumatic and Hydraulic System Warning Devices and Safety Critical Components.

12.6.1.5.1. Warning devices that are activated by hazardous over or under pressure shall be selected whenever necessary.

12.6.1.5.2. The warning device shall either activate automatic response mechanisms or shall notify operational personnel of impending hazards.

12.6.1.5.3. Warning devices to indicate hazardous over or under pressures to operating personnel shall be specified.

12.6.1.5.4. These warning devices shall actuate at predetermined pressure levels designed to allow time for corrective action.

12.6.1.5.5. Safety critical actuation of pneumatic systems shall not be adversely affected by any back pressure resulting from concurrent operations of any other parts of the system under any set of conditions.

12.6.1.5.6. Components that can be isolated and contain residual pressure shall be equipped with gage reading and bleed valves for pressure safety checks.

12.6.1.5.7. Bleed valves shall be directed away from operating personnel.

12.6.1.5.8. Fittings or caps for bleeding pressure are not acceptable.

12.6.1.5.9. Pressurized reservoirs that are designed for gas/fluid separation with provisions to entrap gas that may be hazardous to the system or safety critical actuation and prevent its recirculation in the system shall be specified. Specific instructions shall be posted adjacent to the filling point for proper bleeding when servicing.

12.6.1.5.10. Compressed gas emergency systems shall be bled directly to the atmosphere away from the vicinity of personnel rather than to reservoir.

12.6.1.5.11. If the gas is combustible, consideration shall be given to the selection of safety critical components and methods for reducing the potential for accidental ignition or explosion.

12.6.1.5.12. Where necessary to prevent a hazardous sequence of operations and provide a fail-safe capability at all times, interlocks shall be specified. For example, the OPEN position of remotely controlled valves that can hazardously pressurize lines leading to remotely controlled (or automatic) disconnect couplings shall be interlocked to preclude the OPEN valve position coincident with the disconnected condition of the couplings.

12.6.1.5.13. Pressure systems that combine several safety critical functions shall have sufficient controls for isolating failed functions for the purpose of safely operating the remaining functions.

12.6.1.5.14. All pressure systems shall have pressure indicating devices to monitor critical flows and pressures marked to show safe upper and lower limits of system pressure.

12.6.1.5.15. The pressure indicators shall be located to be readily visible to the operating crew.

12.6.1.5.16. All systems shall be protected for pressure above 500 psi in all areas where damage can occur during servicing or other operational hazards.

12.6.1.5.17. Pressure lines and components of 500 psi or higher that are adjacent to safety critical equipment shall be shielded to protect such equipment in the event of leakage or burst of the pressure system.

12.6.1.5.18. Automatic disengagement or bypass shall be provided for pneumatic systems that provide for manual takeover in the event of a hazardous situation.

12.6.1.5.19. Positive indication of disengagement shall be provided.

12.6.1.5.20. Safety critical pneumatic actuators shall have positive mechanical stops at the extremes of safe motion.

12.6.1.5.21. Adjustable orifice restrictor valves shall not be used in safety critical pneumatic systems.

12.6.1.6. Flight Hardware System Pneumatic Components.

12.6.1.6.1. Pneumatic components (other than tanks) for safety critical systems shall exhibit safe endurance against hazardous failure modes for not less than 400% of the total number of expected cycles including system tests.

12.6.1.6.2. The configuration of pneumatic components shall permit bleeding of entrapped moisture, lubricants, particulate material, or other foreign matter hazardous to the system.

12.6.1.6.3. Compressors that are designed to sustain not less than 2.5 times delivery pressure after allowance for loss of strength of the materials equivalent to not less than that caused by 1,000 hours aging at 275° F shall be selected.

12.6.1.7. Flight Hardware Pneumatic and Hydraulic System Design Loads.

12.6.1.7.1. Installation of all lines and components to withstand all expected acceleration and shock loads shall be specified. **Note**: Shock isolation mounts may be used if necessary to eliminate destructive vibration and interference collisions.

12.6.1.7.2. The mounting of components, including valves, on structures having sufficient strength to withstand torque and dynamic loads and not supported by the tubing shall be specified.

12.6.1.7.3. Light-weight components that do not require adjustment after installation (for example, check valves) may be supported by the tubing, provided that a tube clamp is installed on each such tube near the component.

12.6.1.7.4. Tubing shall be supported by cushioned steel tube clamps or by multiple-block type clamps that are suitably spaced to restrain destructive vibration.

12.6.1.8. Flight Hardware Pneumatic and Hydraulic System Electrical and Electronic Devices.

12.6.1.8.1. Electrical components for use in potentially ignitable atmospheres shall be demonstrated to be incapable of causing an explosion in the intended application.

12.6.1.8.2. Electrically energized hydraulic components shall not propagate radio-frequency energy that is hazardous to other subsystems in the total system, or interfere in the operation of safety critical electronic equipment. (See MIL-STD-464C, *Electromagnetic Environmental Effects Requirements for Systems*.)

12.6.1.8.3. Pressure system components and lines shall be electrically grounded to metallic structures.

12.6.1.8.4. All solenoids shall be capable of safely withstanding a test voltage of not less than 1500 V rms at 60 Hz for 1 minute between terminals and case at the maximum operating temperature of the solenoid in the functional envelope.

12.6.1.8.5. Electric motor-driven pumps used in safety critical systems shall not be used for ground test purposes unless the motor is rated for reliable, continuous, and safe operation. Otherwise, the test parameters may perturb reliability calculations.

12.6.1.9. Flight Hardware Pneumatic and Hydraulic System Pressure Relief Devices.

12.6.1.9.1. Pressure relief devices shall be specified on all systems having a pressure source that can exceed the maximum allowable pressure of the system or where the malfunction/failure of any component can cause the maximum allowable pressure to be exceeded.

12.6.1.9.2. Relief devices are required downstream of all regulating valves and orifice restrictors unless the downstream system is designed to accept full source pressure.

12.6.1.9.3. On space systems, where operational or weight limitations preclude the use of relief valves and systems operate in an environment not hazardous to personnel, they can be omitted (1) if the ground or support system contains such devices and they cannot be isolated from the airborne system during the pressurization cycle, and (2) the space vehicle cannot provide its own protection.

12.6.1.9.3.1. Where a ground system is specifically designed to service an unmanned flight vehicle, pressure relief protection may be provided within the ground equipment, if no capability exists to isolate the pressure relief protection from the flight vehicle during the pressurization cycle.

12.6.1.9.4. Where safety factors of less than 2.0 are used in the design of flight hardware pressure vessels, a means for automatic relief, depressurization, and pressure verification of safety critical vessels in the event of launch abort shall be provided. Spacecraft (payload) pressure vessels may be designed without automatic relief (other means of safe relief shall be provided) if a safety analysis validates that a rupture will not damage the safety systems.

12.6.1.9.5. Whenever any pressure volume can be confined and/or isolated by system valving, an automatic pressure relief device shall be provided.

12.6.1.9.6. Pressure relief devices shall vent toxic or inert gases to safe areas, away from the vicinity of personnel. Scrubbers or vapor disposal systems shall also be used at a safe distance from personnel. **Note**: Pop-valves, rupture disks, blow-out plugs, armoring, and construction to contain the greatest possible overpressure that may develop are examples of corrective measures for system safety.

12.6.1.9.7. Shut-off valves for maintenance purposes on the inlet side of pressurized relief valves are permissible if a means for monitoring and bleeding trapped pressure is provided and the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Appendix M, Paragraph M-5 are met. It is mandatory that the valve be locked open when the system is re-pressurized.

12.6.1.9.8. Hydrostatic testing systems for vessels that are not designed to sustain negative internal pressure shall be equipped with fail-safe devices for relief of hazardous negative pressure during the period of fluid removal. **Note**: Check valves and valve interlocks are examples of devices that can be used for this purpose.

12.6.1.9.9. Vessels that can be collapsed by a negative pressure shall have negative pressure relief and/or prevention devices for safety during storage and transportation.

12.6.1.9.10. Pressurized reservoirs shall be designed so that all ullage volumes are connected to a relief valve that shall protect the reservoir and power pump from hazardous overpressure or back pressure of the system.

12.6.1.9.11. The air pressure control for pressurized reservoirs shall be an externally nonadjustable, pressure regulating device. If this unit also contains a reservoir pressure relief valve, it shall be designed so that no failure in the unit permits over pressurization of the reservoir.

12.6.1.10. Flight Hardware Pneumatic and Hydraulic System Contamination. Safety and safety critical contamination shall be prevented from entering or developing in flight hardware pneumatic or hydraulic system components. Safety and safety critical systems shall be designed to include provisions for detection, filtration, and removal of contaminants.

Table 12.5. Design Considerations for Addressing Contamination.

The following contamination-related considerations should be addressed in the design of pressurized systems. Contamination includes solid, liquid, and gaseous material.
a. Contamination should be prevented from entering or developing within the system.
b. The system should be designed to include provisions to detect contamination.
c. The system should be designed to include provisions for removal of contamination and provisions for initial purge with fluid or gas that cannot degrade future system performance.
d. The system should be designed to be tolerant of contamination.
e. All pressurizing fluids entering safety critical system should be filtered through a 10 micron filter, or finer, before entering the system.
f. All pressure systems should have fluid filters in the system, designed and located to reduce the flow of contaminant particles to a safe minimum.
g. All of the circulating fluid in the system should be filtered downstream from the pressure pump or immediately upstream from safety critical actuators.
h. Entrance of contamination at test points or vents should be minimized by downstream filters.
i. The bypass fluid or case drain flow on variable displacement pumps should be filtered. j. When the clogging of small orifices could cause a hazardous malfunction or failure of the system, they should be protected by a filter element designed to prevent clogging of the orifice. Note that this includes servo valves. k. Filters or screens should not be used in suction lines of power pumps or hand pumps of

safety critical systems.
l. Air filters should be specified for hydraulic reservoir air pressurization circuits and located to protect the pressure regulating equipment from contamination.
m. Dry compressed air should be specified for hydraulic reservoir pressurization.
n. A moisture removal unit should be specified to protect the pressure regulation lines and equipment.
o. Unpressurized Reservoirs. Unpressurized hydraulic reservoirs should have filters and desiccant units at the breather opening to preclude introduction of moisture and contaminants into the reservoir.

12.6.1.11. Flight Hardware Pneumatic and Hydraulic System Bleed Ports.

12.6.1.11.1. Where necessary, bleed ports shall be provided to remove accumulations of residue or contaminants.

12.6.1.11.2. High point bleed ports shall be provided where necessary for removal of trapped gases.

12.6.1.11.3. The bleed valve shall be directed away from operating personnel and possible ignition sources.

12.6.1.11.4. Components, cavities, or lines that can be isolated shall be equipped with bleed valves that can be used to release retained pressure, or they shall indicate that continued pressure exists in the system.

12.6.1.11.5. Bleed valves used for reducing pressure on systems containing hazardous fluids shall be routed to a safe disposal area.

12.6.1.11.6. Auxiliary Bleed Ports.

12.6.1.11.6.1. Auxiliary bleed ports shall be provided where necessary to allow bleed off for safety purposes.

12.6.1.11.6.2. Bleeder valves shall be located so that they can be operated without removal of other components, and shall permit the attachment of a hose to direct the bleed-off fluid into a container.

12.6.1.11.7. Reservoir filler caps shall include design provisions that shall automatically bleed the reservoir on opening so that possible ullage pressure cannot impart hazardous kinetic energy to either the filler caps, the fluid in the reservoir, or the system.

12.6.1.12. Flight Hardware Pneumatic and Hydraulic System Control Devices.

12.6.1.12.1. Safety critical pressure systems incorporating two or more directional control valves shall be designed to preclude the possibility of inadvertently directing the flow or pressure from one valve into the flow path or pressure path intended for another valve, with any combination of valve settings possible in the total system.

12.6.1.12.2. Control devices shall be designed to prevent overtravel or undertravel that may contribute to a hazardous condition or damage to the valve.

12.6.1.12.3. All pressure and volume controls shall have stops, or equivalent, to prevent settings outside their nominal safe working ranges.

12.6.1.12.4. Control components that have integral manually operated levers and stops shall be capable of withstanding the following limit torques in **Table 12.6**.

Table 12.6. Limit Torque Requirements.

Lever Radius (R)	**Design Torque**
Less than 3 inches	50 x R inch-pound
3 to 6 inches	75 x R inch-pound
Over 6 inches	150 x R inch-pound

12.6.1.13. Flight Hardware Pneumatic and Hydraulic System Manually Operated Levers.

12.6.1.13.1. Components that have integrated manually operated levers shall provide levers and stops capable of withstanding the limit torques specified by MIL-STD-1472.

12.6.1.13.2. Levers and stops shall be provided on remote controls capable of withstanding a limit torque of 1,800 inch-pounds.

12.6.1.13.3. Because jamming is possible, sheathed flexible actuators shall not be used for valve controls in safety critical pressure systems (for example, push-pull wires and torque wires that are sheathed are not acceptable).

12.6.1.14. Flight Hardware Pneumatic and Hydraulic System Accumulators.

12.6.1.14.1. Accumulators shall be designed IAW the pressure vessel standards for ground systems and located for minimal probability of mechanical damage and for minimum escalation of material damage or personnel injury in the event of a major failure such as tank rupture.

12.6.1.14.2. Accumulator gas pressure gauges shall not be used to indicate system pressure for operational or maintenance purposes.

12.6.1.14.3. Gas type and pressure level shall be posted on, or immediately adjacent to, the accumulator.

12.6.1.15. Flight Hardware Pneumatic and Hydraulic System Flexible Hose. Flexible hose requirements are specified in section **12.2.10.4**.

12.6.1.16. Flight Hardware Pneumatic and Hydraulic System Qualification Test Requirements. Qualification tests are not required on lines and fittings. Internal/external pressure testing shall be conducted on all other pressure components to demonstrate no failure at the design burst pressure. Seamless lines, tubing, and pipe are exempt.

12.6.1.17. Flight Hardware Pneumatic and Hydraulic System Acceptance Test Requirements.

12.6.1.17.1. Testing Flight Hardware Pneumatic and Hydraulic Components Before Assembly.

12.6.1.17.1.1. All pressurized components such as valves, pipe, tubing, and pipe and tube fittings shall be hydrostatically proof tested to a minimum of 1.5 times the component MAWP for a minimum of 5 minutes. **Note**: In the event that component testing before assembly is not feasible, components may be hydrostatically tested after assembly into a subsystem or system to 1.5 times the system MOP. This approach shall be approved by Wing Safety.

12.6.1.17.1.2. Proof testing shall demonstrate that the components sustain proof pressure levels without distortion, damage, or leakage.

12.6.1.17.1.3. Both the inlet and discharge sides of a relief valve shall be proof tested. When the discharge side has a lower pressure rating than the inlet, they are to be proof tested independently.

12.6.1.17.1.4. The following inspections shall be performed after proof testing:

12.6.1.17.1.4.1. Mechanical components such as valves and regulators shall be inspected for external deformation, deterioration, or damage.

12.6.1.17.1.4.2. Damaged, distorted, or deteriorated parts shall be rejected and replaced and the test repeated.

12.6.1.17.1.5. Functional and leak tests shall be performed at the component MAWP after the proof test.

12.6.1.17.1.6. Pneumatic pressure system components shall undergo sufficient qualification and acceptance testing to demonstrate that the system and components meet design and safety requirements when subjected to prelaunch and launch environments such as vibration, shock, acceleration, and temperature.

12.6.1.17.1.7. Test plans and test reports shall be made available to Wing Safety.

12.6.1.17.1.8. Pressure relief valves shall be tested for proper setting and flow capacity before installation and first use on the ranges.

12.6.1.17.1.9. Pressure gauges and transducers shall be hydrostatically tested to a minimum of 1.5 times the system MOP/MEOP.

12.6.1.17.1.10. Pressure gauges and transducers shall be calibrated before installation.

12.6.1.17.1.11. Pneumatic proof testing to a proof pressure of 1.25 times MOP (not to exceed MAWP) is permissible only if hydrostatic proof testing is impractical, impossible, or jeopardizes the integrity of the system or system element. Prior approval for pneumatic proof testing at the ranges shall be obtained from Wing Safety.

12.6.1.17.2. Testing Flight Hardware Pneumatic and Hydraulic Systems After Assembly. All newly assembled pressure systems shall be hydrostatically tested to 1.5 times MOP before use. MOP here refers to the maximum operating pressure that personnel are exposed to. Where this is not possible, Wing Safety shall determine the adequacy of component testing and alternate means of testing the assembled system.

12.6.1.17.3. Flight Hardware Pneumatic and Hydraulic System Leak Tests.

12.6.1.17.3.1. All newly assembled pressure systems shall be leak tested at the system MOP/MEOP before first use at the ranges.

12.6.1.17.3.2. This test shall be conducted at the ranges unless prior approval from Wing Safety has been obtained.

12.6.1.17.3.3. Minimum test requirements are as follows:

12.6.1.17.3.3.1. The gas used during the leak test shall be the same as the system fluid media except that for hazardous gas systems, a system-compatible, non-hazardous gas may be used that has a density as near as possible to the system fluid; for example, helium should be used to leak test a gaseous hydrogen system.

12.6.1.17.3.3.2. Mechanical connections, gasketed joints, seals, weld seams, and other items shall be visually bubble tight for a minimum of 1 minute when an approved leak test solution is applied.

12.6.1.17.3.3.3. Alternate methods of leak testing such as the use of portable mass spectrometers may be specified when required on a case-by-case basis.

12.6.1.17.4. Flight Hardware Pneumatic and Hydraulic System Validation and Functional Tests.

12.6.1.17.4.1. All newly assembled pressure systems shall have a system validation test and a functional test of each component at system MOP before first use at the ranges.

12.6.1.17.4.2. These tests shall be conducted at the ranges unless prior approval from Wing Safety has been obtained.

12.6.1.17.4.3. Minimum test requirements are as follows:

12.6.1.17.4.3.1. These tests shall demonstrate the functional capability of all non-passive components such as valves, regulators, and transducers.

12.6.1.17.4.3.2. All prelaunch operational sequences for the system shall be executed.

12.6.1.17.4.3.3. All parallel or series redundant components shall be individually tested to ensure single fault tolerant capabilities are functional before launch.

12.6.1.17.4.3.4. All shutoff and block valves shall be leak checked downstream to verify their shutoff capability in the CLOSED position.

12.6.1.17.5. Flight Hardware Pneumatic and Hydraulic System Bonding and Grounding Tests. All newly assembled pressure systems containing flammable and combustible fluids shall be tested to verify that the requirements of section 12.2.12 of this volume have been met.

12.6.1.17.6. Test Requirements for Modified and Repaired Flight Hardware Pneumatic Systems.

12.6.1.17.6.1. Any pressure system element, including fittings or welds, that has been repaired, modified, or possibly damaged before having been proof tested, shall be retested at proof pressure before its normal use.

12.6.1.17.6.2. A modified or repaired pressure system shall be leak tested at the system MOP/MEOP before its normal use. This test shall be conducted at the ranges unless prior approval from Wing Safety has been obtained.

12.6.1.17.6.3. A modified or repaired pressure system shall be revalidated and functionally tested at the system MOP before its normal use.

12.6.1.17.6.4. If any pressure system element such as a valve, regulator, gauges, or tubing has been disconnected or reconnected for any reason, the affected system or subsystem shall be leak tested at MOP/MEOP.

12.6.2. Flight Hardware Hazardous Fluid System Components, Including Hypergolic, Cryogenic, and Hydraulic Systems. Hypergolic and cryogenic components are required to meet the requirements in sections **12.7**, **12.8**, **12.9**, and **12.10** in addition to the following:

12.6.2.1. Cycling capability for safety critical components shall be not less than 400% of the total number of expected cycles, including system tests, but not less than 2,000 cycles.

12.6.2.2. For service above a temperature of 160°F, an additional cycling capability equivalent to the above shall be required as a maximum. **Note**: The intent of this requirement is twofold: (1) to prevent viscosity breakdown from heat in hydraulic systems, and (2) to consider the effects of elevated temperature in determining the safe cycle life of the components.

12.6.2.3. Safety critical actuators shall have positive mechanical stops at the extremes of safe motion.

12.6.2.4. Hydraulic fluid reservoirs and supply tanks shall be equipped with remotely operated shutoff valves.

12.6.2.5. Shuttle valves shall not be used in safety critical hydraulic systems where the event of a force balance on both inlet ports may occur, causing the shuttle valve to restrict flow from the outlet port.

12.6.2.6. Systems incorporating accumulators shall be interlocked to either vent or isolate accumulator fluid pressure when power is shutoff.

12.6.2.7. Adjustable orifice restrictor valves shall not be used in safety critical systems.

12.6.2.8. When two or more actuators are mechanically tied together, only one lock valve shall be used to lock all the actuators.

12.6.2.9. Lock valves shall not be used for safety critical lockup periods likely to involve extreme temperature changes, unless fluid expansion and contraction effects are safely accounted for.

12.6.2.10. Flight Hardware Hazardous Fluid System Reservoirs.

12.6.2.10.1. Whenever possible, the hydraulic reservoir should be located at the highest point in the system.

12.6.2.10.2. If the requirement in paragraph **12.6.2.10.1** is not possible in safety critical systems, procedures shall be developed to detect air in actuators or other safety critical components and to ensure that the system is properly bled before each use.

12.6.2.11. Systems installations shall be limited to a maximum pressure of 15,000 psig. **Note**: There is no intent to restrain development of systems capable of higher pressures; however, the use of such systems shall be preceded by complete development and qualification that includes appropriate safety tests.

12.6.2.12. The inlet pressure of pumps in safety critical systems shall be specified to prevent cavitation effects in the pump passages or outlets.

12.6.2.13. Safety critical systems shall have positive protection against breaking the fluid column in the suction line during standby.

12.6.2.14. Systems for primary flight control of manned vehicles shall have redundant features for all major aspects of operation and control and be essentially independent of systems non-critical to safety. **Note**: Provision may be made for a safety critical system to draw power from a non-critical system, provided that no single failure can cause loss of both systems because of this connection.

12.6.2.15. Systems that provide for manual takeover shall automatically disengage or allow by-pass of the act of manual takeover.

12.6.2.16. Safety critical systems or alternate by-pass systems provided for safety shall not be rendered inoperative because of back pressure under any set of conditions.

12.6.2.17. The system shall be designed so that a lock resulting from an unplanned disconnection of a self-seating coupling or other component shall not cause damage to the system or to adjacent property or injury to personnel.

12.6.2.18. Systems using power-operated pumps shall include a pressure regulating device and an independent safety relief valve.

12.6.2.19. Flight Hardware Hazardous Fluid System Thermal Pressure Relief Valves.

12.6.2.19.1. Thermal expansion relief valves shall be installed as necessary to prevent system damage from thermal expansion of hydraulic fluid as in the event of gross overheating.

12.6.2.19.2. Internal valve leakage shall not be considered an acceptable method of providing thermal relief.

12.6.2.19.3. Thermal relief valve settings shall not exceed 150 psi above the value for system relief valve setting.

12.6.2.19.4. Vents shall outlet only to areas of relative safety from a fire hazard.

12.6.2.19.5. Hydraulic blow-out fuses (soft plugs) shall not be used in systems having temperatures above 160° F.

12.6.2.20. Pressure relief valves shall be located in the systems wherever necessary to ensure that the pressure in any part of a power system shall not exceed the safe limit above the regulated pressure of the system.

12.7. Flight Hardware Pneumatic System Design Requirements. Specific requirements for the design of flight hardware pneumatic systems and specific pneumatic system components are described below:

12.7.1. Flight Hardware Pneumatic System Piping.

12.7.1.1. NPT connectors shall not be used in hazardous pressure system piping.

12.7.1.2. Socket-welded flanges shall not be used in hazardous pressure system piping.

12.7.1.3. All piping and fitting welds shall be 100% radiographically inspected.

12.7.2. Flight Hardware Pneumatic System Tubing. All tubing and fitting welds shall be 100% radiographically inspected before and after the pressure test and inspected by surface NDE techniques before and after the pressure test.

12.7.3. Flight Hardware Pneumatic System Regulators.

12.7.3.1. Regulators shall be selected so that their working pressure falls within the center 50% of their total pressure range if it is susceptible to inaccuracies or creep at either end of its pressure range.

12.7.3.2. Pressure regulator actuators shall be capable of shutting off the fluid when the system is at the maximum possible flow and pressure.

12.7.3.3. Designs using uncontained seats are unacceptable.

12.7.3.4. Systems that contain regulators that are remotely operated during prelaunch operations shall be designed to be fail-safe if pneumatic or electric control power to the regulator is lost.

12.7.4. Flight Hardware Pneumatic System Valves.

12.7.4.1. Valve actuators shall be operable under maximum design flow and pressure.

12.7.4.2. Manually operated valves shall be designed so that overtorquing the valve stem cannot damage soft seats to the extent that seat failure occurs.

12.7.4.3. Designs using uncontained seats are prohibited.

12.7.4.4. Valves that are not intended to be reversible shall be designed or marked so that they shall not be connected in a reverse mode.

12.7.4.5. All electrical control circuits for remotely actuated valves shall be shielded or otherwise protected from hazardous stray energy.

12.7.4.6. Remotely controlled valves shall provide for remote monitoring of OPEN and CLOSED positions during prelaunch operations.

12.7.4.7. Systems that contain remotely operated valves shall be designed to be fail-safe if pneumatic or electric control power to the valve is lost during prelaunch operations.

12.7.4.8. Check valves shall be provided where back flow of fluids would create a hazard.

12.7.4.9. Special care shall be taken in the design of oxygen systems to minimize the heating effect due to rapid increases in pressure. Fast opening valves that can produce high velocity kinetic effects and rapid pressurization shall be avoided.

12.7.4.10. Valve stem travel on manual valves shall be limited by a positive stop at each extreme position.

12.7.4.11. The application or removal of force to the valve stem positioning device shall not cause disassembly of the pressure-containing structure of the valve.

12.7.5. Flight Hardware Pneumatic System Pressure Indicating Devices.

12.7.5.1. A pressure indicating device shall be located on the downstream side of each pressure regulator and on any storage system.

12.7.5.2. These pressure indicating devices shall be designed to be remotely monitored during prelaunch operations.

12.7.6. Flight Hardware Pneumatic System Flexible Hoses. Flexible hose requirements are specified in section **12.2.10.4**.

12.7.7. Flight Hardware Pneumatic System Pressure Relief Devices.

12.7.7.1. Pressure relief devices shall be installed on all systems having an on-board pressure source that can exceed the MAWP of any component downstream of that source unless the system is single fault tolerant against overpressurization during prelaunch operations.

12.7.7.2. Flight systems that require on-board pressure relief capability shall be designed to the following minimum requirements:

12.7.7.2.1. The pressure relief device shall be installed as close as is practical downstream of the pressure reducing device or source of pressure such as compressor and gas generator.

12.7.7.2.2. Pressure relief devices should be set to operate at a set pressure not to exceed 110% of the system MOP.

12.7.7.2.3. The relieving capacity of the relief device shall be equal to or greater than the maximum flow capability of the upstream pressure reducing device or pressure source and should prevent the pressure from rising more than 20% above the system MOP.

12.7.7.2.4. The relief device vent outlet piping shall be sized to prevent excessive back pressure from adversely affecting the function of the relief device.

12.7.7.2.5. All relief devices and associated piping shall be structurally restrained to minimize any thrust effects on the pressure system vessels or piping.

12.7.7.2.6. The effects of the discharge from relief devices shall be assessed and analyzed to ensure that operation of the device shall not be hazardous to personnel or equipment. Items to be analyzed are thrust loads, noise, impingement of high velocity gas or entrained particles, toxicity, oxygen enrichment, and flammability.

12.7.7.2.7. All pressure relief devices shall be vented separately unless the following can be positively demonstrated:

12.7.7.2.7.1. The creation of a hazardous mixture of gases in the vent system and the migration of hazardous substances into an unplanned environment is impossible.

12.7.7.2.7.2. The capacity of the vent system is adequate to prevent a pressure rise of more than 20% above MOP when all attached pressure relief devices are wide open and the system is at full pressure and volume generating capacity.

12.7.7.2.8. No obstructions shall be placed downstream of the relief device.

12.7.7.2.9. Relief devices shall be located so that other components cannot render them inoperative.

12.7.8. Flight Hardware Pneumatic System Vents.

12.7.8.1. Pressure systems shall be designed so that pressure cannot be trapped in any part of the system without vent capability.

12.7.8.2. Vent system outlets should be in a location normally inaccessible to personnel or shall be conspicuously identified.

12.7.8.3. Vent outlets shall be protected against rain intrusion and entry of birds, insects, and animals.

12.7.8.4. Oxidizer and fuel vent outlets to the atmosphere shall be separated sufficiently to prevent mixing of vented fluids.

12.7.8.5. All vent outlets shall be designed to prevent accumulation of vented gases in dangerous concentrations (oxygen rich) in areas frequented by unprotected personnel.

12.7.8.6. Hydrogen vents shall discharge to atmosphere through an approved burner.

12.7.8.7. Special attention shall be given to the design of vent line supports at vent outlets due to potential thrust loads.

12.7.8.8. Each line venting into a multiple-use vent system shall be protected against back pressurization by means of a check valve if the upstream system cannot withstand the back pressure or where contamination of the upstream system cannot be tolerated.

12.8. Flight Hardware Hydraulic System Design and Test Requirements . In addition to the following requirements, flight hardware hydraulic systems shall meet the minimum design fabrication and test requirements of sections **12.6.1** and **12.6.2**.

12.8.1. Flight Hardware Hydraulic System General Design Requirements.

12.8.1.1. Where necessary, hydraulic system low-points shall be provided a drain fitting (bleed ports) to allow draining of condensates or residue for safety purposes. **Note**: Entrapped air, moisture, and cleaning solvents are examples of foreign substances that may be hazardous to the system, component, or control equipment.

12.8.1.2. Bleed ports shall be located so that they can be operated without removal of other components and shall permit the attachment of a hose to direct the bleed off material into a container away from the positions of the operators.

12.8.1.3. Test points shall be provided on hydraulic systems so that disassembly for test is not required.

12.8.1.4. Test points shall be easily accessible for the attachment of ground test equipment.

12.8.1.5. For all power-generating components, pump pulsations shall be controlled to a level that does not adversely affect system tubing, components, and support installation.

12.8.1.6. Where system leakage can expose hydraulic fluid to potential ignition sources, fire resistant or flameproof hydraulic fluid shall be used.

12.8.2. Flight Hardware Hydraulic System Accumulators and Reservoirs. All accumulators and reservoirs that are pressurized with gas to pressures greater than 100 psig shall be designed IAW section **12.3**.

12.8.3. Flight Hardware Hydraulic System Pressure Indicating Devices.

12.8.3.1. A pressure indicating device shall be located on any pressurized storage system with a pressure greater than 100 psig.

12.8.3.2. These devices shall be designed to be remotely monitored during prelaunch operations.

12.8.4. Flight Hardware Hydraulic System Pressure Relief Devices.

12.8.4.1. Pressure relief devices shall be installed on all systems having an on-board pressure source that can exceed the MAWP of any component downstream of that source unless the system is single fault tolerant against overpressurization during prelaunch operations.

12.8.4.2. Flight systems that require on-board pressure relief capability shall meet the following minimum requirements:

12.8.4.2.1. The pressure relief device shall be installed as close as practical downstream of the pressure sources such as pumps, turbines, or gas generators.

12.8.4.2.2. Pressure relief devices shall be set to operate at a set pressure not to exceed 110% of the system MOP.

12.8.4.2.3. The relieving capacity of the relief device shall be equal to or greater than the maximum flow capability of the upstream pressure source and should prevent the pressure from rising more than 20% above the system MOP.

12.8.4.2.4. The effects of discharge from relief devices shall be assessed and analyzed to ensure that operation of the device shall not be hazardous to personnel or equipment. Items to be analyzed include thrust loads, toxicity, combustibility, flammability, and others as necessary.

12.8.4.2.5. Relief devices shall be located so that other components cannot render them inoperative.

12.8.4.2.6. No obstructions shall be placed downstream of the relief valve or burst disk outlet.

12.8.5. Flight Hardware Hydraulic System Vent and Drain Systems. Hydraulic systems shall be designed so that pressure and fluids cannot be trapped in any part of the system without vent and/or drain capability.

12.8.6. Testing Flight Hardware Hydraulic System Components Before Assembly. All system elements pressurized with gas to pressures greater than 100 psig shall be qualification tested IAW paragraph **12.3.4.1** and acceptance tested IAW sections **12.3.4.2** and **12.6.1.17.1**.

12.8.7. Testing Flight Hardware Hydraulic Systems After Assembly.

12.8.7.1. Tests shall meet the requirements of paragraph **12.6.1.17.2**.

12.8.7.2. Leak tests shall meet the requirements of section **12.6.1.17.3**.

12.8.7.3. System validation and functional tests shall meet requirements of section **12.6.1.17.4**.

12.8.7.4. Modified and repaired flight hardware shall meet the requirements of section **12.6.1.17.6**.

12.9. Flight Hardware Hypergolic Propellant System Design and Test Requirements.

12.9.1. Flight Hardware Hypergolic Propellant System General Design Requirements.

12.9.1.1. Propellant systems shall have low point drain capability unless designed for positive pressure purging.

12.9.1.2. Low point drains shall be accessible and located in the system to provide the capability of removing propellant from the tanks, piping, lines, and components at all times after loading.

12.9.1.3. Propellant systems shall be designed to be flushed with compatible fluids and purged with inert gas.

12.9.1.4. For prelaunch failure modes that could result in a time-critical emergency, provision shall be made for automatic switching to a safe mode of operation. Caution and warning signals shall be provided for these time-critical functions.

12.9.1.5. Propellant systems shall also comply with the pneumatic system requirements of section **12.7.**

12.9.1.6. Items used in any fuel or oxidizer system shall not be interchanged after exposure to the respective media.

12.9.1.7. Bi-propellant systems shall have the capability of loading and/or unloading the fuel and oxidizer one at a time.

12.9.1.8. Propellant (liquid or gas) migration into an associated pneumatic system shall be controlled. **Note**: The pneumatic system should be compatible with all of the propellants served by the pneumatic supply.

12.9.2. Flight Hardware Hypergolic Propellant System Piping and Tubing.

12.9.2.1. NPT connectors and fittings shall not be used in hypergolic system piping and tubing.

12.9.2.2. Socket weld flanges shall not be used in hypergolic system piping.

12.9.2.3. All pipe and tube welded joints shall be 100% radiographically inspected before and after the acceptance pressure test and inspected by surface NDE techniques before and after the pressure test.

12.9.3. Flight Hardware Hypergolic Propellant System Valves.

12.9.3.1. Valve actuators shall be operable under maximum design flow and pressure.

12.9.3.2. Flow control valves shall be designed to be fail-safe if pneumatic or electric control power is lost during prelaunch operations.

12.9.3.3. Check valves shall be provided where back flow of fluids would create a hazard.

12.9.3.4. Valve connectors and connections shall be designed, selected, or located, or, as a last resort, marked to prevent connection to an incompatible system.

12.9.3.5. Remotely controlled valves shall provide for remote monitoring of open and closed positions during prelaunch operations. Monitoring of remotely controlled, pyrotechnically operated valve open and closed positions shall not be required if the function power is deenergized (i.e., an additional fourth inhibit is in place between the power source and the three required inhibits) and the control circuits for the three required inhibits are disabled. In other words, no single failure in the control circuitry will result in the removal of an inhibit until the hazard potential no longer exists.

12.9.3.6. All electrical control circuits for remotely actuated valves shall be shielded or otherwise protected from hazardous stray energy.

12.9.3.7. Designs using uncontained seats are prohibited.

12.9.3.8. Valves that are not intended to be reversible shall be designed or marked so that they cannot be connected in a reverse mode.

12.9.3.9. Manually operated valves shall be designed so that overtorquing the valve stem cannot damage soft seats to the extent that seat failure occurs.

12.9.3.10. Valve stem travel on manual valves shall be limited by a positive stop at each extreme position.

12.9.3.11. The application or removal of force to the stem positioning device shall not cause disassembly of the pressure containing structure of the valve.

12.9.3.12. All electromechanical actuator electric wiring shall be sealed to prevent fluid ignition.

12.9.4. Flight Hardware Hypergolic Propellant System Pressure Indicating Devices.

12.9.4.1. A pressure indicating device shall be located on any storage vessel and on any section of the system where pressurized fluid can be trapped.

12.9.4.2. These pressure indicating devices shall be designed to be remotely monitored during prelaunch operations.

12.9.5. Flight Hardware Hypergolic Propellant System Flexible Hoses. Flexible hose requirements are specified in section **12.2.10.4** in addition to the following:

12.9.5.1. Flexible hoses shall consist of a flexible inner pressure carrier tube (compatible with the service fluid). This tube shall be constructed of elastomeric (typically poly-tetrafluoroethylene [PTFE]) or corrugated metal (typically 300 series stainless steel) material reinforced by one or more layers of 300 series stainless steel wire and/or fabric braid. **Note**: In applications where stringent permeability and leakage requirements apply, hoses with a metal inner pressure carrier tube should be used. Where these hoses are used in a highly corrosive environment, consideration should be given to the use of Hastalloy C-22 in accordance with ASTM B575 for the inner pressure carrier tube and C-276 material for the reinforcing braid.

12.9.5.2. Hose shall be dedicated to a service media. Interchanging of flexible hoses used in incompatible service media, such as hypergolics, shall be avoided. Permeation is not totally negated by the cleaning process.

12.9.6. Flight Hardware Hypergolic Propellant System Pressure Relief Devices.

12.9.6.1. Pressure relief devices shall be installed on all systems having an on-board pressure source that can exceed the MAWP or MEOP of any component downstream of that source unless the system is single fault tolerant against overpressurization during prelaunch operation.

12.9.6.2. Flight systems that require on-board pressure relief capability shall be designed to the following minimum requirements:

12.9.6.2.1. The pressure relief device shall be installed as close as is practical downstream of the pressure reducing device or source of pressure such as a compressor or gas generator.

12.9.6.2.2. Pressure relief devices should be set to operate at a set pressure not to exceed 110% of the system MOP/MEOP.

12.9.6.2.3. The relieving capacity of the relief device shall be equal to or greater than the maximum flow capability of the upstream pressure reducing device or pressure source and should prevent the pressure from rising more than 20% above the system MOP/MEOP.

12.9.6.3. The relief device vent outlet piping shall be sized to prevent excessive back pressure from adversely affecting the relief device function.

12.9.6.4. All relief devices and associated piping shall be structurally restrained to minimize any thrust effects to the pressure system vessels or piping.

12.9.6.5. The effects of the discharge from relief devices shall be assessed and analyzed to ensure that operation of the device shall not be hazardous to personnel or equipment. Items to be analyzed are thrust loads, toxicity, combustibility, flammability, and others as deemed necessary by Wing Safety.

12.9.6.6. All pressure relief devices shall be vented separately unless the following criteria can be positively demonstrated:

12.9.6.6.1. The creation of a hazardous mixture of gases in the vent system and the migration of hazardous substances into an unplanned environment is impossible.

12.9.6.6.2. The capacity of the vent system is adequate to prevent a pressure rise more than 20% above MOP when all attached pressure relief devices are wide open and the system is at full pressure and volume generating capacity.

12.9.6.7. No obstructions shall be placed downstream of the relief device.

12.9.6.8. Relief devices shall be located so that other components cannot render them inoperative.

12.9.7. Flight Hardware Hypergolic Propellant Vent Systems.

12.9.7.1. All vent effluent resulting from routine operations shall be scrubbed and/or incinerated before venting to the atmosphere through vent stacks.

12.9.7.2. Hypergolic systems shall be designed so that vapors or liquids cannot be trapped in any part of the system without vent and/or drain capability.

12.9.7.3. Vent system outlets shall be in a location normally inaccessible to personnel and shall be conspicuously identified.

12.9.7.4. Vent outlets shall be protected against rain intrusion and entry of birds, insects, and animals.

12.9.7.5. Oxidizer and fuel vent outlets to the atmosphere shall be separated sufficiently to prevent mixing of vented fluids.

12.9.7.6. Special attention shall be given to the design of vent line supports at vent outlets due to potential thrust loads.

12.9.7.7. Each line venting into a multiple-use vent system shall be protected against back pressurization by means of a check valve if the upstream system cannot withstand the back pressure or where contamination of the upstream system cannot be tolerated.

12.9.7.8. Pressure relief vents shall be designed and located so that vapors cannot enter any inhabited areas.

12.9.7.9. Incompatible fluids shall not be discharged into the same vent or drain system.

12.9.7.10. Fuel and oxidizer vent systems shall be equipped with a means of purging the system with an inert gas to prevent explosive mixtures.

12.9.8. Testing Flight Hardware Hypergolic Propellant System Components Before Assembly.

12.9.8.1. All systems elements shall be qualification tested IAW section **12.3.2.6** and acceptance tested IAW sections **12.3.2.7** and **12.6.1.17.1**.

12.9.8.2. Pneumatic proof testing to a proof pressure of 1.25 times MOP/MEOP (not to exceed MAWP) is permissible only if hydrostatic proof testing is impractical, impossible, or jeopardizes the integrity of the system or system element. Prior approval for pneumatic proof testing at the ranges shall be obtained from Wing Safety.

12.9.8.3. All hypergolic valves shall be tested for both internal and external leakage at their MAWP.

12.9.8.3.1. No external leakage is allowed. Valves shall be visually bubble tight, using approved soap solution and techniques. Internal leakage of valves shall not exceed limits specified in the valve performance specification.

12.9.8.3.2. Certain critical system components may require helium leak checks using a mass spectrometer detector to verify leak rates do not exceed 1 x 10^{-6} cc/sec of helium gas at standard temperature and pressure (STP).

12.9.9. Testing Flight Hardware Hypergolic Propellant Systems After Assembly. All newly assembled propellant pressure systems shall meet the test requirements of paragraph **12.6.1.17.2** after assembly.

12.9.9.1. Flight Hardware Hypergolic Propellant System Leak Tests.

12.9.9.1.1. Pneumatic leak testing at system MOP/MEOP of all completely assembled and cleaned vessel pipe and tubing sections, with components installed, shall be completed before introduction of propellant.

12.9.9.1.2. Minimum test requirements are as follows:

12.9.9.1.2.1. Test gas should use a minimum volume of 10% helium.

12.9.9.1.2.2. All mechanical joints such as gasket joints, seals, and threaded joints and weld seams shall be visually bubble tight, using approved soap solution and techniques.

12.9.9.1.2.3. The functional validity of installed block valves should be checked by incrementally venting downstream sections and pinhole leak checking. This test shall be conducted at the ranges unless prior approval from Wing Safety has been obtained.

12.9.9.1.3. When required, alternate methods of leak testing such as the use of portable mass spectrometers may be specified on a case-by-case basis.

12.9.9.2. Flight Hardware Hypergolic Propellant System Validation and Functional Tests. All newly assembled pressure systems shall meet the system validation and functional testing requirements of section **12.6.1.17.4**.

12.9.9.3. Flight Hardware Hypergolic Propellant Systems Bonding and Grounding. All newly assembled pressure systems shall meet the bonding and grounding requirements of section **12.2.12**.

12.9.10. Testing Modified and Repaired Flight Hardware Hypergolic Propellant Systems. Modified and repaired flight hardware propellant systems shall meet the test requirements of section **12.6.1.17.6**.

12.10. Flight Hardware Cryogenic Systems Design and Test Requirements.

12.10.1. Flight Hardware Cryogenic System General Design Requirements.

12.10.1.1. Propellant systems shall have low point drain capability.

12.10.1.1.1. Low point drains shall be accessible and located in the system to provide the capability of removing propellant from the tanks, piping, lines, and components.

12.10.1.1.2. In addition, the cryogenic fuel system shall be designed to be purged with inert fluids.

12.10.1.2. Bi-propellant systems shall have the capability of loading the fuel and oxidizer one at the time.

12.10.1.3. For prelaunch failure modes that could result in a time-critical emergency, provision shall be made for automatic switching to a safe mode of operation. Caution and warning signals shall be provided for these time-critical functions.

12.10.1.4. Pneumatic systems servicing cryogenic systems shall comply with the pneumatic pressure system requirements of section **12.7**.

12.10.1.5. Cryogenic systems shall be designed to control liquefaction of air.

12.10.1.6. For systems requiring insulation, nonflammable materials shall be used in compartments or spaces where fluids and/or vapors could invade the area.

12.10.1.7. Vacuum-jacketed systems shall be capable of having the vacuum verified.

12.10.1.8. Purge gas for LH2 and cold GH2 lines should be gaseous helium (GHe).

12.10.1.9. Precautions shall be taken to prevent cross-mixing of media through common purge lines by use of check valves to prevent back flow from a system into a purge distribution manifold.

12.10.1.10. Titanium and titanium alloys shall not be used where exposure to GOX (cryogenic) or LOX is possible.

12.10.2. Flight Hardware Cryogenic System Vessels and Tanks. Cryogenic vessels and tanks shall be designed IAW the requirements in section **12.3**.

12.10.3. Flight Hardware Cryogenic System Piping and Tubing.

12.10.3.1. The amount and type of thermal insulation (insulation material or vacuum-jacketed) shall be determined from system thermal requirements.

12.10.3.2. The use of slip-on flanges shall be avoided.

12.10.3.3. Flanged joints in LH2 systems shall be seal welded.

12.10.3.4. Flanged joint gaskets shall not be reused.

12.10.3.5. Cryogenic systems shall provide for thermal expansion and contraction without imposing excessive loads on the system. **Note**: Bellows, reactive thrust bellows, or other suitable load relieving flexible joints may be used.

12.10.3.6. All pipe and tube welds shall be 100% radiographically inspected before and after the acceptance proof test. The accept/reject criteria shall be submitted to Wing Safety for review and approval.

12.10.4. Flight Hardware Cryogenic System Valves.

12.10.4.1. Cryogenic systems shall be designed to ensure icing does not render the valve inoperable.

12.10.4.2. Remotely controlled valves shall provide for remote monitoring of the open and closed positions.

12.10.4.3. Remotely operated valves shall be designed to be fail-safe if pneumatic or electric control power is lost during prelaunch operations.

12.10.4.4. All electrical control circuits for remotely actuated valves shall be shielded or otherwise protected from hazardous stray energy.

12.10.4.5. Manually operated valves shall be designed so that overtorquing the valve stem cannot damage seats to the extent that seat failure occurs.

12.10.4.6. Valve stem travel on manual valves shall be limited by a positive stop at each extreme position.

12.10.4.7. The application or removal of force to the stem positioning device shall not cause disassembly of the pressure containing structure of the valve.

12.10.4.8. Manual or remote valve actuators shall be operable under maximum design flow and pressure.

12.10.4.9. Valves that are not intended to be reversible shall be designed or marked so that they cannot be connected in a reverse mode.

12.10.4.10. Stem position local or remote indicators shall sense the position of the stem directly, not the position of the actuating device.

12.10.4.11. All electromechanical actuator electrical wiring shall be sealed to prevent fluid ignition.

12.10.5. Flight Hardware Cryogenic System Pressure Indicating Devices.

12.10.5.1. A pressure indicating device shall be located on any cryogenic vessel and/or tank and on any section of the system where cryogenic liquid can be trapped.

12.10.5.2. These pressure indicating devices shall be designed to be remotely monitored during prelaunch operations.

12.10.6. Flight Hardware Cryogenic System Flexible Hoses. Flexible hose requirements are specified in section **12.2.10.4** in addition to the following:

12.10.6.1. Flexible hoses used in cryogenic system shall be of the single-wall, double-wall, or double-wall, vacuum-jacketed type.

12.10.6.2. All convoluted portions of flexible hoses shall be covered with stainless steel wire band.

12.10.7. Flight Hardware Cryogenic System Pressure Relief Devices.

12.10.7.1. All cryogenic vessels and tanks shall be protected against overpressure by means of at least one pressure relief valve.

12.10.7.2. Minimum design requirements are as follows:

12.10.7.2.1. The pressure relief device shall be installed as close as practical to the cryogenic vessel or tank.

12.10.7.2.2. Pressure relief valves shall be set to operate at set pressures determined on a case-by-case basis by the Range User.

12.10.7.2.3. The relieving capacity of the relief valve shall be determined on a case-by-case basis by the Range User.

12.10.7.3. All pressure relief devices shall be vented separately unless the following can be positively demonstrated:

12.10.7.3.1. The creation of a hazardous mixture of gases in the vent system and the migration of hazardous substances into an unplanned environment is impossible.

12.10.7.3.2. The capacity of the vent system is adequate to prevent a pressure rise more than 20% above MOP when all attached pressure relief devices are wide open and the system is at full pressure and volume generating capacity.

12.10.7.4. All relief devices and associated piping shall be structurally restrained to eliminate any deleterious thrust effects on cryogenic system vessels or piping.

12.10.7.5. The effects of the discharge from relief devices shall be assessed and analyzed to ensure that operation of the device shall not be hazardous to personnel or equipment. **Note**: Items to be analyzed are thrust loads, impingement of high velocity gas or entrained particles, toxicity, oxygen enrichment, and flammability.

12.10.7.6. No obstructions shall be placed downstream of the relief valves.

12.10.7.7. Relief valves shall be located so that other components cannot render them inoperative.

12.10.8. Flight Hardware Cryogenic System Vents.

12.10.8.1. GH2 shall be vented to atmosphere through a burner system.

12.10.8.2. Cryogenic systems shall be designed so that fluids cannot be trapped in any part of the system without drain or vent (relief valve or vent valve) capability.

12.10.8.3. Each line venting into a multiple-use vent system shall be protected against back pressurization by a check valve if the upstream system cannot withstand the back pressure or where contamination of the upstream system cannot be tolerated.

12.10.8.4. Vents shall be placed in a location normally inaccessible to personnel and at a height or location where venting is not normally deposited into habitable spaces.

12.10.8.5. Each vent shall be conspicuously identified using appropriate warning signs, labels, and markings.

12.10.8.6. Vent outlets shall be located far enough away from incompatible propellant systems and incompatible materials to ensure no contact is made during vent operations.

12.10.8.7. Incompatible fluids shall not be discharged into the same vent or drain system.

12.10.8.8. Fuel vent systems shall be equipped with a means of purging the system with an inert gas to prevent explosive mixtures.

12.10.8.9. Vent outlets shall be protected against rain intrusion and entry of birds, insects, and animals.

12.10.8.10. Special attention shall be given to the design of vent line supports at vent outlets due to potential thrust loads.

12.10.9. Testing Flight Hardware Cryogenic System Components Before Assembly.

12.10.9.1. All cryogenic vessels and tanks shall be qualification tested IAW section **12.3.2.6** and acceptance tested IAW section **12.3.2.7**.

12.10.9.2. Flight hardware cryogenic system components shall meet the test requirements of section **12.6.1.17.1** before assembly.

12.10.10. Testing Flight Hardware Cryogenic Systems After Assembly.

12.10.10.1. Flight hardware cryogenic systems shall meet the test requirements of paragraph **12.6.1.17.2** after assembly.

12.10.10.2. All newly assembled cryogenic systems shall be leak tested.

12.10.10.3. The system shall be pressurized to the system MOP using gaseous helium for LH2 systems and GN2 for LOX systems.

12.10.10.4. Following the leak test, all newly assembled cryogenic systems shall have a system validation test performed at system MOP before first operational use at the ranges.

12.10.10.5. Minimum test requirements are as follows:

12.10.10.5.1. The intended service fluid (LO2, LH2) shall be used as the validation test fluid.

12.10.10.5.2. The functional capability of all components and subsystems shall be validated.

12.10.10.5.3. All prelaunch operational sequences for the system shall be exercised, including emergency shutdown, safing, and unloading procedures.

12.10.10.5.4. Vacuum readings of all vacuum volumes shall be taken and recorded before, during, and after the test.

12.10.10.5.5. No deformation, damage, or leakage is allowed.

12.10.11. Testing Modified and Repaired Flight Hardware Cryogenic Systems.

12.10.11.1. Any cryogenic system element, including fittings or welds, which has been repaired, modified, or possibly damaged before the system leak test shall be retested.

12.10.11.2. The component retest sequence shall be as follows:

12.10.11.2.1. The component shall be hydrostatically proof tested at ambient temperature to 1.5 times the component MOP/MEOP (not to exceed MAWP).

12.10.11.2.2. The component shall be reinstalled into the cryogenic system and a leak check performed at system MOP or MEOP.

12.10.11.2.3. The functional capability of the modified and/or repaired component shall be revalidated using the intended service fluid at system MOP or MEOP.

12.10.11.3. If any cryogenic system elements such as valves, regulators, gauges, or pipes have been disconnected or reconnected for any reason, the affected connection shall be leak checked at MOP.

12.11. Flight Hardware Pressure Systems Data Requirements.

12.11.1. General. The minimum data required to certify compliance with the design, analysis, and test requirements of this chapter are described below.

12.11.1.1. Data required by sections **12.11.2** through **12.11.5** shall be incorporated into the MSPSP or submitted as a separate package when appropriate.

12.11.1.2. Data required by sections **12.11.2** through **12.11.6** shall be placed in a system certification file that shall be to be maintained and updated by the hazardous pressure system operator.

12.11.1.3. This data shall be reviewed and approved by Wing Safety before the first operational use of hazardous pressure systems at the ranges.

12.11.2. Flight Hardware Pressure System General Data Requirements. The following general flight hardware pressure systems data is required:

12.11.2.1. Hazard analysis of hazardous pressure systems IAW a jointly tailored SSPP. (See Volume 1, Attachment 3.)

12.11.2.2. A material compatibility analysis shall be performed IAW the requirements specified in sections **12.2.13** and **12.2.16**.

12.11.2.3. General flight hardware pressure systems data shall be submitted IAW Attachment 2, **A2.2.4.7.1**.

12.11.3. Flight Hardware Pressure System Design Data Requirements. Flight hardware pressure system design data shall be provided IAW Attachment 2, **A2.2.4.7.2**.

12.11.4. Flight Hardware Pressure System Component Design Data.

12.11.4.1. Identification of each component with a reference designation permitting cross-reference with the system schematic.

12.11.4.2. MAWP for all pressure system components and the MOP the component will see when installed in the system.

12.11.4.3. Safety factors or design burst pressure for all pressure system components and identification of actual burst pressures, if available.

12.11.4.4. Proof pressure for each system component and identification of the proof pressure the component will see after installation in the system, if applicable.

12.11.4.5. Materials used in the fabrication of each element within the component including soft goods and other internal elements.

12.11.4.6. Cycle limits if fatigue is a factor of the component.

12.11.4.7. Temperature limits of each system component.

12.11.4.8. Component information shall be placed in tables.

12.11.5. Flight Hardware Pressure System Test Procedures and Reports.

12.11.5.1. All test plans, test procedures and test reports required by this chapter shall be submitted to Wing Safety for review and approval.

12.11.5.2. A list and synopsis of all hazardous pressure system test procedures shall be submitted to Wing Safety for review and approval.

12.11.6. Flight Hardware Pressure System Certification Files.

12.11.6.1. Certification files shall be maintained and updated by the hazardous pressure system operator.

12.11.6.2. These files shall be located at the ranges.

12.11.6.3. The certification file for each hazardous pressure system shall contain the data required in sections **12.11.1** through **12.11.5** in addition to the following:

12.11.6.3.1. As applicable, stress, safe-life, fatigue, and fracture mechanics analysis IAW sections **12.2.5.3**, **12.2.5.4**, and **12.2.5.5**.

12.11.6.3.2. Specification drawings and documents for all components.

12.11.6.3.3. If necessary, a cross-sectional assembly drawing of the component to assess the safety aspects of the internal elements.

12.11.6.3.4. Certification that welding and weld NDE meet applicable standards and have been performed by certified personnel.

12.11.6.3.5. Qualification and acceptance test plans and test reports.

12.11.6.3.6. Certification documentation describing how pressure systems, vessels, and pressurized structures are designed, fabricated, and tested IAW sections **12.2**, **12.3**, and **12.4**, as applicable.

12.11.6.3.7. Certification that all components, including pipe and tube fittings, have successfully passed a hydrostatic proof test.

Chapter 13

ORDNANCE SYSTEMS.

13.1. Ordnance Hazard Classification.

13.1.1. Ordnance General Classification.

13.1.1.1. Ordnance items shall be assigned the appropriate DoD and United Nations (UN) hazard classification and storage compatibility group in accordance with DESR 6055.09.

13.1.1.2. Items that have not previously been classified and cannot be classified based on similarity with previously classified items shall be tested in accordance with AFTO 11A-1-47/ (NAVSEAINST 8020.3/TB700-2/DLAR 8220.1), *Explosive Hazard Classification Procedures*, and classified accordingly.

13.1.1.3. Ordnance items shall also have a DOT classification. The Range User is responsible for obtaining DOT classification.

13.1.1.4. The Range User shall provide the DoD and DOT documentation demonstrating proper classification to Wing Safety for review and approval before delivering ordnance to the ranges.

13.2. Ordnance System General Requirements. All the remaining parts of this chapter establish the design requirements for hazardous ordnance and ordnance systems during transportation, handling, storage, installation, testing, and connection on the ranges. Hazard division 1.4S ordnance and ordnance systems, considered as articles that present no significant hazard, do not have to meet the design requirements identified in this chapter; however, they shall meet the operational requirements identified in Volume 6 of this publication.

13.2.1. Ordnance Subsystem Identification. Ordnance systems include the following subsystems. All of these subsystems are subject to the design requirements described below.

13.2.1.1. Power Source. The firing power source may be a battery, power bus, or a capacitor.

13.2.1.2. Firing Circuit (the path between the firing power source that initiates the ordnance and the initiating device). The firing circuit includes the electrical path or the optical path for laser initiated ordnance.

13.2.1.3. Control Circuit. The control circuit activates and deactivates the safety devices in the firing circuit.

13.2.1.4. Monitor Circuit. The monitor circuit monitors status of the firing circuits.

13.2.1.5. Initiating Device. The initiating device converts electrical, mechanical, or optical energy into explosive energy.

13.2.1.6. Receptor Ordnance. Receptor ordnance includes all ordnance items such as the explosive transfer system (ETS), separation charge, explosive bolt installed downstream of the initiating devices.

13.2.2. Ordnance devices and systems shall be designed to preclude inadvertent firing of any explosive or pyrotechnic components when subjected to environments such as shock, vibration, and static electricity encountered during ground processing.

13.2.3. A FMECA shall be performed on all ordnance systems.

13.3. Ordnance Electrical and Optical Circuits.

13.3.1. General Design Requirements.

13.3.1.1. Ordnance system circuitry shall be protected to preclude energy sources such as electromagnetic energy or stray light from the ranges and/or launch vehicle from causing undesired output of the system. **Note**: Solutions for protection of ordnance system circuitry include shielding, filtering, grounding, and other isolation techniques that can preclude the energy sources such as electromagnetic energy or stray light from the range and/or launch vehicle from causing undesired output of the system.

13.3.1.2. Hazardous ordnance systems shall be designed so that the initiating devices can be installed in the system just before final electrical and/or optical hookup on the launch pad. **Note**: It is understood that the requirement for designing ordnance so that the initiating devices can be installed in the system just before final electrical and/or optical hookup on the launch pad cannot always be met. Exceptions are handled on a case-by-case basis where the Range User has demonstrated compliance with the intent.

13.3.1.2.1. Initiating device locations shall be accessible to facilitate installation and removal and electrical and/or optical connections as late as possible in the launch countdown.

13.3.1.2.2. Launch complexes shall be designed to accommodate this accessibility requirement.

13.3.1.3. Separate power sources and/or busses are required for ordnance initiating systems.

13.3.1.4. RF energy shall not be used to ignite initiating devices.

13.3.1.5. Electrical firing circuits shall be isolated from the initiating ordnance case, electronic case, and other conducting parts of the vehicle.

13.3.1.5.1. If a circuit is grounded, there shall be only one interconnection (single ground point) with other circuits. Static bleed resistors of 10 kilo-ohms to 100 kilo-ohms are not considered to violate the single point ground.

13.3.1.5.2. This interconnection shall be at the power source only.

13.3.1.5.3. Other ground connections with equivalent isolation shall be handled on a case-by-case basis.

13.3.1.6. Ungrounded circuits capable of building up static charge shall be connected to the structure by static bleed resistors of between 10 kilo-ohms and 100 kilo-ohms.

13.3.1.7. Firing circuit design shall preclude sneak circuits and unintentional electrical paths due to such faults as ground loops and failure of solid state switches.

13.3.1.8. Redundant circuits are required if loss of power or signal may result in injury to personnel or be a detriment to safety critical systems.

13.3.1.9. The elements of a redundant circuit shall not be terminated in a single connector where the loss of such connector will negate the redundant feature. **Note**: Redundant circuits should be separated to the maximum extent possible.

13.3.2. Shielding.

13.3.2.1. Shields shall not be used as intentional current-carrying conductors.

13.3.2.2. Electrical firing circuits shall be completely shielded or shielded from the initiating ordnance or laser firing unit (LFU) back to a point in the firing circuit at which filters or absorptive devices eliminate RF entry into the shielded portion of the system.

13.3.2.3. RF shielding shall provide a minimum of 85% of optical coverage ratio. **Note**: Optical coverage ratio is the percentage of the surface area of the cable core insulation covered by a shield. A solid shield rather than a mesh shield would have 100% coverage.

13.3.2.4. There shall be no gaps or discontinuities in the termination at the back faces of the connectors or apertures in any container that houses elements of the firing circuit.

13.3.2.5. Electrical shields terminated at a connection shall be joined around the full 360 degree circumference of the shield.

13.3.2.6. All metallic parts of the initiating ordnance subsystem that are physically connected shall be bonded with a DC resistance of less than 2.5 milliohms.

13.3.2.7. Firing, control, and monitor circuits shall all be shielded from each other.

13.3.3. Wiring.

13.3.3.1. Twisted shielded pairs shall be used unless other configurations such as coaxial leads can be shown to be more effective.

13.3.3.2. For low voltage circuits, insulation resistance between the shield and conductor at 500 VDC minimum shall be greater than 2 megaohms.

13.3.3.3. For high voltage circuits, insulation resistance between the shield and conductor at 150% of rated output voltage or 500 volts, whichever is greater, shall be greater than 50 megaohms.

13.3.3.4. Wires shall be of sufficient size to adequately handle 150% of the design load for continuous duty signals (100 seconds or more) on the safety critical circuit.

13.3.3.5. Splicing of firing circuit wires or overbraid shields is prohibited.

13.3.3.6. The use of wire wrap to connect wire shields is prohibited.

13.3.4. Connectors.

13.3.4.1. The outer shells of electrical connectors shall be made of metal.

13.3.4.2. Electrical and optical connectors shall be selected to eliminate the possibility of mismating. Mismating includes improper installation as well as connecting wrong connectors.

13.3.4.3. Electrical and optical connectors shall be of the self-locking type or lock wiring shall be used to prevent accidental or inadvertent demating.

13.3.4.4. The design shall ensure that the shielding connection for an electrical connector is complete before the pin connection.

13.3.4.5. Shields need not be carried through a connector if the connector can provide RF attenuation and electrical conductivity at least equal to that of the shield.

13.3.4.6. Circuit assignments and the isolation of firing pins within an electrical connector shall be so that any single short circuit occurring as a result of a bent pin shall not result in more than 10% of the no-fire current. Unless otherwise agreed to by Wing Safety, a bent pin analysis shall be performed on all electrical connectors.

13.3.4.7. There shall be only one wire per pin and in no case shall an electrical connector pin be used as a terminal or tie-point for multiple connections.

13.3.4.8. Spare pins are allowed in electrical connectors except where a broken spare pin may have an adverse effect on a firing or control circuit.

13.3.4.9. Source circuits shall terminate in an electrical connector with female contacts.

13.3.4.10. Electrical connectors shall not rely on spring force to mechanically lock mating halves together if they are to be used on safety critical circuits.

13.3.4.11. Electrical connectors shall be capable of adequately handling 150% of the designed electrical load continuous duty signal (100 seconds or more) on safety critical circuits.

13.3.4.12. Optical connectors and receptacles shall be provided with self-locking protective covers or caps that shall be installed except when the connector or receptacle is in use.

13.3.4.13. Separate cables and connectors shall be used when redundant circuits are required.

13.3.5. Switches and Relays.

13.3.5.1. Switches and relays shall be designed to function at expected operating voltage and current ranges under worst case ground environmental conditions, including maximum expected cycle life.

13.3.5.2. Switches and relays used for inhibits shall not be considered adequate for RF isolation and absorption unless demonstrated by analysis and test for the specific environment of use.

13.3.6. Monitoring, Checkout, and Control Circuits.

13.3.6.1. All circuits used to arm or disarm the firing circuit shall contain means to provide remote electrical indication of their armed or safe status.

13.3.6.1.1. These inhibits shall be directly monitored.

13.3.6.1.2. GSE shall be provided to electrically monitor arm and safe status of the firing circuit at all processing facilities including launch complexes up to launch.

13.3.6.2. Monitoring, control, and checkout circuits shall be completely independent of the firing circuits and shall use a separate and non-interchangeable electrical connector.

13.3.6.3. Monitoring, control, and checkout circuits shall not be routed through arm or safe plugs.

13.3.6.4. The electrical continuity of one status circuit (safe or arm) shall completely break before the time that electrical continuity is established for the other status circuit (arm or safe).

13.3.6.5. The safety of the ordnance system shall not be affected by the external shorting of a monitor circuit or by the application of any positive or negative voltage between 0 and 35 volts DC to a monitor circuit.

13.3.6.6. Monitoring and checkout of current in a low voltage electroexplosive system firing line shall not exceed 1/10 the no-fire current of the EED or 50 milliamperes, whichever is less.

13.3.6.7. Monitor circuits shall be designed so that the application of the operational voltage will not compromise the safety of the firing circuit nor cause the ordnance system to be armed.

13.3.6.8. Tolerances for monitor circuit outputs shall be compatible with the tolerances specified for the Wing Safety required parameter to be verified. Tolerances for monitor circuit outputs shall be specified for both RF and hardline.

13.3.6.9. Maximums and minimums for monitor circuit outputs shall be specified.

13.3.6.10. No single point failure in monitoring, checkout, or control circuitry and equipment shall compromise the safety of the firing circuit.

13.3.6.11. Firing circuits that do not share a common fire command shall be electrically isolated from one another so that current in one firing circuit does not induce a current greater than 20 dB below the no-fire current in any firing output circuit. Control circuits shall be electrically isolated so that a stimulus in one circuit does not induce a stimulus greater than 20 dB below the activation level in any firing circuit.

13.3.6.12. The monitor circuit that applies current to the EED shall be defined to limit the open circuit output voltage to 1 volt.

13.4. Initiator Electrical and Optical Circuits.

13.4.1. Electrical and Optical Low Voltage Electromechanical Circuits Design Requirements.

13.4.1.1. All solid rocket motor ignition circuits and other high hazard ordnance systems (as determined by Wing Safety) using low voltage initiators shall provide a minimum of three independent inhibits. **Note**: The term high hazard refers to specific catastrophic events such as the inadvertent firing of a solid rocket motor or actuation of a destruct system that could result in multiple fatalities, typically threatening more than just the ordnance technicians handling the hazardous item, and/or "total" destruction of high value hardware such as the payload, launch vehicle, or facility.

13.4.1.2. EED ordnance systems other than solid rocket motor ignition circuits and other high hazard ordnance systems shall provide a minimum of 2 independent inhibits. At least one inhibit shall be a mechanical device like a safing plug. Any alternative not including such a mechanical device requires Wing Safety approval.

Table 13.1. Clarification on Valid and Independent Inhibits.

A key consideration in providing inhibits in an ordnance circuit is that they be both valid and independent. Valid means the inhibits reside in the direct current path for firing the EED, not in the control circuit used to change the status of an inhibit. For example, if your two-inhibit compliance approach is to close two control circuit relays to close a single firing line relay, you are not compliant because you do not have two valid inhibits. In other words, the single firing line relay is the only inhibit. Independent means a singular action to remove a singular inhibit. You can have two inhibits; for example, two open relays in a firing line. However, if a single command removes both inhibits, (for example, closes both relays), then the inhibits are not independent. In other words, you do not have two independent inhibits. A concept that is often overlooked is that inhibits are not independent if a single failure can negate both inhibits.

13.4.1.3. The safe plug shall provide interruption of the circuit after the “enable” and “fire” switches and as close to the end item ordnance as possible.

13.4.1.4. The final electrical connection of an EED to the firing circuit shall be as close to the EED as possible.

13.4.1.5. EEDs shall be protected from electrostatic hazards by the placement of resistors from line-to-line and line-to-ground (structure). The placement of line-to-structure static bleed resistances is not considered to violate the single point ground requirement as long as the parallel combination of these resistors are 10 kilo-ohms or more.

13.4.1.6. The system circuitry shall be designed and/or located to limit RF power at each EED (produced by range and/or vehicle transmitter) to a level at least 20 dB below the pin-to-pin DC no-fire power of the EED. **Note**: Electromagnetic environment evaluation should either be by analysis or electromagnetic compatibility (EMC) testing. RF power density levels for range facilities are available from Wing Safety.

13.4.2. High Voltage Exploding Bridgewire (EBW) and Explosive Foil Initiator (EFI) Circuits.

13.4.2.1. Launch vehicles and payloads using EBW or EFI systems shall include an EBW-firing unit (EBW-FU) or an electronic safe-and-arm-device firing unit (ESAD-FU).

13.4.2.2. A manual arming and safing plug may also be required depending on the degree of hazard and confidence in the inhibits, as determined by Wing Safety.

13.4.3. Laser Initiated Ordnance Circuits.

13.4.3.1. The optic system design shall preclude stray energy sources from causing an undesired output. This requirement shall be demonstrated during development and qualification testing. **Note**: The optic system undesired stray energy sources include items such as photostrobe, magnified sunlight, arc welding, xenon strobe, lightning, static electricity, and RF energy causing an undesired output.

13.4.3.2. Laser power sources shall have a minimum of 2 independent and verifiable inhibits. One of these inhibits for the main laser shall be a power interrupt plug that removes all airborne and ground power to the LFU.

13.4.3.3. High voltage laser systems used for solid rocket motor ignition circuit shall use one of the following safety devices:

13.4.3.3.1. An LFU used in conjunction with two optical barriers capable of being armed and safed and locked and unlocked remotely; a manual safe plug capable of interrupting power to the barrier control circuits shall also be provided.

13.4.3.3.2. An optical S&A.

13.4.3.3.3. An ordnance S&A.

13.4.3.4. Low voltage laser systems such as a diode laser used for a solid rocket motor ignition circuit shall use one of the following safety devices:

13.4.3.4.1. An optical S&A.

13.4.3.4.2. An ordnance S&A.

13.4.3.5. Specific safety device requirements for systems other than high hazard ordnance systems circuits shall be determined on a case-by-case basis by Wing Safety based on the degree of hazard.

13.4.3.6. If a low energy level end-to-end test is to be performed when the laser initiated ordnance system (LIOS) is connected to the receptor ordnance, the following requirements shall be met:

13.4.3.6.1. The energy level shall be less than 1/10,000 of the no-fire level of the laser-initiated device (LID).

13.4.3.6.2. The single failure mode maximum energy level of the test system shall be less than 1/100 of no-fire level of the LID.

13.4.3.6.3. The test source shall emit a different wavelength than the main firing unit laser.

13.4.3.6.4. One of the following inhibit options shall be implemented during the low energy level test:

13.4.3.6.4.1. An ordnance S&A device and a safe plug that interrupts power to the main laser shall be provided.

13.4.3.6.4.2. Three independent, verifiable inhibits shall be in place to preclude inadvertent initiation of the LID by the main laser firing unit during the low level energy test. One of these inhibits shall be a safe plug that interrupts power to the main laser.

13.4.3.6.4.3. The explosive train shall be disconnected anywhere between the LID and the receptor ordnance.

13.4.3.7. If a main laser subsystem firing test is performed by the Range User when the LIOS is connected to the receptor ordnance, a minimum of 3 independent, verifiable inhibits shall be in place.

13.4.3.7.1. Two of the inhibits shall be optical barriers capable of being independently locked in place.

13.4.3.7.2. The third inhibit shall be a safe plug that interrupts the power control circuits to the optical barriers.

13.4.3.8. Lasers shall be completely enclosed during checkout or provided with GSE that can enclose the laser emission path at all times the system is powered.

13.5. Ordnance Safety Devices.

13.5.1. General Design Requirements. Ordnance safety devices are electrical, electromechanical, optoelectronic, optical, or mechanical devices used in all ordnance subsystems to provide isolation between the power source to firing circuits and firing circuits to initiating devices or receptor ordnance. **Note**: Examples of ordnance safety devices include S&A devices, arm/disarm devices, relays, switches, EBW-FUs, LFUs, and manual arming/safing plugs.

13.5.1.1. Electrical and electronic safety devices shall remain or transfer back to their safe state in the event of input power loss.

13.5.1.2. All safety devices shall be capable of being functionally tested by ground test equipment.

13.5.1.3. Manual safety devices on the launch vehicle and payload that are required to be in place in order for the launch pad to be open for normal work shall be accessible up to launch, requiring only a minimal crew to access the device and safe it. **Note**: It is understood that maintaining accessibility to manual safety devices up to launch and maintaining accessibility to remotely activated devices up to launch and after launch abort cannot always be met. Exceptions are handled on a case-by-case basis where the Range User has demonstrated compliance with the intent.

13.5.1.4. The arrangement of safety devices shall maximize safety by placing the most positive and reliable form of interruption closest to the initiating device.

13.5.1.5. Ordnance and optical mechanical barriers used for safety devices shall demonstrate a reliability of 0.999 at the 95% confidence level to prevent initiation of the receptor ordnance or the LID for LIOS. The test method shall be a Bruceton procedure or other statistical testing method acceptable to Wing Safety.

13.5.1.6. Safety devices shall not require adjustment throughout their service life.

13.5.1.7. Each safety device shall be designed for a service life of at least 10 years after passing the acceptance test.

13.5.1.8. A fuzing system is designed to sense a target or respond to one or more prescribed conditions, such as elapsed time, pressure, or command, and initiate a train of fire or detonation in a munition. Fuzes shall comply with MIL-STD-1316F, *Safety Criteria for Fuze Design*, and contain at least two independent safety features, each of which shall prevent unintentional arming of the fuze.

13.5.2. Ordnance Arming and Safing Plugs.

13.5.2.1. Safing plugs shall be designed to be manually installed to provide electrical and optical isolation of the input power from the electrical and optical ordnance firing circuits.

13.5.2.2. Arming plugs shall be designed to be manually installed to provide electrical and optical continuity from the input power to the electrical and optical ordnance firing circuits.

13.5.2.3. Safe and arm plugs on the launch vehicle and payload that are required to be in place in order for the launch pad or processing facility to be open for normal work shall be accessible at all times, requiring only a minimal crew to access the plug and remove/install it. **Note**: It is understood that maintaining accessibility to arming and safing plugs up to just before final launch complex clear cannot always be met. Exceptions are handled on a case-by-case basis where the Range User has demonstrated compliance with the intent.

13.5.2.4. Arming and safing plugs shall be designed to be positively identifiable by color, shape, and name.

13.5.2.5. For low voltage systems (EEDs) that use a safing plug instead of an electromechanical S&A, the safing plug shall be designed to electrically isolate and short the initiator side of the firing circuit. Isolation shall be a minimum of 10 kilo-ohms.

13.5.3. Low Voltage EED Electromechanical S&As.

13.5.3.1. Electromechanical S&As shall provide mechanical isolation of the EED from the explosive train and electrical isolation of the firing circuit from the EEDs.

13.5.3.2. When the S&A is in the safe position, the power and return lines of the firing circuit shall be disconnected. The bridgewire shall be shorted and grounded through a 10 kilo-ohm to 100 kilo-ohm resistor and the explosive train shall be interrupted by a mechanical barrier capable of containing the EED output energy without initiating the explosive.

13.5.3.3. Transition from the safe to arm position shall require 90 degrees of rotation of the mechanical barrier for rotating S&As containing ordnance in the barrier. Safe to arm transition tolerances for other electromechanical S&A devices require specific Wing Safety approval.

13.5.3.4. The S&A device shall not be capable of propagating the detonation with the barrier rotated at least 50 degrees from safe for a 90-degree rotational barrier. This position shall be 50% of the travel distance between arm and safe for sliding barriers.

13.5.3.5. The mechanical lock in the S&A shall prevent inadvertent transfer from the arm to safe position (or vice versa) under all ground operational environments without the application of any electrical signal.

13.5.3.6. S&A design shall incorporate provisions to safe the ordnance train from any rotor and/ or barrier position.

13.5.3.7. S&As shall be capable of being remotely safed and armed. They shall not be capable of being manually armed, but shall be capable of being manually safed.

13.5.3.8. Remote and manual safing shall be accomplished without passing through the arm position.

13.5.3.9. The S&A safe signal shall not be indicated visually or remotely unless the device is less than 10 degrees from the safe position for rotating systems or 10% from the safe position for sliding barriers.

13.5.3.10. No visual indication of safe or arm shall appear if the device is in between the safe and arm positions. The S&A will be considered “not safe” or armed if the indicator does not show “safe.”

13.5.3.11. The electrical continuity of one status circuit of the S&A device (safe or arm) shall completely break before the time that the electrical continuity is established for the other status circuit (arm or safe).

13.5.3.12. A remote status indicator shall be provided to show the armed or safed condition.

13.5.3.12.1. The device shall also indicate its arm or safe status by visual inspection.

13.5.3.12.2. There shall be easy access to this visual indication throughout ground processing.

13.5.3.13. S&A device locations on the vehicle shall be accessible to facilitate installation and removal and electrical and ordnance connections during final vehicle closeout.

13.5.3.14. A safing pin shall be used in the S&A to prevent movement from the safe to the arm position when the arming signal is applied.

13.5.3.14.1. Rotation and/or transition of the mechanical barrier to align the explosive train and electrical continuity of the firing circuit to the EEDs shall not be possible with the safing pin installed.

13.5.3.14.2. When inserted and rotated, the pin shall manually safe the device.

13.5.3.14.3. Safing pins on the launch vehicle and the payload that are required to be in place in order for the launch pad to be open for normal work shall be accessible up to launch, requiring only a minimal crew to access the device and safe it.

13.5.3.14.4. Safing pin insertion shall require a reasonable force of resistance. **Note**: The force required for safing pin insertion should be between 20 to 40 pounds and/or 20 to 40 inch-pounds of torque.

13.5.3.14.5. The safing pin shall provide a means of attaching warning streamers.

13.5.3.14.6. When installed, each safing pin shall be marked by a red streamer.

13.5.3.14.7. The following requirements apply whenever the arm command has been energized:

13.5.3.14.7.1. Removal of the safing pin shall not be possible if the arming circuit is energized.

13.5.3.14.7.2. The safing pin retention mechanism shall be capable of withstanding applied forces of tension or torque without failure. **Note**: Typical values for previously approved designs had the S&A safing pin retention mechanism capable of withstanding an applied force of at least 100 pounds tension or a torque of at least 100 inch-pounds without failure.

13.5.3.14.8. The following requirements apply whenever the arm command is not energized:

13.5.3.14.8.1. Removal of the safing pin shall not cause the S&A to automatically arm.

13.5.3.14.8.2. Removal of the safing pin shall be inhibited by a locking mechanism requiring 90 degrees rotation of the pin. **Note**: The removal force should be 3 to 10 inch-pounds of torque.

13.5.3.15. All S&A devices shall be designed to withstand repeated cycling from arm to safe for at least 1,000 cycles, or at least 5 times the expected number of cycles, whichever is greater, without any malfunction, failure, or deterioration in performance.

13.5.3.16. A constant 1-hour application of S&A arming voltage with the safing pin installed shall not cause the explosive in the unit to function or degrade to a point that it will no longer function if such a failure could create a hazard.

13.5.3.17. The time required to arm or safe an S&A device shall not exceed 1 second after application of the actuation signal.

13.5.3.18. The S&A shall not initiate and shall be safe to handle for subsequent disposal after being subjected to a 20-foot drop on to a steel plate.

13.5.3.19. The S&A shall have shielding caps attached on the firing connectors during storage, handling, transportation, and installation up to firing line connection.

13.5.3.20. The shielding cap shall have a solid metal outer shell that makes electrical contact with the firing circuit case in the same manner as the mating connector.

13.5.4. Mechanical S&As.

13.5.4.1. Electrically actuated S&As shall be used unless justification for mechanical S&As is provided to and approved by Wing Safety.

13.5.4.2. Wing Safety approved mechanical S&As shall incorporate the same features as electrically actuated devices except that arming and safing is performed mechanically. **Note**: Normally, these devices are armed by a liftoff lanyard or by stage separation.

13.5.4.3. These S&As shall be designed to withstand repeated cycling from the arm to the safe position for at least 300 cycles without malfunction, failure, or deterioration in performance.

13.5.5. EBW Firing Units.

13.5.5.1. The EBW-FU shall provide circuits for capacitor charging, bleeding, charge interruption, triggering, and monitoring.

13.5.5.2. The charged capacitor circuit shall have a dual bleed system with either system capable of independently bleeding off the stored capacitor charge. **Note**: The time interval for bleeding of stored capacitor charge should be based on the level of associated hazard and concept of operations, but not to exceed 5 minutes after power removal.

13.5.5.3. Two separate and independent ground command actions shall be required for removing capacitor charging inhibits, and shall be positively locked out and limited to only authorized personnel.

13.5.5.4. EBW-FU design shall provide a positive remotely controlled means of interrupting the capacitor charging circuit.

13.5.5.5. A gap tube shall be provided that interrupts the EBW trigger circuit.

13.5.5.6. EBW-FUs shall be designed to be discriminatory to spurious signals in accordance with MIL-STD-461G, *Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment*.

13.5.5.7. At a minimum, EBW-FU monitor circuits shall provide the status of the trigger capacitor, high voltage capacitor, arm input, inhibit input (if used), and power.

13.5.5.8. The insulation resistance between each EBW-FU high voltage output circuit and the case shall be designed to not be less than 50 megaohms at 500 Vdc.

13.5.5.9. The isolation resistance between EBW-FU output circuits and any other circuits shall not be less than 50 megaohms at 500 Vdc.

13.5.5.10. Remote discharged indicators for EBW-FUs shall not appear unless the capacitor bank voltage is 1/10 or less of the no-fire voltage of the EBW. The EBW-FU shall be considered “not safe” if the indicator does not show “discharged.”

13.5.5.11. The EBW-FU shall be capable of being remotely safed and armed.

13.5.6. Laser Firing Units, Optical Barriers, Optical S&As, and Ordnance S&As.

13.5.6.1. The laser firing unit, optical barrier, optical S&A, and ordnance S&A design requirements shall be applied according to the device used.

13.5.6.2. The conceptual configuration of the devices to be used and their planned prelaunch testing shall be coordinated with Wing Safety as early as possible to ensure the configuration is acceptable.

13.5.6.3. Laser Firing Units (LFU).

13.5.6.3.1. LFU General Design Requirements.

13.5.6.3.1.1. LFUs shall provide a positive, remotely controlled means of interrupting the power to the firing circuit.

13.5.6.3.1.2. Capacitor charging circuits shall have a dual bleed system with each system capable of independently bleeding off the stored charge.

13.5.6.3.1.3. A gap tube shall be provided that interrupts the trigger circuit in a high voltage LFU.

13.5.6.3.1.4. LFUs shall be designed to be discriminatory to spurious signals in accordance with MIL-STD-461.

13.5.6.3.1.5. Low voltage LFUs shall provide a continuous spurious energy monitor and/ or detection circuit on the input firing line capable of indicating when 1/10 of the minimum input firing voltage or current firing is exceeded.

13.5.6.3.2. LFU Monitor Circuits.

13.5.6.3.2.1. At a minimum, LFU monitor circuits shall provide the status of the trigger capacitor, high voltage capacitor, arm input, barrier position, barrier locked/unlocked, inhibit input, and power as applicable.

13.5.6.3.2.2. The electrical continuity of one status circuit shall completely break before the time that the electrical continuity is established for the other status circuit.

13.5.6.3.3. LFU Charged and Discharged Indicators. A remote discharged indicator for LFUs that use a capacitor bank shall not appear unless the capacitor bank voltage is 50% or less of the no-fire voltage of the LID. The LFU shall be considered “not safe” if the indicator does not show “discharged.”

13.5.6.4. Optical Barriers.

13.5.6.4.1. Optical Barrier General Design Requirements.

13.5.6.4.1.1. The safe position of the optical barrier shall be capable of absorbing or redirecting the complete optical energy source to a safe receiver.

13.5.6.4.1.1.1. The barrier shall be capable of absorbing and/or redirecting 100 times the maximum power that the laser can generate.

13.5.6.4.1.1.2. A safety factor will be calculated for each barrier design. **Note**: Depending on barrier design, the safety factor should be calculated using several possible variables such as distance from nominal beam spot to the edge of the barrier or the edge of the aperture, distance, and/ or degrees between arm and safe, laser energy deflected, and mechanical tolerances.

13.5.6.4.1.2. The optical barrier shall maintain the safety margin and function nominally after being pulsed by the main laser a minimum of 4 times the expected lifetime number of pulses or 10 pulses, whichever is greater, at the maximum firing rate and power of the laser.

13.5.6.4.1.3. The control of barriers, mechanical locks, and monitors shall be independent of the firing circuit.

13.5.6.4.1.4. A constant 5-minute application of arming voltage with the mechanical lock of the barriers engaged shall not cause the optical train to go to the arm position.

13.5.6.4.1.5. All optical barriers shall be designed to withstand repeated cycling from the arm to the safe positions for at least 1,000 cycles without any malfunction, failure, or deterioration in performance. If the device is to be used for a program with a known operating life cycle, Wing Safety may accept a design cycle life of at least 5 times the expected number of cycles.

13.5.6.4.2. Optical Barrier Status Indicators.

13.5.6.4.2.1. A remote status indicator for the optical barriers located in LFU or optical S&A shall be provided.

13.5.6.4.2.2. A visual status indicator of optical barrier status shall be provided on the device or at a nearby location so that it is easily seen by operating personnel.

13.5.6.4.2.2.1. If a visual status indicator is provided on the barrier, it shall be readily accessible to personnel on the complex and/or facility.

13.5.6.4.2.2.2. The design solution for a visual indicator shall not result in an external light source path for hazardous light energy to enter the LIOS system.

13.5.6.4.2.2.3. If a visual status indicator on the LFU or S&A device is not provided, electronic remote status indicators shall be provided both at the launch pad and launch control center to show the armed or safe status of the LFU or S&A barriers.

13.5.6.4.2.3. The safe signal shall only be indicated when the optical barriers are in a position that will not align the optical train and not allow initiation of the LID with a reliability of 0.999 at the 95% confidence level.

13.5.6.4.2.4. Bruceton-type testing or other statistical methods acceptable to Wing Safety shall be performed to establish reliability.

13.5.6.4.2.5. The optical barrier will be considered "not safe" or armed if the indicator does not show "safe."

13.5.6.5. Optical S&As.

13.5.6.5.1. When an optical S&A device is in the laser safe position, the following criteria shall be met:

13.5.6.5.1.1. The optical transfer assembly shall be interrupted by a minimum of two mechanical barriers that can be mechanically locked in place.

13.5.6.5.1.2. The main laser power circuit shall be electrically disconnected. This main laser power interrupt capability is not required if the power circuit to the mechanical barriers is interrupted by an arm and/or safe plug.

13.5.6.5.1.3. Optical S&As shall be capable of being remotely safed and armed.

13.5.6.5.1.4. Optical S&As shall not be capable of being manually armed but they shall be capable of being manually safed.

13.5.6.5.1.5. Remote and manual safing shall be accomplished without passing through the armed position.

13.5.6.5.2. Optical S&A barriers shall meet the requirements of section **13.5.6.4**.

13.5.6.5.3. The electrical continuity of one status circuit shall completely break before the time that the electrical continuity is established for the other status circuit.

13.5.6.5.4. The S&A shall provide status of the optical barriers (arm, safe), barriers locked/ unlocked, and electrical inhibits.

13.5.6.5.5. The insulation resistance between each S&A circuit and the case shall not be less than 2 megaohms at 500 Vdc.

13.5.6.5.6. All S&A devices shall be designed to withstand repeated cycling from arm to safe for at least 1,000 cycles or at least 5 times the expected number of cycles, whichever is greater, without any malfunction, failure, or deterioration in performance.

13.5.6.5.7. A constant 5-minute application of S&A arming voltage shall not cause malfunction, failure, or deterioration in performance.

13.5.6.5.8. The time required to arm or safe an S&A device shall not exceed 1 second after application of the actuation signal.

13.5.6.6. Ordnance S&As.

13.5.6.6.1. Ordnance S&A General Design Requirements.

13.5.6.6.1.1. Ordnance S&As shall provide mechanical isolation of the explosive train.

13.5.6.6.1.2. When the device is in the safe position, the explosive train shall be interrupted by a mechanical barrier capable of containing the explosive.

13.5.6.6.1.3. Safe to Arm Transition.

13.5.6.6.1.3.1. Transition from the safe to arm position shall require 90 degrees of rotation of the mechanical barrier for rotating S&As containing ordnance in the barrier.

13.5.6.6.1.3.2. Safe to arm transition tolerances for other electromechanical S&A devices shall be approved by Wing Safety.

13.5.6.6.1.4. Detonation Propagation.

13.5.6.6.1.4.1. The device shall not be capable of propagating the detonation with the barrier rotated less than 50 degrees from safe for a 90-degree rotational barrier.

13.5.6.6.1.4.2. The device shall not be capable of propagating the detonation with the barrier at 50% of the travel distance between arm and safe for sliding barriers.

13.5.6.6.1.5. Ordnance S&A device locations on the vehicle shall be accessible to facilitate installation and/or removal of ordnance connections during final vehicle closeout.

13.5.6.6.1.6. The S&A shall not initiate and shall be safe to handle for subsequent disposal after being subjected to a 20-foot drop on to a steel plate.

13.5.6.6.2. Ordnance S&A Arm and Safe Mechanisms.

13.5.6.6.2.1. The S&A device shall be designed to incorporate provisions to safe the ordnance train from any rotor or barrier position.

13.5.6.6.2.2. The time required to arm or safe an S&A device shall not exceed 1 second after application of the actuation signal.

13.5.6.6.2.3. All S&A devices shall be designed to withstand repeated cycling from arm to safe for at least 1,000 cycles or at least 5 times the expected number of cycles, whichever is greater, without any malfunction, failure, or deterioration in performance.

13.5.6.6.2.4. A mechanical lock in the S&A shall prevent inadvertent transfer from the arm to safe position or the safe to arm position under all operating environments without the application of any electrical signal.

13.5.6.6.2.5. S&As shall be capable of being remotely safed and armed.

13.5.6.6.2.6. Ordnance S&As shall not be capable of being manually armed but they shall be capable of being manually safed.

13.5.6.6.2.7. Remote and manual safing shall be accomplished without passing through the armed position.

13.5.6.6.3. Ordnance S&A Status Indicators.

13.5.6.6.3.1. The electrical continuity of one status circuit of the S&A device (safe or arm) shall completely break before the time that the electrical continuity is established for the other status circuit (arm or safe).

13.5.6.6.3.2. Ordnance S&A Remote and Visual Status Indicators.

13.5.6.6.3.2.1. A remote status indicator shall be provided to show the armed or safed condition.

13.5.6.6.3.2.2. A visual status indicator shall be provided to show the armed or safed condition by simple visual inspection.

13.5.6.6.3.2.3. Easy access to the visual status indicator shall be provided throughout ground processing.

13.5.6.6.3.3. The S&A safe signal shall not be indicated visually or remotely unless the device is less than 10 degrees from the safe position for rotating systems or 10% from the safe position for sliding barriers.

13.5.6.6.3.4. No visual indication of safe or arm shall appear if the device is in between safe and arm positions. The S&A will be considered “not safe” or armed if the indicator does not show “safe.”

13.5.6.6.4. Ordnance S&A Safing Pins.

13.5.6.6.4.1. A safing pin shall be used in the S&A device to prevent movement from the safe to the arm position when an arming signal is applied.

13.5.6.6.4.2. Rotation and/or transition of the mechanical barrier to align the explosive train shall not be possible with the safing pin installed.

13.5.6.6.4.3. When inserted and rotated, the pin shall manually safe the device.

13.5.6.6.4.4. Safing pins on the launch vehicle and payload that are required to be in place in order for the launch pad to be open for normal work shall be accessible up to launch, requiring only a minimal crew to access the device and safe it.

13.5.6.6.4.5. Safing pin insertion shall require a reasonable force of resistance. **Note**: The force required for safing pin insertion should be between 20 and 40 pounds and/or 20 to 40 inch-pounds of torque.

13.5.6.6.4.6. The safing pin shall provide a means of attaching warning streamers.

13.5.6.6.4.7. When installed, each safing pin shall be marked by a red streamer.

13.5.6.6.4.8. A constant 1-hour application of S&A arming voltage, with the safing pin installed, shall not cause the explosive in the unit to function.

13.5.6.6.4.9. The following requirements apply whenever the arm command has been energized:

13.5.6.6.4.9.1. Removal of the safing pin shall not be possible if the arming circuit is energized.

13.5.6.6.4.9.2. The safing pin retention mechanism shall be capable of withstanding applied forces of tension or torque without failure. **Note**: Typical values for previously approved designs had the S&A safing pin retention mechanism capable of withstanding an applied force of at least 100 pounds tension or a torque of at least 100 inch-pounds without failure.

13.5.6.6.4.10. The following requirements apply whenever the arm command is not energized:

13.5.6.6.4.10.1. Removal of the safing pin shall not cause the S&A to automatically arm.

13.5.6.6.4.10.2. Removal of the safing pin shall be inhibited by a locking mechanism requiring 90 degrees rotation of the pin. **Note**: The removal force should be 3 to 10 inch-pounds of torque.

13.5.7. Electronic Safe and Arm Device (ESAD) Firing Units.

13.5.7.1. The ESAD-FU shall provide circuits for capacitor charging, bleeding, charge interruption, triggering, and monitoring.

13.5.7.2. The ESAD-FU shall have a remote means of charging and discharging of the unit's firing capacitor. Two separate and independent ground command actions shall be required for removing capacitor charging inhibits, and shall be positively locked out and limited to only authorized personnel.

13.5.7.2.1. The ESAD-FU is considered to be in an armed state when the fully charged firing capacitor meets the voltage specification for operational firing.

13.5.7.2.2. The ESAD-FU is considered to be in an unsafe state when the firing capacitor voltage goes above the no-fire voltage level.

13.5.7.2.3. The ESAD-FU is considered to be in a safe state when the firing capacitor voltage is 1/10 or less of the no-fire voltage level.

13.5.7.3. The charged capacitor circuit shall have a dual bleed system with either system capable of independently bleeding off the stored capacitor charge. **Note**: The time interval for bleeding of stored capacitor charge should be based on the level of associated hazard and concept of operations, but not to exceed 5 minutes after power removal.

13.5.7.4. ESAD-FU design shall provide a positive remotely controlled means of interrupting the capacitor charging circuit.

13.5.7.5. ESAD-FUs shall be designed to be discriminatory to spurious signals in accordance with MIL-STD-461G, *Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment*.

13.5.7.6. At a minimum, ESAD-FU monitor circuit(s) shall provide the status of the trigger capacitor, arm input, inhibit(s) input, control(s) input, and power.

13.5.7.7. The ESAD-FU command and firing circuitry shall not trigger inadvertently when subjected to the verified no-fire trigger performance levels.

13.5.7.8. The ESAD-FU shall provide a master arm/safe command for a positive, remotely controlled means of interrupting the power to the firing circuit and is independent of other inhibits.

13.5.7.9. Any logic device, such as a field programmable gate array (FPGA), used in the implementation of safety features shall:

13.5.7.9.1. be permanently programmed for its final flight configuration;

13.5.7.9.2. not be reconfigured at power-up.

13.5.7.10. The ESAD-FU shall power up in the safe condition.

13.5.7.11. The ESAD-FU shall provide single fault tolerance (two inhibits) against firing circuit charging (armed state). Another inhibit against charging the ESAD-FU shall be external to the unit.

13.5.7.12. In the armed condition (when the capacitor is charged), the ESAD-FU shall provide single fault tolerance (two inhibits) against firing.

Table 13.2. Fault Tolerance Clarifications.

When personnel access is required during launch vehicle processing or on the pad, maintain dual fault tolerance against charging of the ESAD-FU. For example: no battery power for a battery-only powered ESAD-FU; a safing plug for ground powered ESAD-FU; or some other concept of operations in which ESAD-FU powering is not a credible scenario. At no time will personnel be present with power provided to the ESAD-FU, with the exception of end-to-end testing with a disconnected secondary ordnance. For zero-fault tolerant firing circuits, arming prior to launch without the immediate intent to launch presents a resource protection risk against inadvertent firing, requiring a waiver. Risk acceptance will be dependent upon a probability assessment quantifying inadvertent firing.

13.5.7.13. Remote discharged indicators for ESAD-FUs shall not appear unless the capacitor voltage is 1/10 or less of the no-fire voltage of the high voltage firing capacitor.

13.5.7.14. The ESAD-FU shall be considered "not safe" if the indicator does not show "discharged."

13.5.7.15. The ESAD-FU shall be capable of being remotely safed and armed.

13.5.7.16. The time to arm an ESAD-FU device shall not exceed 1 second after application of the arming command. The time to safe shall not exceed 5 minutes after power removal.

13.5.7.17. A remote status output indication shall be provided to show the armed or safed condition.

13.5.7.18. A FMECA shall be performed on ESAD-FU ordnance trains.

13.6. Ordnance Initiating Devices.

13.6.1. Ordnance Initiating Device General Design Requirements.

13.6.1.1. The explosive or pyrotechnic mix shall not degrade, decompose, or change chemically over its life, causing a more sensitive device.

13.6.1.2. Ordnance should be designed for a service life of at least 10 years with a design goal of15 years.

13.6.1.3. The decomposition, cook-off, and melting temperatures of all explosives shall be at least 30oC higher than the maximum predicted environmental temperature to which the material will be exposed during storage, handling, transportation, and launch.

13.6.2. Low Voltage EEDs.

13.6.2.1. One amp/one watt no-fire survivability of low voltage EEDs is required, as determined from the 0.1% firing level of the EED with 95% confidence using the Bruceton test or other statistical testing methods acceptable to Wing Safety.

13.6.2.2. EEDs shall be designed to withstand a constant DC firing pulse of 1 ampere and 1 watt power for a period of 5 minutes without initiation or deterioration of performance.

13.6.2.3. The EED main body shall not rupture or fragment when the device is fired. Displacement or deformation of the connector and main housing is permissible; rupture or deformation of the outer end is permissible.

13.6.2.4. The autoignition temperature shall not be less than 150° C.

13.6.2.5. Carbon bridgewires and conductive mixes without bridgewires are prohibited.

13.6.2.6. EEDs shall not fire or deteriorate in performance (if failure can create a hazard) as a result of being subjected to an electrostatic discharge of 25 kV from a 500 picofarad capacitor applied in the pin-to-case mode without a series resistor, and in the pin-to-pin mode with a 5 kilo-ohms resistor in series.

13.6.2.7. The EED shall not initiate and will perform to specification (if failure can create a hazard) after being subjected to a 6-foot drop on to a steel plate.

13.6.2.8. The EED shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-foot drop on to a steel plate.

13.6.2.9. Insulation resistance between pin-to-case shall not be less than 2 megaohms at 500 Vdc.

13.6.2.10. The outer case of the EED main body shall be made of conductive material, preferably metal.

13.6.2.11. RF survivability shall meet the testing criteria described in AIAA S-113A-2016, *Criteria for Explosive Systems and Devices on Space and Launch Vehicles.*

13.6.2.12. Shielding caps shall be provided and placed on the EED during shipment, storage, handling, and installation up to the point of electrical connection.

13.6.2.12.1. The shielding cap shall have an outer shell made of conductive material that provides an RF shield and makes electrical contact with the EED case.

13.6.2.12.2. There shall be no RF gaps around the full 360-degree mating surface between the shielding cap and EED case.

13.6.2.12.3. The shielding cap shall be designed to accommodate the torquing tool during installation.

13.6.2.12.4. Shorting plugs (caps) shall not be used as a substitute for shielding caps.

13.6.3. High Voltage Exploding Bridgewires.

13.6.3.1. Explosive materials shall be secondary explosives. **Note**: Examples of secondary explosives include pentaerythritoltetranitrate (PETN) or cyclotrimethylenetrinitramine (RDX).

13.6.3.2. Insulation resistance pin-to-case shall be designed to not be less than 50 megaohms at 500 Vdc.

13.6.3.3. A voltage blocking gap shall be provided.

13.6.3.3.1. The gap breakdown voltage shall not be less than 650 Vdc when discharged from a 0.025 +10% microfarad capacitor.

13.6.3.3.2. The nominal gap breakdown voltage tolerance shall be specified and approved by Wing Safety.

13.6.3.4. The EBW shall not fire or deteriorate in performance (if failure can create a hazard) upon being subjected to a voltage of 125 to 130 volts root mean square (Vrms) at 60 Hz applied across the terminals or between the terminals and the EBW body for 5 minutes +10 sec.

13.6.3.5. The EBW shall not fire or degrade to the extent that it is unsafe to handle when 230 +10 Vrms at 60 Hz is applied across the terminals or between the terminals and EBW body for 5 minutes +10 sec.

13.6.3.6. The EBW shall not fire or deteriorate in performance (if failure can create a hazard) upon being subjected to a source of 500 +25 Vdc having an output capacitance of 1.0 +10% microfarads applied across the terminals or between the terminals and the EBW body for 60 to 90 seconds.

13.6.3.7. The EBW shall not fire or deteriorate in performance (if failure can create a hazard) after exposure to that level of power equivalent to absorption by the test item of 1.0 watt average power at any frequency within each RF energy range, as specified in **Table 13.3**. The frequency shall be applied across the input terminals of the EBW detonator for 5.0 to 6.0 seconds.

Table 13.3. Exploding Bridgewire (EBW) RF Sensitivity.

Frequency (in Mhz)	Type
5 – 100	Continuous Wave
250 – 300	Continuous Wave
400 – 500	Continuous Wave
800 – 1,000	Continuous Wave
2,000 – 2,400	Continuous Wave
2,900 – 3,100	Continuous Wave
5,000 – 6,000	Continuous Wave
9,800 – 10,000	Continuous Wave
16,000 – 23,000	Pulse Wave *
32,000 – 40,000	Pulse Wave *
* Pulsed repetition frequency shall not be less than 100 Hz and the pulse width shall be a minimum of 1 μs.	

13.6.3.8. The EBW shall not fire or deteriorate in performance (if failure can create a hazard) as a result of being subjected to an electrostatic discharge of 25 kV from a 500 picofarad capacitor applied in the pin-to-case mode without a series resistor and in the pin-to-pin mode with a 5 kilo-ohm resistor in series.

13.6.3.9. The autoignition temperature of the EBW shall not be less than 150°C.

13.6.3.10. The EBW shall not initiate and shall perform to specification (if failure can create a hazard) after being subjected to a 6-foot drop on to a steel plate.

13.6.3.11. The EBW shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-foot drop on to a steel plate.

13.6.4. Laser Initiated Devices (LID).

13.6.4.1. LIDs shall have specific energy density, spot size, pulse width, and wavelength characteristics with a specified tolerance level for each characteristic.

13.6.4.2. LIDs shall not use primary explosives.

13.6.4.2.1. If modified secondary (composition) explosives are used, their sensitivity characteristics shall be established by test IAW the US portion of NATO Allied Ordnance Publication (AOP)-7, *Manual of Data Requirements and Tests for the Qualification of Explosive Materials for Military Use*, or equivalent.

13.6.4.2.2. The test requirements and test report shall be reviewed and approved by Wing Safety.

13.6.4.3. Flight configuration LIDs shall be tested to determine their susceptibility to all stray energy sources present during prelaunch processing up to the launch environment. This susceptibility applies to both inadvertent firing and dudding if dudding can create a hazard. **Note**: Stray energy sources that might affect the LIDs present during prelaunch processing up to the launch environment include items such as strobe, sunlight, arc welder, flashlamps, lightning, RF, AC, and DC electrical energy causing an undesired output.

13.6.4.3.1. At a minimum, the sensitivity characteristics to these energy sources shall be established by functioning a minimum of 45 LIDs per the Bruceton test or other statistical testing method acceptable to Wing Safety in terms of spot size, pulse width, energy density, and wavelength.

13.6.4.3.2. A correlation between the above test and the no-fire level established for the LID shall be provided to Wing Safety for review and approval. At a minimum, the LID no-fire energy shall be 104 greater than any credible stray energy source.

13.6.4.3.3. If the above LID sensitivity requirements are not met, the explosive train (LID to explosive transfer assembly [ETA] or ETA to receptor ordnance interface) shall remain disconnected until just before final pad evacuation for launch or an ordnance S&A device shall be provided between the LID and the ETA.

13.6.4.4. No-fire level survivability is required as determined from the 0.1% firing level of the LID with 95% confidence using the Bruceton test or other statistical methods acceptable to Wing Safety.

13.6.4.4.1. The test shall take into account the effects of the temperature of the explosive as well as effects caused by manufacturing variations in explosive grain size and pressure.

13.6.4.4.2. The no-fire level shall be applied for a minimum of 5 minutes without firing or dudding the LID if dudding can create a hazard.

13.6.4.5. The minimum all-fire level shall be at least 10 times the no-fire level.

13.6.4.6. LIDs shall not be exposed to energy density levels greater than 1/10,000 the no-fire level of the ordnance initiator during prelaunch processing, shipment, storage, handling, installation, and testing. This energy constraint is to be applied at the end of the fiber optic cable just before the cable entering the laser ordnance initiator reflective coating.

13.6.4.7. LIDs shall dissipate heat faster than single failure conditions can input into the device without initiating or dudding (if dudding can create a hazard). An analysis shall be provided to demonstrate compliance with this requirement. This does not include full laser firing energy output.

13.6.4.8. Optical shielding and protective caps shall be provided for LIDs during prelaunch processing, including shipment, storage, handling, installation, and testing.

13.6.4.8.1. Shielding and protective cap devices shall prevent exposure of the LID to energy density levels greater than 1/10,000 of the no-fire level of the LID.

13.6.4.8.2. Reflective coatings of the LID shall not be considered part of the shield.

13.6.4.9. The shielding cap shall be designed to accommodate the tool used during installation without the removal of the cap.

13.6.4.10. Autoignition temperature of the LID shall not be less than 150°C.

13.6.4.11. LIDs shall not initiate and shall perform to specification (if failure can create a hazard) after being subjected to a 6-foot drop test on to a steel plate.

13.6.4.12. The LID shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-foot drop test on to a steel plate.

13.6.4.13. LIDs shall not fire or deteriorate in performance (if failure can create a hazard) as result of being subjected to an electrostatic discharge of 25 kV from a 500 picofarad capacitor. The test configuration shall be approved by Wing Safety.

13.6.5. Percussion Activated Devices.

13.6.5.1. Stab initiation of percussion activated devices (PADs) is prohibited.

13.6.5.2. Each initiator shall have a positive safety interrupter feature that can be mechanically locked in place.

13.6.5.3. The initiator and its interrupter shall be designed to withstand all transportation, handling, and installation environments.

13.6.5.4. The interrupter safety lock shall be designed to remain in place during and after installation.

13.6.5.5. The interrupter safety lock shall be designed to be removed after installation.

13.6.5.6. The design shall ensure the PAD cannot be assembled without the interrupter.

13.6.5.7. Percussion initiators shall be designed so that the operating energy is at least twice the all-fire energy.

13.6.5.8. Percussion initiator no-fire energy shall be such that the percussion initiator shall not fire when subjected to an energy of 50% of the all-fire energy.

13.6.6. Non-Explosive Initiators. Non-explosive initiators (NEI s) shall be handled on a case-by-case basis to ensure safety of the system design.

13.6.7. High Voltage Exploding Foil Initiators.

13.6.7.1. Explosive materials shall be secondary explosives. **Note**: Examples of secondary explosives include pentaerythritoltetranitrate (PETN) or cyclotrimethylenetrinitramine (RDX).

13.6.7.2. The EFI shall undergo radio frequency (RF) sensitivity testing to determine the RF no-fire power level. The approximate frequency and modulation stimuli shown in **Table 13.4**. shall be used:

Table 13.4. Exploding Foil Initiator (EFI) RF Sensitivity.

Frequency (in Mhz)	**Modulation**
1.5	Continuous Wave
27.0	Continuous Wave
154.0	Continuous Wave

250.0	Continuous Wave
900.0	Continuous Wave
2,700.0	Pulse Wave*
5,400.0	Pulse Wave*
8,900.0	Pulse Wave*
15,000.0	Continuous Wave
32,000.0	Pulse Wave*
* Pulsed modulation with pulse width of 1 μs and pulse repetition rate of 1 kHz	

13.6.7.3. The EFI shall not fire as a result of being subjected to an electrostatic discharge of 25 kV from a 500 picofarad capacitor applied in the pin-to-case mode without a series resistor and in the pin-to-pin mode with a 5 kilo-ohm resistor in series.

13.6.7.4. The autoignition temperature of the EFI shall not be less than 150°C.

13.6.7.5. The EFI shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-foot drop on to a steel plate.

13.6.7.6. The EFI shall not auto-ignite, exhibit density variations, or melt when subjected to any nominal high-temperature environment during handling, testing, storage, transportation, installation, or flight.

13.7. Explosive Transfer Systems and Receptor Ordnance. Explosive transfer systems (ETS) are used to transmit the initiation reaction from the initiator to the receptor ordnance. ETSs shall be designed to meet the applicable safety sections of DoD-E-83578 and the requirements below.

13.7.1. The explosive or pyrotechnic mix shall not degrade, decompose, or change chemically over its life causing a more sensitive device.

13.7.2. Explosives used in ETS lines shall be secondary explosives.

13.7.3. Flexible confined detonation cord (FCDC) shall not fragment or separate from end fittings upon initiation. Gaseous emission is permissible.

13.7.4. The ETS shall not detonate and shall be capable of performing its function (if failure can create a hazard) after being subjected to a 6-foot drop on to a steel plate.

13.7.5. The ETS shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-foot drop on to a steel plate.

13.7.6. All ETS interconnections shall provide for safety (lock) wiring or a Wing Safety approved equivalent. **Note**: Design solutions previously approved to prevent accidental or inadvertent demating of ETS interconnections include lock wiring. Other solutions will be considered by Wing Safety on a case-by-case basis.

13.7.7. An electrically conductive path shall exist between ETS components and their attachment fittings. The bonding resistance should be designed to be 2.5 milliohms but in no case shall the resistance exceed 5 ohms.

13.7.8. ETS fittings shall be designed and located to facilitate installation of the end receptor ordnance components in the launch vehicle as late as practical.

13.7.9. Fittings that should not be reversed or interchanged (because they may cause a hazard) shall be designed so that reverse installation or interchange is not possible.

13.7.10. Exposed end fittings shall be equipped with protective caps.

13.7.11. Receptor ordnance shall be designed to meet the applicable safety sections of DoD-E-83578 and this part and shall use secondary high explosives. **Note**: Examples of secondary high explosives used for receptor ordnance include such items as PETN, RDX, cyclotetramethylenetetra-nitramine (HMX), or 2,2,4,4,6,6 hexanitrostilbene (HNS).

13.7.11.1. Explosives shall be non-hygroscopic.

13.7.11.2. Specific approval from Wing Safety is required for all explosive compositions.

13.7.12. The receptor ordnance shall not detonate after being subjected to a 6-foot drop test on to a steel plate.

13.7.13. The receptor ordnance shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-foot drop onto a steel plate.

13.8. Ordnance Test Equipment.

13.8.1. Ordnance Test Equipment General Design Requirements.

13.8.1.1. All ordnance test equipment, such as continuity and bridgewire resistance measurement devices, shall be inspected and tested for voltage and optical isolation and limitation.

13.8.1.1.1. These devices shall be designed so that they will not pass greater than 1/10 of the no-fire energy across an EED bridgewire, or 50 mA, whichever is less.

13.8.1.1.2. These devices shall be analyzed to verify that rough handling, dropping, or single component failure will not result in negating the current-limiting feature.

13.8.1.1.3. Clear cases of unacceptable energy or current for a particular resistance range or ranges shall be excluded from use by disablement by the manufacturer or local authority before certification.

13.8.1.1.4. Certification of each device shall include a tabular listing (to be kept with or marked on each meter) of the energy level and current levels available at each of the selectable ranges for the meter.

13.8.1.1.5. All test equipment shall be designed to meet standard industry safety requirements such as those established by ANSI, IEEE, NFPA, or other standards, as applicable.

13.8.1.2. The test results shall be submitted to Wing Safety for approval before equipment use on the ranges.

13.8.2. Stray Current Monitors.

13.8.2.1. A stray current monitor shall be provided for all low voltage (EED) solid rocket motor ignition circuits and other high hazard ordnance systems as determined by Wing

Safety. **Note**: The term high hazard refers to specific catastrophic events such as the inadvertent firing of a solid rocket motor or actuation of a destruct system that could result in multiple fatalities, typically threatening more than just the ordnance technicians handling the hazardous item, and/or "total" destruction of high value hardware such as the payload, launch vehicle, or facility.

13.8.2.2. The stray current monitor shall be installed and remain connected until the electrical connection of the actual initiators is accomplished. The monitor shall be installed at a time during vehicle processing mutually agreeable to Wing Safety and the Range User.

13.8.2.3. The stray current monitor shall provide a stray current device capable of detecting 1/10 of the maximum safe no-fire current. **Note**: Fuses or automatic recording systems capable of detecting 1/10 of the maximum safe no-fire current are acceptable stray current devices for the stray current monitor.

13.8.2.4. The monitoring device shall be installed in the firing line.

13.8.3. Ground Support Test Equipment. The design of test equipment used to test ground support equipment shall be reviewed and approved by Wing Safety.

13.8.4. Laser Test Equipment.

13.8.4.1. All laser test equipment that has the capability to directly or indirectly fire the LID shall be assessed and approved by Wing Safety.

13.8.4.2. Laser test equipment shall meet the following design criteria:

13.8.4.2.1. The energy level shall be less than 1/10,000 of the no-fire level of the LID.

13.8.4.2.2. The single failure mode energy level of the test equipment shall be less than 1/100 of the no-fire level of the LID.

13.8.4.2.3. The test source shall emit a different wavelength from that of the firing unit laser.

13.9. Ordnance Data Requirements. Ordnance data items shall be submitted IAW the requirements of Attachment 2, sections **A2.2.4.9** and **A2.2.5.11**.

13.9.1. Data to verify compliance with the design and test requirements of this volume shall be submitted to Wing Safety for review and approval before the arrival of ordnance at the ranges.

13.9.2. All schematics and functional diagrams shall have well defined, standard Institute of Electrical and Electronics Engineers (IEEE) or military specification terminology and symbols.

Chapter 14

ELECTRICAL AND ELECTRONIC EQUIPMENT.

14.1. Electrical and Electronic Ground Support Equipment and Flight Hardware General Design Requirements and Standards.

14.1.1. Equipment shall be designed, fabricated, inspected, and tested in accordance with NFPA 70. **Note**: MIL-HDBK-454, *General Guidelines for Electronic Equipment*, should be used as guidance in the design, fabrication, inspection, and testing of electrical equipment.

14.1.2. All wiring shall be copper and contact with dissimilar metals shall be avoided. Aluminum wire shall not be used.

14.1.3. At a minimum, electrical equipment shall be designed to operate within the voltage ratings of ANSI C84.1, *Electric Power Systems and Equipment Voltage Ratings (60 Hz)*.

14.1.4. Electrical and Electronic Ground Support Equipment and Flight Hardware Power Cutoff. All electrical and electronic ground support equipment (EGSE) and flight hardware shall have a means to cut off power before installing, replacing, or interchanging units, assemblies, or portions thereof.

14.1.5. EGSE and Flight Hardware Power Transient. Safety critical systems shall be protected against power transients and power outages.

14.1.6. EGSE and Flight Hardware Connectors. Connector design shall avoid the generation of a hazardous condition that could lead to a hazardous event. **Note**: A hazardous condition is where there is a possibility for the inadvertent connection of an electrical circuit to cause unintentional current to flow where it would cause a short, spark, energize equipment, or initiate ordnance that would create a hazardous event.

14.1.6.1. If a hazardous condition can be created by mismating or reverse polarity, a positive means of preventing connector mismating shall be provided. **Note**: Mismating includes improper installation as well as connecting wrong connectors. Prevention of connector mismating includes alignment pins and key-way arrangements or other possible means to make it impossible to incorrectly mismate. Color coding may be used in addition to, but not in lieu of, the more positive means of connector mismate prevention.

14.1.6.2. If a hazardous event can occur, the following precautions shall be taken:

14.1.6.2.1. Power and signal leads shall not be terminated on adjacent pins of a connector.

14.1.6.2.2. Wiring shall be isolated so that a single short circuit occurring in a connector cannot affect other components.

14.1.6.2.3. Pin locations shall be assigned to prevent inadvertent pin-to-pin and pin-to-case shorts.

14.1.6.2.4. Spare pins shall not be used in connectors controlling hazardous operations or safety critical functions.

14.1.6.2.5. The Range User shall provide a bent pin analysis to Wing Safety on all safety critical and/or hazardous system connectors.

14.1.6.3. Connectors used in safety critical or hazardous systems shall be of the locking type.

14.1.6.4. Connectors relying solely on springs to maintain an electrical contact shall not be used in safety critical or hazardous systems. Connectors for safety critical or hazardous systems shall have a positive locking mechanism to prevent inadvertent, momentary electrical disruption or disconnection of the circuit

14.1.6.5. Plug and socket type connectors shall be used in safety critical or hazardous systems.

14.1.7. EGSE and Flight Hardware Grounding, Bonding, and Shielding.

14.1.7.1. Equipment shall be designed and constructed to ensure that all external parts, shields and surfaces, exclusive of radiating antennas and transmission line terminals, are at ground potential.

14.1.7.2. Shields shall not be used as current carrying ground connections, except for coaxial cables.

14.1.7.3. Circuits that operate safety critical or hazardous functions shall be protected from the electromagnetic environment to preclude inadvertent operation.

14.1.8. EGSE and Flight Hardware Cables.

14.1.8.1. Cables shall be supported and protected against abrasion or crimping.

14.1.8.2. Cables shall be located or protected so as not to present a tripping hazard.

14.1.8.3. Cables in hazardous areas shall be designed so that they do not, in and of themselves, create a hazard.

14.1.8.4. Cables shall be selected to include factors such as toxicity, combustibility and smoke production, offgassing, and compatibility with liquids in the area and environmental exposure.

14.1.9. EGSE and Flight Hardware Batteries.

14.1.9.1. EGSE and Flight Hardware Battery General Design Requirements.

14.1.9.1.1. All batteries shall be capable of being readily accessible for electrical disconnection and/or removal.

14.1.9.1.2. Battery connectors shall be designed to prevent reverse polarity.

14.1.9.1.3. The capability for reverse current to cause a hazardous condition shall be prevented. **Note**: Diodes may be used to prevent reverse current. Diodes may be placed in the battery or in external circuitry.

14.1.9.1.4. If a battery is not connected to the system, the battery terminals or connector plug shall be given positive protection against shorting. **Note**: Protection against shorting of connector terminals may be accomplished by taping or guarding with a suitable temporary connector.

14.1.9.1.5. Polarity of battery terminals shall be marked.

14.1.9.1.6. Identification. Each battery shall be permanently identified with appropriate information:

14.1.9.1.6.1. Component name.

14.1.9.1.6.2. Type of construction; for example lead-acid or nickel-cadmium.

14.1.9.1.6.3. Manufacturer identification.

14.1.9.1.6.4. Part number.

14.1.9.1.6.5. Lot and serial number.

14.1.9.1.6.6. Date of manufacture.

14.1.9.2. EGSE and Flight Hardware Lithium Batteries. The following additional requirements are applicable to lithium batteries used in flight hardware and EGSE. **Note**: Batteries that have a UL listing, intended for public use, and used in a manner consistent with the UL certification are exempt from these requirements.

14.1.9.2.1. All lithium battery designs shall be reviewed and approved by Wing Safety before arrival, usage, packing, storage, transportation, or disposal on the ranges.

14.1.9.2.2. Safety devices shall be incorporated into the lithium battery design.

Table 14.1. Safety Devices for Lithium Battery Design.

Safety devices include fuses, overpressure relief devices, overtemperature cutoff, reverse current blocking diode, current limiting resistor, or other device determined to be acceptable by Wing Safety. The following are examples of safety devices that should be incorporated into the lithium battery design: (1) the use of thermistors or fuses for each battery output; (2) placement of internal diodes between each cell, unless proven by test that any single cell cannot be driven into reversal by the remaining cells; (3) the use of shunt diode protection for cells in series; (4) the use of blocking diodes for parallel rows of cells.

14.1.9.2.3. Each electrical safety device shall have a specific quality control program approved by Wing Safety.

14.1.9.2.4. Safety critical steps and processes shall be identified during development for the manufacturing process. These points in manufacturing shall be reviewed by Wing Safety and a determination made of what points require Wing Safety approval before change and what points the Range User can approve with just notification to Wing Safety after the fact.

14.1.9.2.5. Batteries shall be designed not to create a catastrophic hazard even when the safety tests described in section **14.4** are performed.

14.1.9.3. EGSE and Flight Hardware Lithium-ion (Li Ion) Batteries. The following additional requirements are applicable to lithium-ion batteries used in flight hardware and EGSE. These Li Ion system safety requirements are applicable to any flight hardware or aerospace ground support equipment (GSE) without UL or Mine Safety Appliances

(MSA) Safety Company approval for the cells, batteries, and battery chargers approved specifically for the cell pack used. They are not applicable to Li Ion batteries used in UL or MSA-approved appliances that have Li Ion batteries as part of the certification (e.g., batteries in cell phones and computers). **Note**: Lithium-ion battery designs should address requirements contained in RTCA DO-311, *Minimum Operational Performance Standards for Rechargeable Lithium Battery Systems*.

14.1.9.3.1. Design Requirements for Li Ion Batteries/Cells.

Table 14.2. Li Ion Battery Maximum Expected Operating Pressure (MEOP) Clarification.

In the case of small cell formats (e.g., 18650, 26650, 21700 cells), purchased in large cell lots and manufactured under specifically applicable consensus industry standards, MEOP will be characterized as a quality within the context of that lot buy. If MEOP is demonstrated to be a De Minimis quality for nominal cell operation, pressure specific items do not need to be addressed.

14.1.9.3.1.1. Cell design shall have a minimum 1.5:1 burst pressure based on maximum venting pressure. The cell case shall demonstrate leak before burst characteristics. Cell burst pressure to vent pressure ratio may be tailored based on test qualification data showing consistent margin of system vent before reaching burst pressure.

14.1.9.3.1.2. Each cell and battery shall incorporate a safety-venting device or be designed and manufactured in such a manner that will preclude a violent rupture as a result of the cell venting. The design and construction of the integrated battery will not degrade or obstruct the vent.

14.1.9.3.1.3. Battery case design/cell/cell pack integration shall not impede cell safe functional operation. Battery design shall accommodate the worst case condition of cells within the battery experiencing internal pressure relief. The worst case venting condition shall be demonstrated by test or analysis.

14.1.9.3.1.4. Batteries/cells shall be evaluated for toxic, reactive, flammable and combustible materials with respect to containment and potential system collateral damage. This evaluation shall include the products if the cell case vents.

14.1.9.3.1.5. Battery and cell case design shall have a minimum 3:1 burst pressure based on operating pressure. **Note**: The cell case operating pressures shall be defined based on normal use from beginning of cell life to design end of life.

14.1.9.3.2. Test Requirements for Li Ion Batteries/Cells.

14.1.9.3.2.1. Battery/Cell Case LBB Failure Mode Qualification Testing.

14.1.9.3.2.1.1. Safety-venting shall be demonstrated by test to show that the venting operates as intended and that the vent is adequate to prevent cell/battery fragmentation.

14.1.9.3.2.1.2. Qualification tests shall be conducted on flight quality batteries to demonstrate structural adequacy of the design.

14.1.9.3.2.1.3. Nondestructive inspection (NDI) techniques and methodologies shall be identified in the acceptance test plan. **Note**: Microfocus X-ray technology may be an acceptable NDI technique to verify the integrity of the pressure relief mechanism.

14.1.9.3.2.1.4. Qualification tests shall be conducted on flight quality batteries to ensure the battery can withstand grounds environments during transportation, storage and processing.

14.1.9.3.2.1.5. The MSPSP/Safety Data Package shall state lot testing specifications for safety venting device to be reviewed and approved by Wing Safety.

14.1.9.3.2.1.6. Pressure testing. A pressure cycle test shall be conducted on battery cells. The peak pressure minimum shall be equal to the ground MEOP of the battery cells during each cycle, and the number of cycles shall be a minimum of 4 times the predicted number of ground cycles or 50 cycles, whichever is greater. After the completion of the pressure cycle test, the pressure shall be increased to actual burst of the battery cell. This pressure test may be satisfied by life cycle testing.

14.1.9.3.2.1.7. Cell Short Circuit Test.

14.1.9.3.2.1.7.1. Simulating a battery short circuit failure mode, or if a pressure relief mechanism is not provided, case integrity shall be determined under conditions simulating a battery short circuit failure mode.

14.1.9.3.2.1.7.2. After all internal electrical safety devices have been bypassed, the battery shall be shorted through a load of 0.1 ohms or less, leaving the load attached for not less than 24 hours or the cell case temperature has returned to ambient +/- 10° C.

14.1.9.3.2.1.7.3. Voltage, current, pressure, and temperature shall be continuously monitored and recorded.

14.1.9.3.3. Operational Requirements for Li Ion Batteries/Cells.

14.1.9.3.3.1. Storage of the batteries (when not installed in GSE or the spacecraft) shall be in approved battery storage locations.

14.1.9.3.3.2. Battery and cells shall be treated as always having a voltage potential, therefore, connection or disconnection of a battery shall be considered an electrical personnel hazard and a ‘spark’ potential.

14.1.9.3.3.3. Range users shall have an operational plan for battery/cell handling that includes emergency contingency operations for physical abuse incident and battery installation/removal.

14.1.9.3.3.4. Support equipment (ground or airborne) shall be verified to operate correctly prior to first operational use on the range, including all fault tolerant devices or subsystems, prior to connecting battery. Verification shall include inducing overvoltage/undervoltage/temperature extremes to the monitoring devices as intended when in use prior to connecting of the battery.

14.1.9.3.3.5. On-base transportation to the launch site should meet DoT requirements. Evidence of compliance with DoT requirements for transportation shall be provided.

14.1.9.3.3.6. External heating sources for battery/cell maintenance shall be dual fault tolerant and provide feedback monitoring capability or be analyzed for failure modes on cell/battery heating.

14.1.9.3.3.7. Charging and Discharging.

14.1.9.3.3.7.1. GSE/Flight hardware used for charging (shall prevent each cell from exceeding 4.4 volts) and discharging (driving cells to less than 0 volts) shall be dual fault tolerant. Individual cells that have an internal design which provides high rate discharge protection (e.g., positive temperature coefficient devices and internal fuses) may be considered to already have one inhibit. The GSE shall provide at a minimum one inhibit for charging/discharging control.

14.1.9.3.3.7.2. Discharging shall not take place below -20° C or above 60° C.

14.1.9.3.3.8. Battery/Cell Monitoring.

14.1.9.3.3.8.1. Battery/cell monitoring and recording is required during charging and discharging.

14.1.9.3.3.8.2. Voltages shall be recorded at least every minute for charge rates that exceed the battery capacity (e.g., if capacity is 1 Amp-Hour and charger is supplying greater than 1 Amp of current). Record voltages every 10 seconds for charge rates between 1 and 2 times battery capacity. Record voltages every second for charge rates that exceed 2 times battery capacity.

14.1.9.3.3.8.3. Charging data shall be reviewed for anomalies and verification of voltage limits.

14.1.9.3.3.8.4. Provisions shall be made for charging, monitoring, and recording each cell/cell pack with EGSE that prevents high heat, sparking and high charge/discharge current rates.

14.2. Electronic Ground Support Equipment (EGSE) Design Requirements.

14.2.1. EGSE Design Standards. The following requirements supplement the requirements specified in section **14.1**, NFPA 70, and the guidance provided in MIL-HDBK-454, Requirement 1.

14.2.2. EGSE Switches and Controls.

14.2.2.1. A main power switch shall be provided to cut off power to all circuits in the equipment. A power indicator light shall be provided. If fault isolation switches are incorporated, they shall not operate independently of the main power switch.

14.2.2.2. Power switches shall be located so that accidental contact by personnel cannot place equipment in operation.

14.2.2.3. All switches and controls shall be clearly marked.

14.2.2.4. Switches and controls shall be sufficiently separated and protected if they could be inadvertently actuated, creating a hazardous condition.

14.2.2.5. Critical switches that can produce or induce hazardous conditions if inadvertently activated shall have a protective cover over them.

14.2.3. EGSE Circuit Protection.

14.2.3.1. Protective devices shall be provided for EGSE primary circuits. **Note**: Protective devices include fuses and circuit breakers that are suitable to provide overload/short circuit protection.

14.2.3.2. Protective devices shall be connected to the load side of the main power switch unless neutral power sensing is essential for proper protection of the equipment.

14.2.3.3. Protection shall be provided in each of the three ungrounded conductors of all three-phase EGSE motors so that failure of one conductor shall result in de-energizing all three conductors.

14.2.3.4. All safety devices shall be located for easy access. **Note**: Safety devices include fuses, circuit breakers, resets, and others.

14.2.3.5. Circuit breaker trips shall be detectable by visual inspection.

14.2.3.6. Replaceable components and test points shall be readily accessible.

14.2.3.7. Electrical fuse and switch boxes shall be properly marked to show the voltage present, rated fuse capacity, and EGSE that the circuit controls. **Note**: Outside marking should be made on enclosures to identify the existence of a safety protective device within the enclosure. The safety device rating should be marked on the outside or inside of the enclosure/switchbox.

14.2.3.8. Each redundant EGSE circuit shall have its own circuit breaker or fuse.

14.2.3.9. Each circuit shall not have the capability to inhibit, by loss of control, more than one safety critical control device.

14.2.3.10. Megohm meters (megger high voltage resistance meters) shall be current limited depending on application. **Note**: Fuses or equivalent devices may be used as current limiting devices, as applicable.

14.2.4. EGSE Cables. EGSE cables shall not share the same trench as propellant lines.

14.2.5. EGSE Batteries.

14.2.5.1. Sufficient ventilation shall be provided for EGSE batteries that produce flammable gasses to ensure concentrations of vapor do not reach 25% of the lower explosive limit (LEL).

14.2.5.2. Polarity of EGSE battery terminals shall be marked.

14.2.6. EGSE for Charging Flight and EGSE Batteries.

14.2.6.1. Battery charging EGSE shall be current limited by design and shall provide protection and monitoring to prevent battery damage or failure. **Note**: For protection of the battery, the EGSE battery charging equipment charging rate should not be able to initiate or sustain a run-away failure of the battery. A temperature monitoring system should also be used in addition to other methods of charge control to protect the battery.

14.2.6.2. Analysis or testing shall be conducted to demonstrate compliance with the requirements of paragraph **14.2.6.1**.

14.2.7. Fixed and Portable EGSE in Hazardous Locations.

14.2.7.1. General. At a minimum, electrical equipment and its installation shall comply with the requirements of the most recent edition of the NFPA 70 (NEC). Wing Safety shall approve exceptions.

14.2.7.2. Definition of Hazardous (Classified) Locations. Hazardous (Classified) locations are defined in NEC Article 500, *Hazardous (Classified) Locations*.

14.2.7.3. Explosives and Propellants Not Covered in NEC Article 500. For range installations, the following paragraphs define the minimum requirements to be applied in the definitions of locations in which explosives, pyrotechnics, or propellants are present or are expected to be present. These requirements shall be followed unless less stringent classifications are justified and approved as part of the design data submittal process. Wing Safety and the Fire Marshal shall approve all potential critical facility hazardous location designations.

14.2.7.3.1. Class I, Division 1. Complete definitions of classified locations are found in NFPA 70. These include the following locations:

14.2.7.3.1.1. Within 25 feet of any vent opening unless the discharge is normally incinerated or scrubbed to nonflammable conditions [less than 25% of lower explosive limit (LEL)]. This distance may be increased if the vent flow rate creates a flammability concern at a distance greater than 25 feet.

14.2.7.3.1.2. Below grade locations in a Class I, Division 2 area.

14.2.7.3.1.3. Locations in which flammable liquids, vapors, or gases may be present in the air during normal operations.

14.2.7.3.1.4. Locations in which there is a credible risk that ignitable concentrations of vapors or gases may be present in the air during abnormal operations due to a failure, leakage, or maintenance/repair.

14.2.7.3.2. Class I, Division 2. Complete definitions of classified locations are found in NFPA 70.

Table 14.3. Class I, Division 2 Hazardous Locations.

Class I, Division 2 usually includes locations where volatile flammable liquids or flammable gases or vapors are used but, in the judgment of Wing Safety and the Fire Marshal, would become hazardous only in case of an accident or of some unusual operating condition. The quantity of flammable material that might escape in case of an accident, the adequacy of ventilating equipment, and the total area involved are all factors that merit consideration in determining the classification and extent of each location.

14.2.7.3.2.1. Piping without valves, check valves, meters, and similar devices would not ordinarily introduce a hazardous condition even though used for flammable liquids or gases. Locations used for the storage of flammable liquids or of liquefied or compressed gases in sealed containers would not normally be considered hazardous unless also subject to other hazardous conditions.

14.2.7.3.2.2. As determined by Wing Safety and the Fire Marshal, locations may actively change classification depending on the flammable fluid system activity and configuration. For these types of locations, fixed or permanently installed electrical equipment shall be designed for the worst case hazardous environment.

14.2.7.3.2.3. Portable electrical equipment shall be designed for the worst case hazardous environment in which it will be used. Portable equipment that is not designated for use in a particular hazardous environment is not allowed in that environment.

14.2.7.3.2.4. Class I, Division 2 locations include the following equipment or areas:

14.2.7.3.2.4.1. Storage vessels (including carts and drums): 25 feet horizontally and below to grade (or below grade if below grade installations are present) and 4 feet vertically above the vessel (25 feet in any direction for hydrogen).

14.2.7.3.2.4.2. Transfer lines: 25 feet horizontally and below to grade (or below grade if below grade installations are present) and 4 feet above the line (25 feet in any direction for hydrogen).

14.2.7.3.2.4.3. Launch vehicle (liquid fueled vehicle, stage, or payload): 100 foot radius horizontally from and 25 feet vertically above (100 feet for hydrogen) the highest leak or vent source and below the vehicle to grade (or below grade if below grade installations are present).

14.2.7.3.2.4.4. Enclosed locations such as rooms, work bays, and launch complex clean rooms that are used to store and handle flammable and combustible propellants when the concentration of vapors inside the room resulting from a release of all fluids stored and handled equals or exceeds the LEL. The quantity of fluids used in the analysis to determine vapor concentration shall be the maximum amount allowed in the explosives site plan.

14.2.7.3.2.4.5. Locations adjacent to a Class I, Division 1 location into which ignitable concentrations of gases or vapors might occasionally be communicated, unless communication is prevented by adequate positive pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided.

14.2.7.3.3. Hazardous Commodity Groups. Hazardous commodities are grouped by similar characteristics.

14.2.7.3.3.1. These fuels shall be considered ignitable regardless of the ambient temperature.

14.2.7.3.3.2. The following fuels shall be categorized as follows:

14.2.7.3.3.2.1. Group B: Liquid or gaseous hydrogen.

14.2.7.3.3.2.2. Group C: Hypergolic fuels such as N2H4, MMH, UDMH, A50.

14.2.7.3.3.2.3. Group D: Hydrocarbon fuels (rocket propellant [RP] and jet propellant [JP]).

14.2.7.3.3.2.4. Exposed Solid Propellants. The atmosphere within 10 feet of exposed solid propellant shall be classified as a Class I, Division 2 location.

Table 14.4. Exposed Solid Rocket Motors.

Solid rocket motors are considered exposed in the following situations:
1. The motor nozzle is not attached and the aft end of the motor does not have a cover.
2. The motor nozzle is attached but does not have a nozzle plug.
3. The unassembled motor segments do not have front and rear covers.
4. The igniter is removed from the motor and cover is not provided.

14.2.7.4. Electrical Systems and Equipment Hazard Proofing. Electrical systems and equipment used in hazardous locations shall be designed and listed for the locations IAW the following requirements:

14.2.7.4.1. Explosion proof apparatus shall meet the requirements of NFPA 70, Article 501 for Class I, Division 1 or Division 2, and shall be listed and labeled by a nationally recognized testing laboratory per 29 CFR 1910.7, *Definition And Requirements for a Nationally Recognized Testing Laboratory*.

14.2.7.4.2. Non-incendive apparatus shall meet the requirements of NFPA 70, Article 501 and are restricted to installations in Class I locations only. They shall be listed and labeled by a nationally recognized testing laboratory such as UL, Factory Mutual (FM) Laboratories, or those accredited by OSHA under the Nationally Recognized Testing Laboratory (NRTL) accreditation program, 29 CFR 1910.7.

14.2.7.4.3. Intrinsically safe equipment and systems intended for Class I, Division 1 or Division 2 locations shall meet the requirements of the NEC Article 504, *Intrinsically Safe Systems*, and UL 913, *Standard for Safety, Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division I Hazardous Areas*, and be listed and labeled by a nationally recognized laboratory such as UL, FM, or those accredited by 29 CFR 1910.7.

14.2.7.4.4. The use of purged and pressurized electrical enclosures, designed in accordance with NFPA 496, Purged and Pressurized Enclosures for Electrical Equipment, for the purpose of eliminating or reducing the hazardous location classification as defined in NEC, Article 500 is acceptable with the following additional requirements:

14.2.7.4.4.1. The purged and pressurized enclosure shall be maintained at a nominal 1/2 inch of water unless a lower pressure is approved by Wing Safety. In no case shall the pressure in the enclosures be less than 1/10 inch of water.

14.2.7.4.4.2. Rooms into which unprotected personnel may enter shall be purged with air only.

14.2.7.4.4.3. Purged rooms and enclosures shall be provided with an audible alarm set to trigger when the pressure drops below 1/4 inch water.

14.2.7.4.5. Equipment inspected and tested to other government standards such as MIL-STD-810, *Environmental Engineering Considerations and Laboratory Testing*, may be used if approved by Wing Safety in coordination with Civil Engineering.

14.3. Electrical and Electronic Flight Hardware.

14.3.1. Electrical and Electronic Flight Hardware Design Standards. Airborne electrical and electronic equipment shall be designed to meet the intent of NFPA 70, Article 501, *Class I Locations*, to the maximum extent possible.

14.3.2. Flight Hardware Electromechanical Initiating Devices and Systems.

14.3.2.1. Electromechanical initiating devices and systems shall be evaluated to determine the associated ordnance hazard classification. **Note**: Electromechanical initiating devices and systems, including nonexplosive initiators (NEIs), are used for such purposes as structure deployment or actuation release mechanisms.

14.3.2.2. Design, test, and data requirements shall be determined by Wing Safety on a case-by-case basis.

14.3.2.3. At a minimum, the system safety fault tolerances described in **Chapter 3** and the initiating ordnance design requirements shall be addressed.

14.3.3. Flight Hardware Batteries.

14.3.3.1. Flight battery cases shall be designed to an ultimate safety factor of 3 to l with respect to worst case pressure buildup for normal operations. For flight hardware batteries with LBB failure modes, minimum burst factor of safety shall be 1.5.

14.3.3.1.1. This pressure buildup shall take into account hydraulic and temperature extremes.

14.3.3.1.2. Batteries that have chemically limited pressure increases and whose battery/cell case can be designed to withstand worst case pressure buildup in abnormal conditions can reduce the safety factor to 2:1 (ultimate) and 1.5:1 (yield). Lower factors of safety determined by a Wing Safety approved analysis can be used on a case-by-case basis. **Note**: Batteries that have nickel hydrogen chemistries are examples of batteries that have chemically limited pressure increases. Examples of abnormal conditions are direct short and extreme temperatures. Wing Safety approved analyses include fracture mechanics that can be used on a case-by-case basis.

14.3.3.2. Sealed batteries shall have pressure relief capability unless the battery case is designed to a safety factor of at least 3 to 1 based on worst case internal pressure.

14.3.3.2.1. Pressure relief devices shall be set to operate at a maximum of 1.5 times the operating pressure and sized so that the resulting maximum stress of the case does not exceed the yield strength of the case material.

14.3.3.2.2. Nickel-hydrogen batteries and/or cells that are proven by test to withstand worst case pressure buildup in abnormal conditions (such as direct short and thermal extremes that can be experienced when installed with no reliance on external controls such as heaters and air conditioning) are not required to have pressure relief capability.

14.3.3.3. Flight Hardware Batteries with LBB Failure Mode. The battery cells shall be demonstrated to have a LBB failure mode per section **12.3.2**; and when sealed battery cases are used, they shall also be demonstrated to have a LBB failure mode.

14.3.3.3.1. Flight Hardware Batteries with LBB Failure Mode Factor of Safety. Unless otherwise specified, the minimum burst factors for battery cells and sealed battery cases shall be 1.5.

14.3.3.3.2. Flight Hardware Batteries with LBB Failure Mode Fatigue-Life Demonstration. In addition to the stress analysis conducted IAW the requirements of section **12.2.5.3**, a conventional fatigue-life analysis shall be performed, as appropriate, on the unflawed structure to ascertain that the pressure vessel, acted upon by the spectra of operating loads, pressures and environments, meets the life requirements.

14.3.3.3.2.1. A life factor of 5 shall be used in the analysis.

14.3.3.3.2.2. Testing of unflawed specimens to demonstrate fatigue-life of a specific pressure vessel together with stress analysis is an acceptable alternative to fatigue test of the vessel.

14.3.3.3.2.3. Fatigue-life requirements are considered demonstrated when the unflawed specimens that represent critical areas such as membrane section, weld joints, heat-affected zone, and boss transition section successfully sustain the limit loads and MEOP in the expected operating environments for the specified test duration without rupture.

14.3.3.3.2.4. The required test duration is 4 times the specified service life.

14.3.3.3.3. Flight Hardware Batteries with LBB Failure Mode Qualification Testing.

14.3.3.3.3.1. Qualification tests shall be conducted on flight quality batteries to demonstrate structural adequacy of the design.

14.3.3.3.3.2. The following tests are required:

14.3.3.3.3.2.1. Random Vibration Testing. Random vibration testing shall be performed on batteries per the unit qualification test requirements of SMC-S-016, as tailored.

14.3.3.3.3.2.2. Thermal Vacuum Testing. Thermal vacuum test shall be performed on batteries per the unit qualification test requirements of SMC-S-016, as tailored.

14.3.3.3.3.2.3. Pressure Testing. A pressure cycle test shall be conducted on battery cells. The peak pressure shall be equal to the MEOP of the battery cells during each cycle, and the number of cycles shall be 4 times the predicted number of operating cycles or 50 cycles, whichever is greater. After the completion of the pressure cycle test, the pressure shall be increased to actual burst of the battery cell. The actual burst pressure shall be greater than or equal to 1.5 times MEOP of the battery cell. For batteries having sealed cases, similar tests shall be conducted on the sealed cases, if applicable.

14.3.3.3.4. Flight Hardware Batteries with LBB Failure Mode Acceptance Test Requirements.

14.3.3.3.4.1. Acceptance tests shall be conducted on batteries before being committed to flight.

14.3.3.3.4.2. The following tests are required:

14.3.3.3.4.2.1. Proof Pressure Test. Whenever feasible, battery cells shall be proof pressure tested to 1.25 times the MEOP of the cells. For sealed battery cases, pressure tests shall be performed at a level of 1.25 times the MEOP of the cases.

14.3.3.3.4.2.2. Nondestructive Examination. Surface and volumetric NDE techniques shall be performed after the proof pressure test.

14.3.3.3.5. Flight Hardware Batteries with LBB Failure Mode Recertification Test Requirements.

14.3.3.3.5.1. All refurbished pressure vessels shall be recertified after each refurbishment by the acceptance test requirements for new hardware to verify their structural integrity and to establish their suitability for continued service before commitment to flight.

14.3.3.3.5.2. Pressure vessels that have exceeded the approved storage environment (temperature, humidity, time, and others) shall also be recertified by the acceptance test requirements for new hardware.

14.3.3.3.6. Flight Hardware Batteries with LBB Failure Mode Special Requirements. Batteries shall be designed such that battery cells are within containment devices (or cases). These containment devices (or cases) shall be demonstrated to be able to prevent the escape of any hazardous contents over an insignificant quantity deemed acceptable by the procuring and safety agencies.

14.3.3.4. Flight Hardware Batteries with Brittle Fracture Failure Mode.

14.3.3.4.1. Batteries with battery cells exhibiting brittle fracture failure mode shall meet the requirements defined in section **12.4.3**.

14.3.3.4.2. In addition, a thermal vacuum test shall be conducted as part of the qualification testing.

14.4. Test Requirements for Lithium Batteries .

Table 14.5. Lithium Batteries.

Lithium batteries are thermal batteries, also called molten salt batteries. Lithium batteries are different from Li-ion batteries, even though they both contain the element Lithium. Lithium batteries are primary cell batteries, that is, batteries where the electrochemical reaction is not reversible.

14.4.1. Unless otherwise agreed to by Wing Safety, the following tests shall be performed before the use or storage of lithium batteries at the ranges. These tests are likely to cause violent reactions, so all possible safety precautions shall be observed. **Note**: Batteries that have a UL listing and are intended for public use are exempt from these requirements.

14.4.2. Lithium Battery Constant Current Discharge and Reversal Test.

14.4.2.1. The constant current discharge and reversal test shall determine if the pressure relief mechanism functions properly or case integrity is sustained under circumstances simulating a high rate of discharge.

14.4.2.2. The test shall be performed according to the following criteria:

14.4.2.2.1. The test shall consist of a constant current discharge using a DC power supply.

14.4.2.2.2. The fusing of the battery shall be bypassed (shorted).

14.4.2.2.3. The discharge shall be performed at a level equal to the battery fuse current rating and the voltage of the battery.

14.4.2.2.4. After the battery voltage reaches 0 volts, the discharge shall be continued into voltage reversal at the same current for a time equivalent to l.5 times the stated ampere-hour capacity of the battery pack.

14.4.2.2.5. Voltage, pressure, and temperature shall be continuously monitored and recorded.

14.4.3. Lithium Battery Short Circuit Test.

14.4.3.1. The short circuit test shall determine if the pressure relief mechanism functions properly under conditions simulating a battery short circuit failure mode; or if a pressure relief mechanism is not provided, case integrity shall be determined under conditions simulating a battery short circuit failure mode.

14.4.3.2. The test shall be performed according to the following criteria:

14.4.3.2.1. After all internal electrical safety devices have been bypassed, the battery shall be shorted through a load of 0.0l ohms or less, leaving the load attached for not less than 24 hours.

14.4.3.2.2. Voltage, current, pressure, and temperature shall be continuously monitored and recorded.

14.4.4. Lithium Battery Drop Test. A drop test shall be performed according to the below criteria. **Note**: Other tests may be required by Wing Safety depending upon design, storage, operating environments, and other criteria. If required, additional tests shall be identified by Wing Safety during the SRR and PDR. Manufacturing lot acceptance tests may be required of safety devices in the battery design to ensure safety critical functions have not been altered.

14.4.4.1. The battery in the activated state shall be dropped from a 3-foot height to a concrete pad on the edge of the battery, on the corner of the battery, and on the terminals of the battery.

14.4.4.2. The battery shall not vent or start a hazardous event when dropped.

14.4.4.3. A physical analysis shall be performed after the drop test to determine what handling procedures are required to safely dispose of the batteries if dropped on the ranges.

14.5. Electrical and Electronic Equipment Data Requirements . Flight hardware data shall be submitted IAW the requirements of Attachment 2, **A2.2.4.8**. EGSE data shall be submitted IAW the requirements of Attachment 2, **A2.2.5.10**.

Chapter 15

MOTOR VEHICLES.

15.1. General.

15.1.1. For purposes of this chapter, the term motor vehicles encompasses conventional trucks, truck-tractors, trailers, tankers, and lift trucks and special-purpose trailers intended for exclusive use on the range only.

15.1.2. These design, test, and documentation requirements apply to motor vehicles used for general purposes and to transport critical hardware or bulk hazardous materials such as toxics, flammables, combustibles and explosives, and hazardous commodities on CCAFS/VAFB roads and tracks.

15.1.3. Hazardous commodities not listed in NFPA 497 shall be evaluated by Wing Safety for appropriate hazard classification on a case-by-case basis.

15.2. Motor Vehicles Other Than Lift Trucks.

15.2.1. General Design Standards.

15.2.1.1. Motor vehicles that do not meet DOT public transportation requirements shall not be permitted to transport hazardous materials on the ranges unless the vehicle is covered by a formal DOT exemption and is approved by Wing Safety.

15.2.1.2. Motor vehicles for the transport of explosives shall conform to AFMAN 91-201 and DESR 6055.09.

15.2.1.3. Special-purpose trailers for range use only shall conform to AFMAN 91-201 and DESR 6055.09.

15.2.1.4. If the motor vehicle is not exempted from DOT and DoD requirements, the following data shall be submitted to Wing Safety for review and approval before using the vehicles on the ranges:

15.2.1.4.1. Design, test, and NDE inspection requirements for vehicles.

15.2.1.4.2. A FMECA shall be performed unless it can be demonstrated to the satisfaction of Wing Safety that a FMECA is not required.

15.2.1.4.3. Engineering documentation such as analyses (performance, stress, SFPs), tests, and inspections that justifies acceptance of DOT noncompliances based on "equivalent safety" or "meets DOT intent" criteria.

15.2.2. Special-Purpose Trailers Used to Transport Critical or Hazardous Loads Design Requirements.

15.2.2.1. Trailers and their ancillary support equipment such as outriggers and support stands shall be designed with a yield factor of safety of at least 2 based on limits loads and material minimum yield strength and 1.5 against overturning at worst case conditions expected at the ranges.

15.2.2.2. Load test tags shall be attached to the trailer and marked with the following minimum information:

15.2.2.2.1. Part number.

15.2.2.2.2. Date and weight of most recent load test (or date of next load test).

15.2.2.2.3. Rated load.

15.2.2.2.4. Date of most recent NDE (or date of next NDE).

15.2.3. Special-Purpose Trailers Used to Transport Critical or Hazardous Loads Tests.

15.2.3.1. Initial Tests. At a minimum, the following tests shall be performed before first operational use at the ranges:

15.2.3.1.1. Road/load test at 125% rated load at typical range terrain and design speeds for selected applications.

15.2.3.1.2. Volumetric and surface NDE shall be performed on all SFP components and SFP welds and 10% of non-SFP welds located in the load path before and after the road/load test.

15.2.4. Motor Vehicles Used to Transport Critical or Hazardous Loads Data Requirements. Data requirements shall be submitted IAW the requirements of Attachment 2, **A2.2.5.17**.

15.3. Lift Trucks.

15.3.1. Lift Truck Standards.

15.3.1.1. Lift trucks shall be in accordance with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation* and UL 583, *UL Standard for Safety Electric-Battery-Powered Industrial Trucks*.

15.3.1.2. Lift trucks used to transport explosives and propellants or operate in explosive and propellant locations shall also meet the requirements of AFMAN 91-201 and DESR 6055.09.

15.3.2. Lift Truck General Design Requirements.

15.3.2.1. Lift trucks shall be equipped with shoulder-high wing safety seats with seatbelts.

15.3.2.2. Personnel platforms attached to lift trucks shall be designed and tested IAW section **6.4**.

15.3.3. Lift Truck Tests. Lift trucks shall be tested in accordance with ASME/ITSDF B56 Series Safety Standards, NFPA 505 and UL 583.

15.3.4. Lift Truck Data Requirements. Data requirements shall be submitted IAW the requirements of Attachment 2, **A2.2.5.17**.

Chapter 16

COMPUTER SYSTEMS AND SOFTWARE.

16.1. General.

16.1.1. The requirements for computer systems and software that are used to control and/or monitor operations identified as safety critical are described below. The software safety effort shall be an integral portion of the Range User system safety program. The relationship between the software safety effort and the other elements of the system safety program will be addressed in a program-specific System Safety Program Plan (SSPP). **Note**: These requirements are not intended to be used as a checklist; instead, they are to be used in conjunction with the system safety hazard analysis process specified in AFSPCMAN 91-710 Volume 1, Attachment 3, as tailored in the specific program's SSPP.

16.1.2. The requirements shall be tailored to the system or system type under development. Unless specifically excluded by Wing Safety, these requirements shall apply to all computer systems and subsystems that perform safety critical functions during the assembly, handling, checkout, test, and launch of missiles and space vehicles. **Note**: These systems and subsystems include auxiliary support equipment (such as cranes and ground transport), vehicle ground support equipment (such as fuel and oxidizer), and airborne systems.

16.1.3. In addition to contractor-developed computer systems and software, these requirements apply to specific code implementations and technologies, and other software products (e.g., open source, commercial off-the-shelf (COTS), government off-the-shelf (GOTS), programmable logic controllers (PLCs), firmware such as erasable programmable read only memory (EPROM or EEPROM), reused code).

Table 16.1. Firmware, COTS, GOTS and Reused Software.

Chapter 16, in its entirety, applies to all forms of software and firmware; however, special attention should be paid to the following: Firmware (e.g., EPROMs or EEPROMs) should contain unique version identifiers and be validated via checksum or some other method before installation and use. COTS, GOTS and reused software should be examined and evaluated as to their appropriateness for the intended use. Unused portions of reused software should be removed.

16.1.4. Software shall be classified, designed, developed, tested and assessed for risk in accordance with MIL-STD-882E, which in turn references the *Joint Software Systems Safety Engineering Handbook* (JSSSEH) for further details. Joint Services – Software Safety Authorities *Software System Safety – Implementation Process and Tasks Supporting MIL-STD-882E* (JS-SSA-IG), provides implementation details and options for how developers can take the requirements of MIL-STD-882E and the guidance of the JSSEH to define processes and tasks required for a compliant software safety program. Software design, development and testing shall be conducted according to a software safety plan which is integrated into the overall System Safety Program.

16.2. Determination of Safety Significant Software Functions and Level of Rigor .

16.2.1. The Range User shall identify all of the following:

16.2.1.1. All software contributions to system hazards. Safety-significant functions shall be positively identified in hardware, software, and firmware domains.

Table 16.2. Safety Significant Software Functions.

Safety-significant is a term applied to a condition, event, operation, process, or item that is identified as either safety-critical or safety-related. Safety-critical applies when the mishap severity consequence is either catastrophic or critical, and safety-related applies when the mishap severity consequence is either marginal or negligible. It is recommended that safety critical functions (SCF) be identified and agreed to by Wing Safety very early in the program along with detailed documentation. SCFs are defined as any computer system function that, (1) if not performed, (2) if performed out of sequence, or (3) if performed incorrectly, may directly or indirectly cause a safety hazard to exist.

16.2.1.2. The safety requirements associated with safety-significant software components and safety-related items.

16.2.1.3. All safety-critical functions, which include, but are not necessarily limited to:

16.2.1.3.1. Software used to control and/or monitor safety-critical systems.

16.2.1.3.2. Software used for fault detection in safety-critical computer hardware or software.

16.2.1.3.3. Software used to transmit safety-critical data, including time-critical data and data about hazardous conditions.

16.2.1.3.4. Software that responds to the detection of a safety-critical fault.

16.2.1.3.5. FTS software (ground systems). **Note**: Airborne FTS software is addressed in RCC 319.

16.2.1.3.6. Software that computes safety-critical data.

16.2.1.3.7. Software used to access safety-critical data.

16.2.1.3.8. Processor interrupt software associated with previously designated safety-critical computer system functions.

16.2.1.4. The mapping to the architecture, interfaces, and designs of safety-significant functions.

16.2.1.5. The identification of the software assurance process as it relates to developing safe software using a software control category (SCC), software safety criticality level, and level of rigor (LOR) approach to software development and testing.

16.2.1.6. The identification of how defined safety-significant functions possess the appropriate integrity within the design (as defined by the level of rigor tasks) for fault detection, isolation, annunciation, tolerance, and recovery.

16.2.2. Safety-significant software functions (SSSF) shall be assigned a software criticality index (SwCI) based on severity and SCC, as outlined in MIL-STD-882E, Table V – Software Safety Criticality Matrix. Derivation of criticality shall be based on both requirements and concept of operations. **Note**: It is recommended that SwCI 1 software functions be avoided and that additional levels of protection be implemented as a preferred means of hazard mitigation strategy. At SwCI 3 or above, configuration control must apply to the smallest compiled module or unit.

16.2.3. Application of LOR shall be based on SwCI in accordance with Appendix A of the JS-SSA-IG, as tailored by the program. Appendix A LOR requirements specify minimum design, analysis, development, test, inspection, and data requirements for safety software. Single-point failure analysis shall account for potential system failures due to software and its interaction with other software components, hardware components, and human components of the system.

Table 16.3. Level of Rigor Lessons Learned.

Failure to achieve all LOR requirements will result in safety program requirements to re-assess risk with missing or deficient artifacts or processes. Failure to achieve all LOR requirements does not mean increased risk but unknown uncharacterized software behavior that may increase safety risk. If the safety system is susceptible to security vulnerabilities, then consultation with security personnel may be warranted to discuss the security concerns during the planning phase and tailoring. If security implementations would adversely affect personnel or public safety, preference must be given to the safety software.

16.3. Hardware and Software Safety Design Requirements. The following subparagraphs identify general hardware and software requirements that shall be met for all safety critical computer system functions.

16.3.1. Computer Systems.

16.3.1.1. Computer systems shall be validated for operation in the intended environment. **Note**: Validation of central processing unit (CPU) functionality should be based on testing.

16.3.1.2. Under maximum system loads, CPU throughput shall not exceed 80% of its design value. **Note**: Although CPU throughput of 80% is acceptable, experience has shown that a value of 70% is desirable.

16.3.1.3. Computer system architecture shall be single failure fault tolerant.

16.3.1.3.1. No single software fault/output shall initiate a hazardous operation. **Note**: Safety will also be enhanced if the system is designed so that memory locations not intended to be used during a particular operation will tend to bring the system to a safe or stable state if inadvertently accessed.

16.3.1.3.2. No single software fault/output shall cause a critical accident.

16.3.1.3.3. No single or double software fault/output shall cause a catastrophic accident.

16.3.1.3.4. Fulfilling the following requirements in addition to the other requirements in **Chapter 16** shall constitute meeting the computer system requirements in paragraphs **16.3.1.3.1** through **16.3.1.3.3** above. Range Users shall identify and provide the following items to Wing Safety:

16.3.1.3.4.1. All hazardous operations that can be triggered by software, either intentionally or unintentionally.

16.3.1.3.4.2. All critical accidents that can be triggered by software.

16.3.1.3.4.3. All catastrophic accidents that can be triggered by software.

16.3.1.3.4.4. Scenarios where a single software fault/output can create a condition that can trigger a hazardous operation or critical accident. Consideration shall be given to data integrity, memory use, timeliness and correct sequencing of data, and situations where the interaction of modules, hardware, software, and/or users may be problematic.

16.3.1.3.4.5. Scenarios where a single or double software fault/output can produce a condition that can trigger a catastrophic accident.

16.3.1.3.4.6. Analyses and test reports that verify the capability to monitor the system during runtime to ensure the faulty conditions are corrected.

16.3.1.4. Safety critical computer system function flight architecture that will be exposed to cosmic radiation shall protect against CPU single event upset (SEU) and other single event effects (SEE). An SEU occurs when an energetic particle travels through a transistor substrate and causes electrical signals within the transistor. **Note**: SEUs can be protected against through redundancy, error correcting memory, voting between parallel CPUs, or other approved approaches.

16.3.1.5. Sensitive components of computer systems shall be protected against the harmful effects of electromagnetic radiation and/or electrostatic discharge.

16.3.1.6. As agreed to by Wing Safety, the computer system shall periodically verify that safety critical hardware and SCFs, including safety data transmission, are operating correctly.

16.3.2. Computer System Power.

16.3.2.1. Computer systems shall be powered up and/or restarted in a safe state.

16.3.2.2. A computer system shall not enter a hazardous state as a result of an intermittent power transient or fluctuation.

16.3.2.3. In the event of the single failure of primary power to a computer system or computer system component, that system or some cooperating system shall take action automatically to transition to a stable state. **Note**: In the context of response to failure or retreat from some unsafe state, a stable state is the safest possible state that can be achieved without causing a more hazardous state to occur during that transition.

16.3.2.4. Software used to power up safety critical systems shall power up the required systems in a safe state.

16.3.3. Computer System Anomaly and Failure Detection.

Table 16.4. Anomaly and Failure Detection Alerts.

In addition to those anomalies listed, software should be designed to alert appropriate operators to such things as:
CPU running at greater than 80% of specified load.
Pending memory overflow.
Pending buffer overflows.

16.3.3.1. Before initiating hazardous operations, computer systems shall perform checks to ensure that they are in a safe state and functioning properly. These checks include checking safety critical circuits, components, inhibits, interlocks, exception limits, safing logic, memory integrity, and program loads.

16.3.3.2. The following hazardous conditions and failures, including those from multiple sources, shall be detected:

16.3.3.2.1. Invalid input data or sequences of data passed to software modules, either by human input, other software modules, or external inputs.

16.3.3.2.2. Invalid data output from software modules that are outside a specified range for safe operation.

16.3.3.2.3. Timing errors that cause software-timed events to violate specifications.

16.3.3.2.4. Data transmission errors.

16.3.3.2.5. Loss of memory integrity.

16.3.3.2.6. Greater than allowed safe input data rates.

16.3.3.2.7. The existence of an invalid pattern for a critical value, regardless of its storage location.

16.3.3.2.8. Exceptions, such as “divide by zero” or “file not found.”

16.3.3.2.9. Data transfer messages corrupted or not in the proper format.

16.3.4. Computer System Anomaly and Failure Response.

16.3.4.1. All events mentioned in section 16.3.3 shall be reported to the appropriate system operator consoles in real time, prioritized as to severity, and logged to an audit file.

Table 16.5. Safety Critical Function (SCF) Display Alerts.

Displays that support SCFs can vary widely but every attempt should be made to ensure that the operators are alerted to the most important anomalies. A method of prioritization is necessary. For example, anomalies of the same priority should be grouped together; all warnings displayed first, cautions next, and advisories last. The most recent anomaly should be displayed at the top of the priority subgroup. Details of each anomaly should be accessible with a single operator action.

16.3.4.1.1. The display shall distinguish between read and unread anomaly alerts.

16.3.4.1.2. The display shall support reporting multiple anomalies.

16.3.4.1.3. The display shall distinguish between anomaly alerts for which corrective action has been taken and those that are still pending.

16.3.4.2. Upon detecting an event described in section **16.3.3**, the software shall remain in or revert to a stable state.

16.3.4.3. Upon detecting a failure during vehicle processing, the software shall maintain the FTS in its current state in addition to meeting the requirements in section **16.3.4.1** and paragraph **16.3.4.2** above.

16.3.4.3.1. The software shall maintain the FTS in the safe state before arming.

16.3.4.3.2. After the FTS is armed, the software shall retain the FTS in the armed state.

16.3.4.3.3. When the FTS receiver is on internal power, the software shall maintain the FTS receiver on internal power.

16.3.5. Computer System Testing and Maintenance.

16.3.5.1. Non-operational hardware and software required for testing or maintenance shall be clearly identified.

16.3.5.2. Systems shall include interlocks, as necessary, to mitigate hazards when performing maintenance or testing.

16.3.5.3. Interlocks shall be designed to prevent an inadvertent override.

16.3.5.4. Interlocks that are required to be overridden shall not be autonomously controlled by a computer system, unless dictated by a timing requirement.

16.3.5.5. Interlocks that are required to be overridden and are autonomously controlled by a computer system shall be designed to prevent an inadvertent override.

16.3.5.6. The status of overridden interlocks shall be displayed on the appropriate operator console(s).

16.3.5.7. A positive indication of interlock(s) restoration shall be provided and verified on the appropriate operator console(s) before restoring a system to its operational state.

16.4. Software Requirements.

16.4.1. Software Test Requirements.

16.4.1.1. SCF software test documentation shall be coordinated with Wing Safety. SCF software testing shall be conducted IAW the approved test plan and include the following:

16.4.1.1.1. Reaction of software to system (hardware, software, or combination of hardware and software) errors or failures.

16.4.1.1.2. Boundary conditions (in, out, crossing).

16.4.1.1.3. Critical values (e.g., singularities and behavior around singularities such as crossing over a singularity or approaching a singularity from either direction).

Note: For example, zero is a special case of a more general issue in that certain numeric representations may cause a fault (e.g., floating point exception).

16.4.1.1.4. Minimum and maximum input data rates in worse case configurations.

16.4.1.1.5. Regression testing for changes to SCF software code.

16.4.1.1.6. Operator interface/human errors during SCF operations.

16.4.1.1.7. Error handling.

16.4.1.1.8. Special features such as partitioning upon which the protection of SCF features is based.

16.4.1.1.9. Formal testing for software to include analysis and documentation (software analysis, test plan, and test report).

16.4.1.1.10. Test coverage for all execution paths; with all statements executed at least once and every branch tested at least once.

16.4.1.1.11. A revised inventory, relative to software CDR, of safety critical data (local and configuration) and non-safety critical data along with justification for the partitioning. Justification should be based on safety analysis performed and defined system engineering processes.

16.4.1.1.12. Revised analysis results, relative to software CDR, for safety critical data analysis performed, including verification of data items between and within software modules, reaction of the software system to faults and transformation of fault types between system elements, and the progression of data through the system. Software analysis tools should be used to the greatest extent practical.

16.4.2. Software Coding Practices. The Range User/software developers should apply the software coding practices described in the JSSEH. **Note**: Experience has indicated that computer systems architectures that contain separate instruction and data memory and buses, or separate program memory and data memory through memory protection hardware, segment protection, or page protection prove useful for risk mitigation.

16.4.3. Human-Computer Interface.

16.4.3.1. General human-computer interface requirements are found in the Global Information Grid (GIG) Technical Guidance Federation. **Note**: MIL-STD-1472, *Human Engineering*, provides requirements for displays and controls designated specifically for government operator use.

16.4.3.2. The system shall be designed such that the operator may exit current processing to a known stable state with a single action. **Note**: Care should be taken to prevent the operator from inadvertently initiating a hazardous operation; therefore, the "single action" should be designed to minimize that possibility.

16.4.3.3. Computer systems shall minimize the potential for inadvertent actuation of hazardous operations.

16.4.3.4. Only one operator at a time shall control safety critical computer system functions.

16.4.3.5. Operator-initiated hazardous functions shall require two or more independent operator actions.

Table 16.6. Examples of Acceptable Actions to Initiate a Hazardous Operation.

Examples of acceptable actions to initiate a hazardous operation are:
Pressing a key which produces an alert to notify the operator of the impending hazardous operation, followed by a second keystroke to invoke the operation.
Removal of a physical block such as a switch cover followed by flipping the switch.
Moving a cursor on a display monitor to a desired position to highlight a selection, followed by clicking to confirm and accept the highlighted selection.

16.4.3.6. Software shall provide confirmation of valid command and/or data entry to the operator.

16.4.3.7. Software shall provide two different sensory feedback methods to the operator that indicates command receipt and status of the operation commanded. **Note**: The system should provide both visual and aural feedback to ensure the operator knows that the system has accepted the action and is processing it.

16.4.3.8. Software shall provide the operator with real-time status reports of operations.

16.4.3.9. Error messages that distinguish safety critical states/errors from non-safety critical states/errors shall be provided.

16.4.3.10. The system shall ensure that a single failure or error cannot prevent the operator from taking safing actions.

16.4.4. Software Data Standards.

16.4.4.1. Software shall not use a bit pattern of all 1s or all 0s to denote the safe and arm (potentially hazardous) states.

16.4.4.2. The arm and safe states shall be represented by unique bit patterns of length at least 4 bits in such a way that the safe state pattern cannot represent the arm pattern as a result of a 1or 2-bit error.

16.4.5. Configuration Control.

16.4.5.1. The Range User shall provide a software configuration management (SCM) plan to Wing Safety. **Note**: The system should be designed to prevent or minimize the chance for inadvertent or unauthorized access to and modification of system software by system operators.

16.4.5.2. Software and firmware shall be put under formal configuration control as soon as a software baseline is established.

16.4.5.3. A Software Configuration Control Board (SCCB) shall be established to approve changes to configuration-controlled software before implementation.

16.4.5.4. A member from the system safety engineering team shall be a member of the SCCB and tasked with the responsibility of evaluating all software changes for their potential safety impact.

16.5. Computer System and Software Data Requirements. Computer system and software data shall be provided IAW Attachment 2, **A2.2.4.14** and **A2.2.5.18**.

16.6. Independent Verification and Validation (IV&V) Analysis Support.

Table 16.7. Independent Verification and Validation (IV&V) Analysis Support.

IV&V analysis support should be considered for SCFs with a serious SwCI or high risk SwCI. This determination should be based on the tailored application of the software safety standards as contained in the Range User's program specific SSPP and further defined in the software safety plan.

16.6.1. IV&V Support.

16.6.1.1. The Range User shall ensure appropriate V&V requirements are established at the beginning of the program to ensure proper implementation of software safety requirements. This includes an assessment of the scope and level of IV&V to be planned and implemented based on the level of criticality and risk of the software application.

16.6.1.2. IV&V shall be performed by an independent third (3rd) party. The assessor shall not be part of the developer's company or its subsidiaries unless specifically approved by Wing Safety, given sufficient separation exists and can be demonstrated.

16.6.1.3. The IV&V process shall begin during the definition phase and encompass the requirements, design, development, operational evaluation and test, and life cycle program phases.

16.6.1.4. Efforts of V&V used to identify where IV&V is required shall encompass:

16.6.1.4.1. Validation that software-to-software interfaces and software-to-hardware interfaces have been correctly implemented.

16.6.1.4.2. Independent analysis program to evaluate selected hardware, software, firmware and interfaces to demonstrate the algorithms and logic are correctly implemented.

16.6.1.4.3. Model and simulation of selected hardware, software, firmware and interfaces to demonstrate compliance to system and operational requirements.

16.6.1.5. IV&V shall report and track through closure all anomalies throughout the development and operational implementation process.

16.6.1.6. All serious and high risk SwCI anomalies shall be closed with Wing Safety approval prior to use of SwCI at the range. Unverifiable failures that cannot be tracked to a specific piece of hardware or software shall be documented as such. Unverifiable failures shall be documented with any analysis done, special testing performed, configuration of the system at the time of the failure, and any other applicable information for the future.

Chapter 17

WR SEISMIC DESIGN.

17.1. Western Range (WR) Seismic Design Requirement Overview.

17.1.1. Local geological structure determines seismic zone determination (1 through 4), considering the potential severity, frequency, and damage of a seismic event. The WR is in seismic zone 4, the most severe seismic region. The probability of the WR being exposed to a severe earthquake is substantial enough to require taking specific mitigating design measures. This chapter identifies equipment seismic design requirements. Equipment includes aerospace ground equipment (AGE), ground support equipment (GSE), and ground support systems (GSS). For simplification, the terms equipment and/or GSE are used in this chapter to include AGE, GSE, and GSS

17.2. Applicability of Design and/or Anchorage or Restraint Requirements.

17.2.1. Equipment needed or required for post-earthquake recovery, essential equipment (per code definition), or safety critical equipment, shall be designed to remain operational or revert to a “safe mode” during a seismic event, and to be operational immediately following a seismic event. This equipment shall be designed with an importance factor of 1.5 (I = 1.5). **Note**: Based on the Range User analysis, an importance factor of 1.0 may be used if the equipment is not essential to life safety or mission critical. Wing Safety must concur with the results of the analysis.

17.2.2. Equipment whose failure or excessive deflections during a seismic event could propagate to a catastrophic event or endanger personnel, is a high-pressure system, or is a system used to store hazardous or toxic materials shall be designed and anchored to withstand a seismic event. The equipment need not remain operational after the seismic event as long as personnel and environmental safety is preserved; however, equipment whose failure could result in a catastrophic event or endanger personnel shall be designed to revert to an established “safe mode” in the event of a seismic event.

17.2.3. Equipment whose movement could propagate to a catastrophic event, block personnel egress avenues, or injure personnel shall be secured to prevent movement.

17.2.4. Transportation equipment shall be stored with the casters or wheels locked or blocked. Transportation equipment shall be stored in open areas so that if movement occurs during an earthquake, the equipment shall not impact adjoining structures (for example, building columns) and propagate into a facility or equipment failure.

17.2.5. Gravity friction shall not be used to anchor or restrain equipment.

17.3. Basis for Design.

17.3.1. Seismic design of equipment, supports and/or anchorages shall be IAW the *International Building Code (IBC)*, ASCE/SEI 7, and the additional requirements specified in this publication.

17.3.2. Local geotechnical data should be used to determine site soil classification. Data may be available within 300 ft of the equipment or facility and can be used to determine the site soil classification. If a geotechnical report is too costly and not available, a site soil classification D shall be used if deemed appropriate by the range user and safety. **Note**: Site soil classification will affect the amplification of the seismic spectral response and lead to an increase in shear forces. ASCE/SEI 7 accounts for this affect by using the soil shear wave velocity and shear strength to classify the soils and the subsequent site coefficient. This can increase the seismic response coefficient by a greater than 2. Site class E and F should only be used when those soil characteristics are confirmed by a geotechnical study.

17.3.3. Appropriate seismic hazard mitigation shall be implemented for high cost computer or electronic equipment. **Note**: Where it is cost-effective, high-cost computer or electronic equipment should be mounted on seismic isolation bearings to mitigate damage during an earthquake. FEMA 74, *Reducing the Risks of Nonstructural Earthquake Damage, A Practical Guide*, should be used as a guide to reduce the risk of earthquake non-structural damage.

17.3.4. Seismic Loading and Loads Combinations.

17.3.4.1. Seismic loads for AGE/GSE shall be calculated IAW the IBC and ASCE/SEI 7.

17.3.4.2. Seismic loading shall include vertical component in addition to the horizontal component to evaluate the total earthquake load. This is accomplished per ASCE/SEI 7 by multiplying the dead load by the spectral response by 0.2 (0.2 x S_{DS} x D).

17.3.4.3. Calculation of the seismic loads shall consider dynamic amplification and the dynamic characteristics of the GSE and their supports and anchorage to ensure the proper seismic response factor is selected.

17.3.4.4. As an option, equipment anchorage loads may be designed to react to accelerations equivalent to a horizontal force of two times the equipment weight and a vertical force equivalent to 0.4 times the equipment weight applied through the equipment center of gravity. **Note**: Most GSE will be designed according to ASCE/SEI 7 Chapter 13 or 15. Chapter 13 details seismic design requirement for components permanently attached to structures and their supports. Chapter 15 details seismic design requirements for non-building structures that are self-supporting. These chapters will give response coefficient (R) for various structures and bracing.

17.3.4.5. Loads combinations shall be in accordance with IBC and ASCE/SEI 7.

17.3.5. Exemptions. GSE that meets any of the following criteria shall be exempt from seismic design and/or restraint requirements:

17.3.5.1. Internal operational elements of GSE that are confined within the GSE structure.

17.3.5.2. Man-handled GSE physically attached to flight hardware or GSE.

17.3.5.3. GSE categorized as hand tools.

17.3.5.4. GSE temporarily positioned in support of operations may be ruled exempt on a case-by-case basis as determined by Wing Safety based on the results of a risk analysis. The analysis shall address risk for catastrophic failure of the equipment or any potential catastrophic event the equipment may precipitate. These include, but are not limited to: excessive movement that may impact another hazardous system, movement that may block egress routes, release of stored energy or hazardous commodity, whether the identified equipment may be needed for post-earthquake recovery, or a tipping hazard which may present a crushing or pinching hazard.

17.3.6. Existing Equipment. For programs and/or projects planning to reuse existing GSE that does not meet the requirements in this publication, the Range User shall assess that equipment for potential risk. The Range User shall coordinate the risk assessment with Wing Safety and formulate specific risk mitigation plans for the GSE in question.

17.4. WR Seismic Data Requirements. The GSE data package shall be submitted IAW the requirements in Attachment 2, **A2.2.5.19** and shall identify the equipment and potential for seismic hazard and risk.

Chapter 18

SOLID ROCKET MOTORS AND ROCKET MOTOR SEGMENTS.

18.1. General. In addition to the requirements in **Chapter 6** and **Chapter 13** of this volume, the following data and analysis shall be provided for solid rocket motors and rocket motor segments:

18.1.1. Structural analyses for all aerospace ground equipment used to handle rocket motors and segments. This includes items such as handling rings, special breakover fixtures, air pallets, segment and motor stands, special lifting fixtures, and critical motor component installation fixtures.

18.1.2. Initial and periodic NDE plans for the aerospace ground equipment, as required in paragraph **6.2.1.3.2.1.** Single failure items and SFP welds shall be clearly identified.

18.2. Failure Mode Effects and Criticality Analysis (FMECA). A FMECA should be performed for all aspects of solid rocket segment and/or motor handling and buildup. This analysis shall include the following:

18.2.1. A risk assessment of the motor or segment igniting and possibly becoming propulsive upon mechanical, electrical, or thermal shock.

18.2.2. An assessment of the requirements for onsite NDE testing of rocket motor segment and/ or motors. X-ray or ultrasonic testing equipment failure modes, and their effect on the rocket motor/segment shall be analyzed. This analysis is particularly important for equipment used to inspect rocket motor bore.

18.3. Lightning Effects Hazard Analysis . For solid rocket segment/motor processing and storage facilities, a lightning effects hazard analysis that analyzes the effects of a lightning strike on the rocket motor segments and/or motors inside these facilities shall be performed. This analysis shall specify operational restrictions; in other words, no lifting or handling of segments or motors during lightning advisory periods.

18.4. Solid Rocket Motor and Motor Segment Data Requirements . The data requirements found in Attachment 2, **A2.2.4.9.6** shall be submitted for solid rocket motors and motor segments.

BRIAN W. KABAT, Colonel, USAF
Director of Safety

Attachment 1

GLOSSARY OF REFERENCES AND SUPPORTING INFORMATION

References

See AFSPCMAN 91-710 Vol 7, *Range Safety User Requirements Manual Volume 7 - Glossary of References, Abbreviations and Acronyms, and Terms*

Prescribed Forms

See AFSPCMAN 91-710 Vol 7, *Range Safety User Requirements Manual Volume 7 - Glossary of References, Abbreviations and Acronyms, and Terms*

Adopted Forms

See AFSPCMAN 91-710 Vol 7, *Range Safety User Requirements Manual Volume 7 - Glossary of References, Abbreviations and Acronyms, and Terms*

Abbreviations and Acronyms

See AFSPCMAN 91—710 Vol 7, *Range Safety User Requirements Manual Volume 7 - Glossary of References, Abbreviations and Acronyms, and Terms*

Terms

See AFSPCMAN 91—710 Vol 7, *Range Safety User Requirements Manual Volume 7 - Glossary of References, Abbreviations and Acronyms, and Terms*

Attachment 2

MISSILE SYSTEM PRELAUNCH SAFETY PACKAGE.

A2.1. Introduction.

A2.1.1. **Purpose** . The Missile System Prelaunch Safety Package (MSPSP) is a documentation data submittal that provides a detailed description of hazardous and safety critical ground support and flight hardware equipment, systems, and materials and their interfaces used in the launch of launch vehicles, reusable launch vehicles and payloads. It is one of the media through which missile system prelaunch safety approval is obtained.

A2.1.2. **Content** . This attachment contains the content preparation instructions for the data generated by the requirements specified in **Chapter 4**.

A2.1.3. **Applicability** . The requirements in this attachment are applicable to all launch facilities, launch vehicles, spacecraft, and reusable launch vehicle systems.

A2.1.4. **Submittal Process** . An MSPSP shall be submitted to Wing Safety by the Range User with overall responsibility for the launch vehicle, reusable launch vehicle, payload, or ground support systems. For commercial payloads, the payload MSPSP is normally submitted to Wing Safety through the launch vehicle contractor.

A2.1.5. **Final Approval** . A final MSPSP that satisfies all Wing Safety concerns addressed at the CDR shall be submitted to Wing Safety for review and approval at least 45 calendar days before the intended shipment of hardware to the range.

A2.2. Preparation Instructions.

A2.2.1. **Content** .

A2.2.1.1. The MSPSP contains technical information concerning hazardous and safety critical equipment, systems, and materials and their interfaces used in the launch of launch vehicles and payloads. Where applicable, previously approved documentation shall be referenced throughout the package.

A2.2.1.2. The MSPSP is a detailed description of the design, test, and inspection requirements for all ground support systems and flight hardware and materials and their interfaces used in the launch of launch vehicles and payloads. All schematics, functional diagrams, and operational manuals shall have well defined, standard IEEE or military specification terminology and symbols.

A2.2.2. **Format** .

A2.2.2.1. Range User format is acceptable provided the information described below is provided. Suggested formats are shown as applicable. The format presented in this attachment provides two distinct sections: Flight Hardware Systems and Ground Support Systems.

A2.2.2.2. Table of Contents and Glossary. The MSPSP shall contain a table of contents and a glossary.

A2.2.2.3. Introduction. The “introduction” section shall address the scope and purpose of the MSPSP.

A2.2.3. **General Description** .

A2.2.3.1. The "general description" section provides an overview of the launch vehicle, reusable launch vehicle, payload or ground support system as a prologue to the subsystem descriptions. The following information is included in this section:

A2.2.3.2. Physical dimensions and weight.

A2.2.3.3. Nomenclature and description of major subsystems.

A2.2.3.4. Types of motors and propellants to be used.

A2.2.3.5. Sketches and/or photographs of the launch vehicle, payload, or ground support system.

A2.2.3.6. Synopsis of each hazardous and safety critical subsystem.

A2.2.3.7. A list of hazardous subsystems addressed in AFSPCMAN 91-710 Volume 3 which are not present in the launch vehicle or payload system.

A2.2.4. **Flight Hardware Subsystems** .

A2.2.4.1. At a minimum, the "flight hardware subsystems" section shall include the following information and the specific data requirements listed in sections **A2.2.4.6** through **A2.2.4.14** below:

A2.2.4.1.1. Subsystem overview.

A2.2.4.1.2. Nomenclature of major subsystems.

A2.2.4.1.3. Function of the subsystem.

A2.2.4.1.4. Location of the subsystem.

A2.2.4.1.5. Operation of the subsystem.

A2.2.4.1.6. Subsystem design parameters.

A2.2.4.1.7. Subsystem test requirements.

A2.2.4.1.8. Subsystem operating parameters.

A2.2.4.1.9. Summaries of any Wing Safety required hazard analyses conducted.

A2.2.4.2. Supporting data shall be included or summarized and referenced as appropriate with availability to Wing Safety upon request.

A2.2.4.3. Tables, matrixes, and sketches are required for systems and component data. (See sections **A2.2.4.7.2** and **A2.2.4.7.3** below for suggestions.)

A2.2.4.4. Required analyses, test plans, and test results may be included in the MSPSP as appendixes or submitted separately. At a minimum, analyses, test plans, and test reports shall be listed, referenced, and summarized in the MSPSP.

A2.2.4.5. A list of all Wing Safety approved noncompliances.

A2.2.4.6. **Flight Hardware Structures and Mechanisms.**

A2.2.4.6.1. Flight Hardware Structures and Mechanisms General Requirements. In addition to the information required in section **A2.2.4.1**, the material properties of the main structures, mechanisms, and deployables used on launch vehicles and payloads shall be included in the MSPSP.

A2.2.4.6.2. Flight Hardware Used in Lifting Critical Loads. At a minimum, the following documentation is required:

A2.2.4.6.2.1. SFP analysis.

A2.2.4.6.2.2. NDE plan and test results for SFP components and SFP welds.

A2.2.4.6.2.3. Initial proof load test plan and test results.

A2.2.4.6.2.4. Stress analysis.

A2.2.4.7. **Flight Hardware Pressure, Propellant, and Propulsion Systems.**

A2.2.4.7.1. General Data. A detailed description of the pressure, propellant, and propulsion systems of the launch vehicle or payload shall be provided. The description shall include the information identified in section **A2.2.4.1** plus the following:

A2.2.4.7.1.1. Material compatibility analysis.

A2.2.4.7.1.2. Physical and chemical properties and general characteristics of the propellant, test fluid, and gases.

A2.2.4.7.1.3. For hazardous propellants, fluids, and gases, the following shall be submitted:

A2.2.4.7.1.3.1. Specific health hazards such as toxicity and physiological effects.

A2.2.4.7.1.3.2. Threshold limit value (TLV) and maximum allowable concentration (MAC) for eight-hour day, five-day week of continuous exposure.

A2.2.4.7.1.3.3. Emergency tolerance limits including length of time of exposure and authority for limits, (for example, Surgeon General, National Institute for Occupational Safety and Health [NIOSH], independent study).

A2.2.4.7.1.3.4. Maximum credible spill size including volume and surface area and supporting analyses.

A2.2.4.7.1.3.5. Description of hazards other than toxicity such as flammability and reactivity.

A2.2.4.7.1.3.6. Personal protective equipment to be used in handling and using the propellants when this equipment will be used during an operation, and the manufacturer, model number, and other identifying data.

A2.2.4.7.1.3.7. Manufacturer, model number, specifications, operating limits, type of certification, and general description of vapor detecting equipment.

A2.2.4.7.1.3.8. Identification of material incompatibility problems in the event of a spill.

A2.2.4.7.1.3.9. Recommended methods and techniques for decontamination of areas affected by spills or vapor clouds and hazardous waste disposal procedures.

A2.2.4.7.2. Flight Hardware Pressure, Propellant, and Propulsion System Data. The following information shall be submitted for all systems: A schematic that presents the system in a clear and easily readable form with complete subsystems grouped and labeled accordingly. The following information shall be provided in a schematic or a corresponding data sheet. **Note**: Nomenclature of each element should be made adjacent to or in the vicinity of each element.

A2.2.4.7.2.1. Identification of all pressure system components such as valves, regulator, tubes, hoses, vessels, and gauges using standard symbols. **Note**: A legend is recommended. The original mechanical drawings should be referenced.

A2.2.4.7.2.2. MOP of all systems and subsystems at expected operating temperatures.

A2.2.4.7.2.3. Identification of expected source pressures and expected delivery pressures.

A2.2.4.7.2.4. All relief valve pressure settings and flow rates.

A2.2.4.7.2.5. System fluid and maximum expected temperature.

A2.2.4.7.2.6. Pressure ranges of all pressure transducers.

A2.2.4.7.2.7. Pressure settings of pressure regulators.

A2.2.4.7.2.8. Charging pressure of reservoirs and vessels, their nominal capacities, and wall thickness.

A2.2.4.7.2.9. Pressure setting of all pressure switches.

A2.2.4.7.2.10. The nominal outside diameter and wall thickness of all tubing and piping.

A2.2.4.7.2.11. Flow path through all components. **Note**: When the system is to be used in several operating modes, it is easier to provide a separate schematic that depicts flow paths for each operating mode.

A2.2.4.7.2.12. Reference designations for each component so that a cross-reference between schematics and drawings and a pressure system component list or other documentation is possible.

A2.2.4.7.2.13. End-to-end electrical schematics of electrical and electronic components giving full functional data and current loads.

A2.2.4.7.2.14. Connections for testing or servicing.

A2.2.4.7.2.15. A narrative description of the system or subsystem and its operating modes, including a discussion of operational hazards and accessibility of components.

A2.2.4.7.2.16. A sketch or drawing of the system that shows physical layout and dimensions.

A2.2.4.7.2.17. System information shall be placed in tabular form; suggested format is shown below.

Table A2.1. Example System Data Format.

System ID Number	Number of Vessels
System Title	Recertification Date (GSE Only)
Location	Recertification Period (GSE Only)
MOP	Material(s)
Commodity	Inspection Results
Responsible Organization	ISI Requirements (GSE Only)

A2.2.4.7.3. Flight Hardware Pressure, Propellant, and Propulsion Component Design Data. The following information shall be submitted for each component:

A2.2.4.7.3.1. Identification of each component by a reference designation permitting cross reference with the system schematic.

A2.2.4.7.3.2. The MAWP for all pressure system components.

A2.2.4.7.3.3. The MOP the component shall operate at when installed in the system.

A2.2.4.7.3.4. Safety factors or design burst pressure for all pressure system components.

A2.2.4.7.3.5. Actual burst pressures, if available.

A2.2.4.7.3.6. Pre-assembly hydrostatic test proof pressure for each system component.

A2.2.4.7.3.7. If applicable, the proof pressure the component will be tested to after installation in the system.

A2.2.4.7.3.8. Materials used in the fabrication of each element in the component, including soft goods and other internal elements.

A2.2.4.7.3.9. Cycle limits if fatigue is a factor of the component.

A2.2.4.7.3.10. Temperature limits of each system component.

A2.2.4.7.3.11. Component information shall be placed in tabular form; suggested format is shown below.

Table A2.2. Example Vessels Data Format.

Vessel ID Number	Recertification Date (GSE Only)
System ID Number	Recertification Period (GSE Only)
Manufacturer Name	Cyclic Limit
Manufacturer Serial No	Test Pressure
Manufacturer Drawing No.	Vessel Design

Commodity	Material
Orig. MAWP or Design Pressure	Temperature Limits
Burst Pressure	Maximum Stress
Volume	Inside Radius
Location	Thickness
DOT Specification (GSE Only)	Dimensions
Year of Manufacture	ISI Information (GSE Only)
National Board No. (GSE Only)	ISI Results (GSE Only)
Code Stamps (GSE Only)	Recertification MAWP (GSE Only)

Table A2.3. Example Relief Devices Data Format.

ID Number	Set or Burst Pressure
System Number	System MOP
Type	System Commodity
Manufacturer	Flow Capacity
Manufacturer Part No.	Material
Code Stamps (GSE Only)	Temperature Limits
Inlet Size	Test Pressure
Manufacturer Date	ISI Requirements (GSE Only)
Outlet Size	ISI Results (GSE Only)

Table A2.4. Example Pressure Gauges and Sensors Data Format.

ID Number	System Commodity
System Number	MAWP
Manufacturer	Burst Pressure
Manufacturer Date	System MOP
Manufacturer Part No.	Inlet Size
Pressure Range	ISI Requirements (GSE Only)
Material	ISI Results (GSE Only)

Table A2.5. Example Flexible Hoses Data Format.

ID Number	Size (diameter, length)
System Number	Burst Pressure
Manufacturer	Cyclic Limit

Manufacturer Part No.	Test Pressure
Manufacturer Date	Shelf Life
Materials	ISI Requirements (GSE Only)
Temperature Limits	ISI Results (GSE Only)
MAWP/Manufacturer Rated Working Pressure	

A2.2.4.7.4. Flight Hardware Pressure, Propellant, and Propulsion Initial Test Plans and Procedures. A list and summary of all initial test plans, test procedures, and test results for all flight hardware pneumatic, hydraulic, hypergolic, and cryogenic systems, as applicable IAW **Chapter 12**.

A2.2.4.8. **Flight Hardware Electrical and Electronic Subsystems.**

A2.2.4.8.1. General Data. A detailed description of the electrical and electronic subsystems of the launch vehicle or payload shall be provided. The description shall include the information identified in section **A2.2.4.1**.

A2.2.4.8.2. Flight Hardware Battery Design Data. The following information shall be submitted for flight hardware batteries:

A2.2.4.8.2.1. Design versus actual operating parameters of cells and battery.

A2.2.4.8.2.2. Cell chemistry and physical construction.

A2.2.4.8.2.3. Cell vent parameters.

A2.2.4.8.2.4. Toxic chemical emission of cells and evaluation of hazards.

A2.2.4.8.2.5. EPA classification of the battery.

A2.2.4.8.2.6. DOT classification of the battery.

A2.2.4.8.2.7. Physical and electrical integration of cells to form the battery.

A2.2.4.8.2.8. Description of safety devices.

A2.2.4.8.2.9. Case design including vent operation and cell and battery case housing yield point.

A2.2.4.8.2.10. A description of all operations to include packing, transportation, and storage configuration; activation; installation; checkout; charging; usage; removal; and disposal.

A2.2.4.8.2.11. Identification of the hazards associated with each activity in paragraph **A2.2.4.8.2.10** above and the safety controls that shall be in effect.

A2.2.4.8.2.12. Manufacturing qualification and acceptance testing results that are considered safety critical.

A2.2.4.8.2.13. Battery size and weight.

A2.2.4.8.2.14. Specification of the system that uses the battery.

A2.2.4.8.2.15. A description of the EGSE used for packing, transportation, and storage; activation; installation; checkout; analysis; charging; usage; removal; and disposal of the battery.

A2.2.4.8.2.16. A list and summary of test plans, test procedures, and test results IAW section **14.4**.

A2.2.4.8.3. Flight Hardware Electrical and Electronic Subsystem Data. The following information shall be submitted for electrical and electronic subsystems operating in hazardous atmospheres:

A2.2.4.8.3.1. A brief description of power sources and the power distribution network, including schematics and line drawings of the distribution network.

A2.2.4.8.3.2. A description of how faults in electrical circuitry are prevented from propagating into hazardous subsystems, including such information as dedicated power sources and buses, use of fuses, and wiring sizing.

A2.2.4.8.3.3. A description of how inadvertent commands that can cause a hazardous condition are prevented.

A2.2.4.8.3.4. Identification of potential shock hazards.

A2.2.4.8.3.5. A description of how the intent of hazard proofing is met for electrical and electronic systems.

A2.2.4.8.3.6. Complete grounding and bonding methodology.

A2.2.4.8.3.7. A bent pin analysis for all connectors for safety critical or hazardous systems that have spare pins.

A2.2.4.9. **Flight Hardware Ordnance Subsystems.**

A2.2.4.9.1. General Data. A detailed description of the ordnance subsystems of the launch vehicle or space craft shall be provided. The description shall include the information identified in section **A2.2.4.1**.

A2.2.4.9.2. Flight Hardware Ordnance Hazard Classifications and Categories. The following ordnance hazard classification data shall be submitted:

A2.2.4.9.2.1. DOD/UN hazard classifications, including class, division, and compatibility group, in accordance with DESR 6055.09.

A2.2.4.9.2.2. DOT classification.

A2.2.4.9.2.3. The ordnance device and system hazard classification for each ordnance item and system; test results and/or analysis used to classify the ordnance devices and systems.

A2.2.4.9.3. Flight Hardware Ordnance System Data. The following ordnance system data shall be submitted:

A2.2.4.9.3.1. A block diagram of the entire ordnance system.

A2.2.4.9.3.2. A complete line schematic of the entire ordnance system from the power source to the receptor ordnance, including telemetry pick-off points and ground (umbilical) interfaces.

A2.2.4.9.3.3. Diagrams showing the location of all ordnance components on the vehicle.

A2.2.4.9.3.4. A description of wiring, ETS, and FOC routing.

A2.2.4.9.3.5. A description of electrical, ETS, and optical connections and connectors.

A2.2.4.9.3.6. Detailed, complete schematics of the entire ordnance system showing component values such as resistance and capacitance, tolerances, shields, grounds, connectors, and pin outs.

A2.2.4.9.3.6.1. The schematics shall include all other vehicle components and elements that interface or share common usage with the ordnance system.

A2.2.4.9.3.6.2. All pin assignments shall be accounted for.

A2.2.4.9.3.7. Detailed narrative description and functional schematic of the operation of the ordnance system. The narrative description and functional schematic shall be capable of being used to determine the configuration and resulting fault tolerance of the vehicle and ground ordnance systems at any time during prelaunch processing, launch countdown, or launch, including all credible failure scenarios.

A2.2.4.9.3.8. The FMECA for each ordnance system.

A2.2.4.9.3.9. An operational flow of the ordnance system processing and checkout, including timelines and summaries of each procedure to be used.

A2.2.4.9.3.10. A sketch showing the accessibility of manual arming and safing devices.

A2.2.4.9.3.11. Specification drawings and documents for all airborne and ground ordnance systems.

A2.2.4.9.4. Flight Hardware Ordnance Component Design Data. The following ordnance component design data shall be submitted:

A2.2.4.9.4.1. A complete and detailed description of each ordnance system component and how it functions.

A2.2.4.9.4.2. Specification drawings and documents for all airborne and ground ordnance components.

A2.2.4.9.4.3. Illustrated breakdown of all mechanically operated ordnance components.

A2.2.4.9.4.4. Part number, manufacturer, and net explosive weight for each ordnance item.

A2.2.4.9.4.5. Temperature and humidity requirements for each ordnance item.

A2.2.4.9.4.6. Bridgewire resistance, maximum safe no-fire current, and minimum all-fire current for each low voltage EED.

A2.2.4.9.4.7. Maximum no-fire voltage and minimum all-fire voltage for each EBW.

A2.2.4.9.4.8. Maximum no-fire energy and minimum all-fire energy for each LID and PAD.

A2.2.4.9.4.9. A list and summary of test plans procedures, and results, as required.

A2.2.4.9.4.10. 8 x 10 inch color photographs or electronic copies of all ordnance items. **Note**: The photographs or electronic copies should be of sufficient detail to identify individual ordnance items as well as to show the ordnance item(s) in installed configuration on the vehicle. These photographs are intended to ensure the safety of Explosive Ordnance Disposal personnel who may be directed to render the ordnance safe.

A2.2.4.9.5. Flight Hardware Ordnance Component Handling and Storage Data. Specific requirements for handling and storing the flight ordnance shall be submitted.

A2.2.4.9.6. Solid Rocket Motors and Rocket Motor Segments. In addition to the requirements listed for ordnance, the following data shall be provided for solid rocket motors and rocket motor segments:

A2.2.4.9.6.1. Propellant Properties.

A2.2.4.9.6.1.1. Propellant explosive hazard classification (DoD, DOT, including test results), if not previously addressed by paragraph **A2.2.4.9.2.1**.

A2.2.4.9.6.1.2. Propellant formulation (composition).

A2.2.4.9.6.1.3. Propellant autoignition temperature.

A2.2.4.9.6.1.4. Propellant static sensitivity (energy in Joules required to ignite the propellant).

A2.2.4.9.6.1.5. Propellant conductivity.

A2.2.4.9.6.2. Propellant Reactions to Impact on Hard Surface.

A2.2.4.9.6.2.1. Ignition threshold drop height.

A2.2.4.9.6.2.2. Low order detonation threshold drop height.

A2.2.4.9.6.2.3. Critical impact velocity (threshold velocity required to break up propellant sufficiently so that it will transit from deflagration to detonation in a 1 inch diameter schedule 40 steel pipe).

A2.2.4.9.6.3. Igniter data.

A2.2.4.9.6.3.1. Type of propellant and propellant properties data as specified in sections **A2.2.4.9.6.1** and **A2.2.4.9.6.2** above.

A2.2.4.9.6.3.2. Igniter through bulkhead initiator (TBI) data.

A2.2.4.9.6.3.3. Igniter weight.

A2.2.4.9.6.3.4. Igniter grounding provisions.

A2.2.4.9.6.3.5. Igniter storage requirements.

A2.2.4.9.6.3.6. Igniter handling requirements.

A2.2.4.9.6.3.7. Igniter testing and inspection requirements.

A2.2.4.9.6.3.8. Igniter packaging requirements (if shipped separately).

A2.2.4.9.6.4. Rocket Motor/Segment Data.

A2.2.4.9.6.4.1. Motor/segment case description, including design safety factors.

A2.2.4.9.6.4.2. Method of proof testing the rocket motor/segment case before propellant loading.

A2.2.4.9.6.4.3. Weight of propellant.

A2.2.4.9.6.4.4. Cross-section drawings showing propellant grain design details, case insulation, including physical dimensions, and joint details for segmented rocket motors.

A2.2.4.9.6.4.5. Motor/segment nondestructive testing requirements.

A2.2.4.9.6.4.6. Motor/segment storage requirements.

A2.2.4.9.6.4.7. Motor/segment handling requirements.

A2.2.4.9.6.4.8. Motor/segment grounding requirements.

A2.2.4.9.6.4.9. Description of structural, mechanical, and electrical subsystems.

A2.2.4.9.6.4.10. Description of materials and properties of seals and O-rings.

A2.2.4.9.6.5. Data submission and analysis, as described in **Chapter 18**. If these data and analysis are submitted as part of another section of the MSPSP, it is only necessary to cross-reference that analysis here.

A2.2.4.10. **Flight Hardware Non-Ionizing Radiation Sources.**

A2.2.4.10.1. General Data. A detailed description of the non-ionizing radiation sources shall be provided. The description shall include the information identified in section **A2.2.4.1**.

A2.2.4.10.2. Flight Hardware RF Emitter Data. The following information shall be submitted for RF emitters:

A2.2.4.10.2.1. Site Plans. Site plans shall be submitted to Wing Safety and the IRSO for all RF generating equipment. The site plan shall include the following information:

A2.2.4.10.2.1.1. Location of generating equipment.

A2.2.4.10.2.1.2. RF hazard areas.

A2.2.4.10.2.1.3. Description and use of nearby facilities and operating areas.

A2.2.4.10.2.2. Design and Test Data. At a minimum, the following RF emitter design and test data shall be submitted:

A2.2.4.10.2.2.1. Emitter peak and average power.

A2.2.4.10.2.2.2. Pulse widths.

A2.2.4.10.2.2.3. Pulse repetition frequencies.

A2.2.4.10.2.2.4. Pulse codes.

A2.2.4.10.2.2.5. Maximum rated duty cycle.

A2.2.4.10.2.2.6. Type and size of antenna.

A2.2.4.10.2.2.7. Antenna gain and illumination.

A2.2.4.10.2.2.8. Beam width and beam skew.

A2.2.4.10.2.2.9. Operating frequency in MHz.

A2.2.4.10.2.2.10. Insertion loss between transmitter and antenna.

A2.2.4.10.2.2.11. Polarization of transmitted wave hardware.

A2.2.4.10.2.2.12. An analysis of the RF hazard area with and without antenna hats/ dummy load, and results of any testing.

A2.2.4.10.2.2.13. A table that lists all of the RF emitters aboard a launch vehicle, payload, and ground support systems and their hazard areas (distances).

A2.2.4.10.2.2.14. A description of interlocks, inhibits, and other safety features that prevent inadvertent exposures.

A2.2.4.10.2.2.15. A copy of the IRSO approved Radiation Protection Program RF Use Request Authorization.

A2.2.4.10.2.2.16. A copy of the Wing Safety and IRSO approved site plan.

A2.2.4.10.2.2.17. A list and summary of test plans, test procedures, and test results IAW section **8.1.3**.

A2.2.4.10.3. Flight Hardware Laser System (Class 1M, 2M, 3B, and 4) Data. At a minimum, the following laser system data shall be submitted:

A2.2.4.10.3.1. A general description of the system and its operation including how, where, why, and by whom the laser will be used; the laser system also includes calibration equipment.

A2.2.4.10.3.2. Drawings of the system that identify and show the location and operation of all components, interfaces, safety interlocks, and stops.

A2.2.4.10.3.3. For lasers that generate or use hazardous or corrosive materials, the data required for hazardous materials as described in section **A2.2.4.13.2**.

A2.2.4.10.3.4. For lasers that use cryogenic fluids for cooling or operational enhancement, the data required for cryogenic systems and hazardous materials as described in section **A2.2.4.13.2**.

A2.2.4.10.3.5. For laser systems using high voltages and/or high capacitance, the data required for electrical ground support equipment as described in section **A2.2.5.10**.

A2.2.4.10.3.6. Laser System Performance Data.

A2.2.4.10.3.6.1. Type, class, nomenclature, manufacturer model number, general identification, and other pertinent information.

A2.2.4.10.3.6.2. General description of the test, pertinent drawing of the operation site, and associated equipment.

A2.2.4.10.3.6.3. Lasing material.

A2.2.4.10.3.6.4. Continuous wave (CW) or pulse identification.

A2.2.4.10.3.6.5. Wavelength.

A2.2.4.10.3.6.6. Bandwidth.

A2.2.4.10.3.6.7. Average power and/or energy per pulse and/or maximum output energy.

A2.2.4.10.3.6.8. Pulse duration and pulse rate.

A2.2.4.10.3.6.9. Beamwidth at 1/e point for both axes.

A2.2.4.10.3.6.10. A sketch of the beam pattern and location and energy density of hot spots and effects of weather and reflectivity.

A2.2.4.10.3.6.11. Beam divergence at 1/e point for both axes.

A2.2.4.10.3.6.12. Emergent beam diameter.

A2.2.4.10.3.6.13. Coolant.

A2.2.4.10.3.6.14. Amount of energy reflected back through the eyepiece or pointing device.

A2.2.4.10.3.6.15. Electrical voltage applied to the system.

A2.2.4.10.3.6.16. Any other pertinent laser parameter such as distribution of energy onbeam and scanrate as determined by the Range User or Wing Safety.

A2.2.4.10.3.6.17. Composition, color, and specularly or diffusely reflected surface characteristics of intended targets.

A2.2.4.10.3.6.18. Maximum incident energy on targets.

A2.2.4.10.3.6.19. Target characteristics including secondary hazards that may be affected by the laser, including fuels and other flammables, sensitive electronic components, FTSs, and others.

A2.2.4.10.3.6.20. Intended method (such as binoculars or spotter scope) of viewing the beam and/or its reflections.

A2.2.4.10.3.6.21. Safety devices such as interlocks, filters, shutters, and aiming devices.

A2.2.4.10.3.6.22. Azimuth and elevation and/or electrical and mechanical elevation stops.

A2.2.4.10.3.7. Hazard Evaluation Data. Analysis and supporting data outlining possible laser system failures for all phases of laser system uses shall be submitted. Such data includes the following:

A2.2.4.10.3.7.1. All critical failure modes, failure mode effects, and failure probabilities including possible effects on secondary hazards and the subsequent results.

A2.2.4.10.3.7.2. Routine occupational hazard exposure that has been experienced in the past with the system or similar systems along with recommended methods for reducing or eliminating the hazards.

A2.2.4.10.3.8. Biophysiological Data.

A2.2.4.10.3.8.1. Safe eye and skin distances based on permissible exposure limits.

A2.2.4.10.3.8.2. Safety clearance and hazard zones.

A2.2.4.10.3.8.3. Personal protective equipment required for personnel remaining inside clearance zones.

A2.2.4.10.3.9. A copy of the IRSO approved Radiation Protection Plan Laser Use Request Authorization.

A2.2.4.10.3.10. A list and summary of test plans, test procedures, and test results IAW section **8.2.3**.

A2.2.4.11. **Flight Hardware Ionizing Radiation Sources.**

A2.2.4.11.1. General Data. A detailed description of the ionizing radiation sources shall be provided. The description shall include the information identified in section **A2.2.4.1**.

A2.2.4.11.2. Flight Hardware Ionizing Radiation Subsystem Data. The following data shall be submitted:

A2.2.4.11.2.1. The final SAS as required by AFMAN 91-110 or equivalent document if non-Air Force Range User. The SAS shall be referenced in the MSPSP and submitted as an accompanying document.

A2.2.4.11.2.1.1. Status reports on the SAS approval.

A2.2.4.11.2.1.2. Verification of approval for launch by separate correspondence IAW the requirements of AFMAN 91-110 or the equivalent.

A2.2.4.11.2.2. Manufacturer of the source.

A2.2.4.11.2.3. Date of source preparation.

A2.2.4.11.2.4. Source identification number.

A2.2.4.11.2.5. Cross-sectional sketch showing dimensions of the source.

A2.2.4.11.2.6. Source container or holder construction material.

A2.2.4.11.2.7. Physical source form such as powder or plate.

A2.2.4.11.2.8. Chemical source form such as metal or oxide.

A2.2.4.11.2.9. Strength in curies.

A2.2.4.11.2.10. Type of protective cover material over the source.

A2.2.4.11.2.11. Date and result of last wipe test.

A2.2.4.11.2.12. Method of sealing against leakage.

A2.2.4.11.2.13. Radionuclide solubility in sea water.

A2.2.4.11.2.14. Description, including diagrams, showing exact placement of the source in the vehicle or payload.

A2.2.4.11.2.15. A brief description of intended use.

A2.2.4.11.2.16. Radiation levels in millirem per hour for all modes of operation and all radiation container surfaces accessible to personnel.

A2.2.4.11.2.17. Description of potential accidents that would cause release of radioactive material including potential personnel exposure and ground contamination.

A2.2.4.11.2.18. A summary of the possible consequences of a release of radioactive material at the ranges including the maximum credible release and recommendations for methods to reduce or eliminate the resulting hazards.

A2.2.4.11.2.19. Description of recovery plans for land and sea launch abort scenarios.

A2.2.4.11.2.20. Location and name of responsible organization and licensed individual assigned to supervise handling of this material.

A2.2.4.11.2.21. Detailed nuclear system design.

A2.2.4.11.2.22. Normal and potentially abnormal environments and failure modes that can affect the processing, launch, and flight of a nuclear system.

A2.2.4.11.2.23. The predicted responses of the nuclear system to processing, launch, and flight environments and failures.

A2.2.4.11.2.24. The predicted resulting nuclear risk.

A2.2.4.11.2.25. Ground support systems design data as required by the appropriate sections of this publication.

A2.2.4.11.2.26. Detailed ground processing flow.

A2.2.4.11.2.27. A copy of the IRSO approved Use Authorization as required by AFI 40-201, and any Wing Supplements/Instructions (ER only).

A2.2.4.11.2.28. A copy of the *Radiation Protection Plan* as required by Wing-specific supplements or instructions to AFMAN 91-110.

A2.2.4.11.2.29. A list and summary of test plans, test procedures, and test results IAW section **9.2.2**.

A2.2.4.11.3. Flight Hardware Ionizing Radiation Producing Equipment and Devices. The following data shall be submitted:

A2.2.4.11.3.1. Manufacturer and model number.

A2.2.4.11.3.2. A description of the system and its operation.

A2.2.4.11.3.3. A description of the interlocks, inhibits, and other safety features.

A2.2.4.11.3.4. If installed on a flight system, a diagram showing the location of the equipment or devices.

A2.2.4.11.3.5. A description of the radiation levels, in millirems per hour, accessible to personnel for all modes of operation and all surfaces accessible to personnel; levels with doors and access panels removed shall be included.

A2.2.4.11.3.6. A copy of the IRSO approved Use Authorization as required by AFI 40-201, and any Wing Supplements/Instructions, allowing the use of these radiation sources during ground processing activities (ER only).

A2.2.4.11.3.7. A copy of the *Radiation Protection Plan* as required by Wing-specific supplements or instructions to AFMAN 91-110.

A2.2.4.12. **Flight Hardware Acoustical Subsystems.**

A2.2.4.12.1. General Data. A detailed description of acoustical hazard sources shall be provided. The description shall include the information identified in section **A2.2.4.1**.

A2.2.4.12.2. Flight Hardware Acoustics Hazards Data. The following data requirements shall be submitted for acoustic hazards:

A2.2.4.12.2.1. The location of all sources generating noise levels that may result in hazardous noise exposure for personnel and the sound level in decibels on the A scale (dBA) for that noise.

A2.2.4.12.2.2. The anticipated operating schedules of these noise sources.

A2.2.4.12.2.3. Methods of protection for personnel who may exposed to sound pressure levels above 85 dBA (8-hour time weighted average).

A2.2.4.12.2.4. A copy of the Bioenvironmental Engineering approval, as applicable, stating the equipment and controls used are satisfactory.

A2.2.4.13. **Flight Hardware Hazardous Materials Subsystems.**

A2.2.4.13.1. General Data. A detailed description of the hazardous material shall be provided. The description shall include the information identified in section **A2.2.4.1**.

A2.2.4.13.2. Flight Hardware Hazardous Materials Data. At a minimum, the following hazardous materials data shall be submitted:

A2.2.4.13.2.1. A list of all hazardous materials on the flight system and used in ground processing.

A2.2.4.13.2.2. A description of how each of these materials and liquids is used and in what quantity.

A2.2.4.13.2.3. A description of flammability and, if applicable, explosive characteristics.

A2.2.4.13.2.4. A description of toxicity including TLV and other exposure limits, if available.

A2.2.4.13.2.5. A description of compatibility including a list of all materials that may come in contact with a hazardous liquid or vapor with test results provided or referenced.

A2.2.4.13.2.6. A description of electrostatic characteristics with test results provided or referenced, including bleed-off capability of the as-used configuration.

A2.2.4.13.2.7. A description of personal protective equipment to be used with the hazardous material and liquid.

A2.2.4.13.2.8. A summary of decontamination, neutralization, and disposal procedures.

A2.2.4.13.2.9. A Safety Data Sheet (SDS) for each hazardous material and liquid on flight hardware or used in ground processing; the SDS shall be available for review at each location in which the material is stored or used.

A2.2.4.13.2.10. Description of any detection equipment, location, and proposed use.

A2.2.4.13.2.11. Additional Data for Plastic Materials.

A2.2.4.13.2.11.1. Identification of the cleaning methods to be used to maintain surface cleanliness and conductivity, if applicable.

A2.2.4.13.2.11.2. Identification of the minimum acceptable voltage accumulation levels for the plastic materials or operations.

A2.2.4.13.2.11.3. Identification of the method for ensuring conductivity between adjoining pieces of the plastic materials.

A2.2.4.13.2.11.4. Assessment of the environmental effects on plastic materials such as humidity, ultraviolet light, and temperature that could cause degradation of conductivity flammability or electrostatic properties.

A2.2.4.13.2.12. A list and summary of test plans, test procedures, and test results IAW section **10.2**.

A2.2.4.14. **Computing Systems Data.** The Range User shall provide the following information to Wing Safety in the MSPSP:

A2.2.4.14.1. System description including hardware, software, and layout of operator console and displays.

A2.2.4.14.2. Flow charts or diagrams showing hardware data busses, hardware interfaces, software interfaces, data flow, and power systems.

A2.2.4.14.3. Logic diagrams, Software Design Descriptions (SDDs).

A2.2.4.14.4. Operator user manuals and documentation.

A2.2.4.14.5. List and description of all safety critical computer system functions, including interfaces.

A2.2.4.14.6. Software hazard analyses.

A2.2.4.14.7. Software Test Plans (STPs), Software Test Descriptions (STDs), and Software Test Results (STRs) in accordance with IEEE/EIA 12207.

A2.2.4.14.8. Software Development Plan (SDP) that includes discussions on conformance with applicable coding standards, configuration control, PLCs, COTS, and software reuse (for example, see Space and Missile Systems Center (SMC) Standard SMC-S-012, *Software Development*)

A2.2.4.14.9. Documentation describing Independent Validation & Verification (IV&V) process used to ensure safety requirements have been correctly and completely implemented.

A2.2.5. **Ground Support Systems.**

A2.2.5.1. At a minimum, the "ground support system" section shall include the following information and the specific data requirements listed in sections **A2.2.5.6** through **A2.2.5.19** below:

A2.2.5.1.1. Subsystem overview.

A2.2.5.1.2. Nomenclature of major subsystems.

A2.2.5.1.3. Function of the subsystem.

A2.2.5.1.4. Location of the subsystem.

A2.2.5.1.5. Operation of the subsystem.

A2.2.5.1.6. Subsystem design parameters.

A2.2.5.1.7. Subsystem test requirements.

A2.2.5.1.8. Subsystem operating parameters.

A2.2.5.1.9. Summaries of any Wing Safety required hazard analyses conducted.

A2.2.5.2. Supporting data shall be included or summarized and referenced as appropriate with availability to Wing Safety upon request.

A2.2.5.3. Tables, matrixes, and sketches are required for systems and component data. (See sections **A2.2.4.7.2** and **A2.2.4.7.3** for suggestions.)

A2.2.5.4. Required analyses, test plans, and test results may be included in the MSPSP as appendixes or submitted separately. At a minimum, analyses, test plans, and test reports shall be listed, referenced, and summarized in the MSPSP.

A2.2.5.5. A list of all Wing Safety approved noncompliances.

A2.2.5.6. **Ground Support Material Handling Equipment.** Design and test plan data for the following government and Range User furnished material handling equipment (MHE) shall be provided.

A2.2.5.6.1. General Data. A detailed description of MHE shall be provided. The description shall include the information identified in section **A2.2.5.1**.

A2.2.5.6.2. Ground Support Slings Used to Handle Critical Hardware. At a minimum, the following data is required:

A2.2.5.6.2.1. SFP analysis.

A2.2.5.6.2.2. NDE plan and test results for SFP components.

A2.2.5.6.2.3. Initial proof load test plan and test results.

A2.2.5.6.2.4. Stress analysis.

A2.2.5.6.3. Ground Support Below-the-Hook Lifting Devices Used to Handle Critical Hardware. At a minimum, the following documentation is required:

A2.2.5.6.3.1. SFP analysis.

A2.2.5.6.3.2. NDE plan and test results for SFP components.

A2.2.5.6.3.3. Initial proof load test plan and test results.

A2.2.5.6.3.4. Stress analysis.

A2.2.5.6.4. Ground Support Handling Structures Used to Handle Critical Hardware. At a minimum, the following documentation is required:

A2.2.5.6.4.1. SFP analysis.

A2.2.5.6.4.2. NDE plan and test results for SFP and non-SFP components and SFP and non-SFP welds.

A2.2.5.6.4.3. Initial proof load test plan and test results.

A2.2.5.6.4.4. Stress analysis for structures.

A2.2.5.6.4.5. Safe-life analysis, if applicable.

A2.2.5.6.4.6. O&SHA and FMECA analyses for structural mechanisms like spin tables, rotating structures, and portable launch support frames.

A2.2.5.6.5. Support Structures Used to Handle Critical Hardware. At a minimum, the following documentation is required:

A2.2.5.6.5.1. SFP analysis.

A2.2.5.6.5.2. NDE plan and test results for SFP and non-SFP components and SFP and non-SFP welds.

A2.2.5.6.5.3. Initial proof load test plan and test results.

A2.2.5.6.5.4. Stress analysis for structures.

A2.2.5.6.5.5. Safe-life analysis, if applicable.

A2.2.5.6.6. Ground Support Load Positioning Devices and Load Measuring/Indicating Devices Used to Handle Critical Hardware. At a minimum, the following documentation is required:

A2.2.5.6.6.1. SFP analysis.

A2.2.5.6.6.2. NDE plan and test results for SFP components and SFP welds.

A2.2.5.6.6.3. Initial proof load test plan and test results.

A2.2.5.6.6.4. Stress analysis.

A2.2.5.6.7. Ground Support Rigging Hardware Used to Handle Critical Hardware. At a minimum, the following documentation is required:

A2.2.5.6.7.1. SFP analysis.

A2.2.5.6.7.2. NDE plan and test results for SFP components.

A2.2.5.6.7.3. Initial proof load test plan and test results.

A2.2.5.6.8. Flight Hardware Used to Lift Critical Hardware. At a minimum, the following documentation is required:

A2.2.5.6.8.1. SFP analysis.

A2.2.5.6.8.2. NDE plan and test results for SFP components and SFP welds.

A2.2.5.6.8.3. Initial proof test plan and test results.

A2.2.5.6.8.4. Stress analysis.

A2.2.5.6.9. MHE Used to Handle Non-Critical Hardware. At a minimum, the initial proof load test plan and results shall be documented and be made available upon request.

A2.2.5.7. **Ground Support Cranes and Hoists.**

A2.2.5.7.1. Ground Support Cranes and Hoists Used to Handle Critical Hardware. At a minimum, the following documentation is required:

A2.2.5.7.1.1. SFP analysis.

A2.2.5.7.1.2. O&SHA.

A2.2.5.7.1.3. FMECA.

A2.2.5.7.1.4. NDE plan and test results for crane hooks and SFP components and SFP welds on crane support structures, overhead crane and hoist support structures, and 10% of non-SFP welds on overhead crane and hoist support structures.

A2.2.5.7.1.5. Software test plans and results if applicable.

A2.2.5.7.1.6. Initial crane and hoist test plans and test results.

A2.2.5.7.1.7. Stress analysis for crane and hoist support structures.

A2.2.5.7.1.8. Crane specifications.

A2.2.5.7.1.9. Certificate of conformance to specifications.

A2.2.5.7.1.10. CAD output data, if available.

A2.2.5.7.2. Cranes and Hoists Used to Handle Non-Critical Hardware. At a minimum, the following documentation is required:

A2.2.5.7.2.1. NDE plan and test results for crane hooks.

A2.2.5.7.2.2. Initial crane and hoist test plans and test results.

A2.2.5.7.2.3. Crane specifications.

A2.2.5.7.2.4. Certification of conformance to specifications.

A2.2.5.7.2.5. Non-DoD certifications where applicable.

A2.2.5.8. **Removable, Extendible, and Hinged Personnel Work Platforms.** At a minimum, the following documentation is required:

A2.2.5.8.1. SFP analysis.

A2.2.5.8.2. NDE plan and test results for SFP and non-SFP components and SFP and non-SFP welds.

A2.2.5.8.3. Initial proof load test plan and test results.

A2.2.5.8.4. Stress analysis.

A2.2.5.9. **Ground Support Pressure and Propellant Systems.**

A2.2.5.9.1. General Data. A detailed description of the pressure and propellant systems shall be provided. The description shall include the information identified in sections **A2.2.5.1**, **A2.2.4.7.1.1** through **A2.2.4.7.1.3** as well as the in-service operating, maintenance, and ISI plan.

A2.2.5.9.2. Ground Support Pressure and Propellant System Data. The system data as identified in section **A2.2.4.7.2** shall be submitted in addition to a copy of any DOT approved exemptions for mobile and portable hazardous pressure systems.

A2.2.5.9.3. Ground Support Pressure and Propellant System Component Design Data. At a minimum, the information identified in section **A2.2.4.7.3** shall be submitted for ground support pressure system components.

A2.2.5.10. **Ground Support Electrical and Electronic Subsystems.**

A2.2.5.10.1. General Data. A detailed description of electrical and electronic subsystems shall be provided. The description shall include the information identified in section **A2.2.5.1**.

A2.2.5.10.2. EGSE Battery Design Data. At a minimum, the battery design data identified in section **A2.2.4.8.2** shall be provided for EGSE batteries.

A2.2.5.10.3. EGSE Design Data. The following EGSE design data is required:

A2.2.5.10.3.1. Identification of EGSE and its use.

A2.2.5.10.3.2. A description of how faults in the EGSE circuitry that can create a hazardous condition are prevented from propagating into the flight system.

A2.2.5.10.3.3. A description of how inadvertent commands that can cause a hazardous condition are prevented.

A2.2.5.10.3.4. Identification of potential shock hazards.

A2.2.5.10.3.5. A description of how the intent of the NFPA is met with respect to hazardous atmospheres.

A2.2.5.10.3.6. Identification of all non-explosion proof equipment powered up during and after propellant loading.

A2.2.5.10.3.7. For explosion proof and intrinsically safe equipment approved by a nationally recognized testing laboratory, the following information shall be provided:

A2.2.5.10.3.7.1. Manufacturer.

A2.2.5.10.3.7.2. Model number.

A2.2.5.10.3.7.3. Hazardous location class and group.

A2.2.5.10.3.7.4. Operating temperature.

A2.2.5.10.3.8. For any explosion proof equipment or components not having a fixed label from a nationally recognized testing laboratory, the data and certification shall be available for inspection in the facility of use.

A2.2.5.10.3.9. Test data and certification on custom or modified equipment that cannot be certified by a nationally recognized testing laboratory for explosion proof equipment.

A2.2.5.10.3.10. Test results for all Range User designed, built, or modified intrinsically safe apparatus as required by a nationally recognized testing laboratory in accordance with UL 913.

A2.2.5.10.3.11. A bent pin analysis for all connectors for safety critical or hazardous systems that have spare pins.

A2.2.5.11. **Ground Support Ordnance Subsystems.**

A2.2.5.11.1. General Data. A detailed description of ordnance subsystems shall be provided. The description shall include the information identified in section **A2.2.5.1**.

A2.2.5.11.2. Ordnance Ground Systems Design Data. The following ordnance ground systems design data is required:

A2.2.5.11.2.1. A complete description of the ground test equipment that will be used in the checkout of ordnance devices and systems, including general specifications and schematics for all test equipment.

A2.2.5.11.2.2. Specifications, schematics, and a complete functional description of the low voltage stray current monitor.

A2.2.5.11.2.3. Schematics of all ordnance system monitor circuits from the ordnance component pick-off points to the PSC termination.

A2.2.5.11.2.4. Calibration data for all monitor circuit terminations that will be provided to the PSC.

A2.2.5.11.2.5. A complete and detailed description of the airborne and ground ordnance telemetry system and how it functions, including general specifications and schematics.

A2.2.5.11.2.6. The following information is required for ordnance continuity and bridgewire resistance measurement devices:

A2.2.5.11.2.6.1. Maximum safe no-fire energy of the ordnance being tested.

A2.2.5.11.2.6.2. A declaration of any certification currently in effect for the instrument along with the manufacturer specifications including:

A2.2.5.11.2.6.2.1. Range.

A2.2.5.11.2.6.2.2. Accuracy.

A2.2.5.11.2.6.2.3. Power supply and recharge capability.

A2.2.5.11.2.6.2.4. Self-test features.

A2.2.5.11.2.6.2.5. Schematics.

A2.2.5.11.2.6.3. Failure analysis including the outcome of the energy analysis (open circuit or maximum terminal voltage) and current limit analysis (short circuit or maximum output current).

A2.2.5.11.2.6.4. Instrument description including any modifications required for operational use and details of safety design features such as interlocks.

A2.2.5.11.2.6.5. Description of intended operations.

A2.2.5.11.2.7. The following information is required for monitor circuit outputs:

A2.2.5.11.2.7.1. Tolerances.

A2.2.5.11.2.7.2. Maximum and minimum values.

A2.2.5.11.2.8. For high voltage exploding bridgewires, the nominal gap breakdown voltage tolerance.

A2.2.5.11.2.9. For laser initiated devices, the following information is required:

A2.2.5.11.2.9.1. If modified secondary (composition) explosives are used, test requirements and reports.

A2.2.5.11.2.9.2. Heat dissipation analysis.

A2.2.5.11.2.10. Ordnance Hazard Classifications and Categories.

A2.2.5.11.2.10.1. DoD/UN hazard classifications (class, division, and compatibility group) in accordance with DESR 6055.09.

A2.2.5.11.2.10.2. DOT classification.

A2.2.5.11.2.10.3. The Range Safety ordnance device and system hazard classification for each ordnance item and system.

A2.2.5.11.2.10.4. Test results and/or analysis used to classify the ordnance devices and systems.

A2.2.5.11.2.11. A list and summary of test plans, test procedures, and test results, as required.

A2.2.5.11.3. Ground Support Ordnance Handling and Storage Data. Specific requirements for handling and storing the ground support ordnance shall be submitted.

A2.2.5.12. **Ground Support Non-Ionizing Radiation Source Data.**

A2.2.5.12.1. General Data. A detailed description of non-ionizing subsystems shall be provided. The description shall include the information identified in section **A2.2.5.1**.

A2.2.5.12.2. Ground Support RF Emitter Data. The information identified in section **A2.2.4.10.2** shall be submitted for RF emitters.

A2.2.5.12.3. Ground Support Laser Systems. At a minimum, the laser system data requirements identified in section **A2.2.4.10.3** shall be submitted.

A2.2.5.13. **Ground Support Ionizing Radiation Source Data.**

A2.2.5.13.1. General Data. A detailed description of ionizing subsystems shall be provided. The description shall include the information identified in section **A2.2.5.1**.

A2.2.5.13.2. Ionizing Radiation Sources Data. At a minimum, the data identified in section **A2.2.4.11.3** shall be provided for all ground radiation producing sources.

A2.2.5.14. **Ground Support Acoustic Hazards.**

A2.2.5.14.1. General Data. A detailed description of acoustical hazards and subsystems shall be provided. The description shall include the information identified in section **A2.2.5.1**.

A2.2.5.14.2. Acoustic Hazards Data. The data identified in section **A2.2.4.12.2** shall be submitted for acoustic hazards.

A2.2.5.15. **Ground Support Hazardous Materials.**

A2.2.5.15.1. General Data. A detailed description of hazardous materials and subsystems shall be provided. The description shall include the information identified in section **A2.2.5.1**.

A2.2.5.15.2. Ground Support Hazardous Materials Data. The hazardous materials data identified in section **A2.2.4.13.2** shall be submitted.

A2.2.5.16. **Pad Safety Console.**

A2.2.5.16.1. General Data. A detailed description of the PSC shall be provided. The description shall include the information identified in section **A2.2.5.1**.

A2.2.5.16.2. PSC Data. The following data shall be submitted for the PSC:

A2.2.5.16.2.1. An overall schematic of the PSC and outside interfaces.

A2.2.5.16.2.2. A narrative of each of the features of the PSC, including the following:

A2.2.5.16.2.2.1. Function.

A2.2.5.16.2.2.2. Operation.

A2.2.5.16.2.2.3. Outside interface.

A2.2.5.16.2.2.4. Operating limits.

A2.2.5.16.2.3. A list and summary of test plans, test procedures, and test results

IAW section **5.6**.

A2.2.5.17. **Motor Vehicle Data.** At a minimum, the following data shall be provided for motor vehicles:

A2.2.5.17.1. General Vehicle Data.

A2.2.5.17.1.1. Documentation certifying that vehicles used to transport bulk hazardous material on the range comply with DOT requirements or are formally exempted by DOT.

A2.2.5.17.1.2. If DOT certification or exemption documentation is not available, the following information is required:

A2.2.5.17.1.2.1. Design, test, and inspection requirements.

A2.2.5.17.1.2.2. Stress analysis.

A2.2.5.17.1.2.3. SFP analysis.

A2.2.5.17.1.2.4. FMECA.

A2.2.5.17.1.2.5. Comparison analysis with similar DOT approved vehicle.

A2.2.5.17.1.2.6. "Equivalent safety" (meets DOT intent) analysis.

A2.2.5.17.2. Special-Purpose Trailer Data.

A2.2.5.17.2.1. Stress analysis.

A2.2.5.17.2.2. SFP analysis.

A2.2.5.17.2.3. Initial proof load test plan and test results.

A2.2.5.17.2.4. Initial road test plan and test results.

A2.2.5.17.2.5. NDE plan and test results for SFPs.

A2.2.5.17.3. Lift Trucks Data.

A2.2.5.17.3.1. Certification that the lift truck meets applicable national standards such as ASME B56 Series Safety Standards.

A2.2.5.17.3.2. For personnel platforms on lift trucks:

A2.2.5.17.3.2.1. Stress analysis.

A2.2.5.17.3.2.2. SFP analysis.

A2.2.5.17.3.2.3. NDE plan and test results for SFP components and SFP welds.

A2.2.5.17.3.2.4. Proof load test plan and test results.

A2.2.5.17.3.3. For lift trucks used to lift or move critical loads; maintenance plans shall be submitted for review and approval.

A2.2.5.18. **Computing Systems Data.** The Range User shall provide the information identified in section **A2.2.4.14** to Wing Safety in the MSPSP.

A2.2.5.19. **WR Seismic Data Requirements** . The GSE data package shall identify the equipment and potential for seismic hazard and risk and shall include:

A2.2.5.19.1. GSE designation and applicable drawing numbers.

A2.2.5.19.2. Whether the equipment is new or existing.

A2.2.5.19.3. GSE description; for example, weight, materials, structural system.

A2.2.5.19.4. How the GSE is used and where and how it is stored.

A2.2.5.19.5. The length of time the GSE is used and stored.

A2.2.5.19.6. Estimate of potential for seismic hazard (for example, propagation to catastrophic event, personnel injury, blocking emergency egress routes, or hitting something) due to equipment failure or movement during a seismic event.

A2.2.5.19.7. Whether the equipment is required to be designed to meet seismic design requirements.

A2.2.5.19.8. Whether the equipment is required to be anchored.

A2.2.5.19.9. Design margin of safety under seismic loading (if applicable).

A2.2.5.19.10. Engineering analysis addressing how the launch vehicle, in typical configurations, will respond to a pre-defined seismic event.

A2.2.5.19.11. Risk analysis of items exempt from the seismic design requirements.

A2.2.5.19.12. Detailed description of the "safe mode" for both safety-critical equipment and equipment whose failure could result in a catastrophic event or a potential for endangering personnel.

A2.3. Compliance Checklist. A compliance checklist of all design, test, analysis, and data submittal requirements in this chapter shall be provided. The checklist shall indicate for each requirement if the proposed design is compliant, non-compliant but meets intent, non-compliant (waiver required) or non-applicable. An example of a compliance checklist can be found in Appendix E of the Eastern and Western Range 127-1, Range Safety Requirements, *Range User Handbook*. The following items are included in this section:

A2.3.1. Criteria/requirement.

A2.3.2. System.

A2.3.3. Compliance.

A2.3.4. Noncompliance.

A2.3.5. Not applicable.

A2.3.6. Resolution.

A2.3.7. Reference.

A2.3.8. Copies of all Wing Safety approved non-compliances including waivers and equivalent levels of safety certifications

A2.4. Modifications to the MSPSP. The change section contains a summary of all changes to the last edition of the MSPSP. All changes shall be highlighted using change bars or similar means of identification.