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**SPECIFICATION
FOR
LOW LEAKAGE RELIEF VALVE**

**ENGINEERING DIRECTORATE
Propulsion Systems Department
Valves, Actuators, &
Ducts Design & Development Branch
ER14**

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1 SCOPE

This specification contains the component design, performance, verification, and delivery requirements for a development low leakage relief valve to be used for ground-based testing.

2 DOCUMENTS

2.1 Order of Precedence

In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.2 Applicable Documents

| | |
|-----------------|---|
| IEST-STD-CC1246 | Product Cleanliness Levels – Applications, Requirements, and Determination |
| MIL-PRF-27201 | Propellant Hydrogen |
| MIL-PRF-27401 | Propellant Pressurizing Agent, Nitrogen |
| MIL-PRF-27407 | Propellant Pressurizing Agent, Helium |
| MIL-STD-130 | Identification Marking of U.S. Military Property |
| MSFC-STD-486 | Standard, Threaded Fasteners, Torque Limits for |
| NASA-STD-4003 | Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment |
| NASA-STD-5001 | Structural Design and Test Factors of Safety for Spaceflight Hardware |
| NASA-STD-5017 | Design and Development Requirements for Mechanisms |
| NASA-STD-5020 | Requirements for Threaded Fastening Systems in Spaceflight Hardware |
| NASA-STD-6008 | NASA Fastener Procurement, Receiving Inspection, and Storage Practices for Spaceflight Hardware |
| NASA-STD-6016 | Standard Materials and Process Requirements for Spacecraft |
| SMC-S-016 | Test Requirements for Launch, Upper-Stage and Space Vehicles |
| TT-I-735 | Isopropyl Alcohol |

2.3 Definitions and Terms

Shall: Used to indicate a requirement which must be implemented and its implementation verified.

To Be Determined (TBD): A value that is not yet known and will be supplied by the purchaser.

To Be Reviewed (TBR): An approximate value is known, but requires review by the purchaser.

To Be Specified (TBS): A value that will be defined by the supplier and agreed to by the purchaser.

Will: Used to indicate a statement of fact and is not verified.

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2.4 Abbreviations and Acronyms

| | |
|-----------------|---|
| “A” | Analysis (used in Table 7) |
| ASTM | American Society for Testing and Materials |
| °F | Degrees Fahrenheit |
| FS | Factor of Safety |
| g | Gravity |
| GHe | Gaseous Helium |
| GN ₂ | Gaseous Nitrogen |
| “I” | Inspection (used in Table 7) |
| IEST | Institute of Environmental Science and Technology |
| in | Inch |
| lbm | Pound (mass) |
| MDP | Maximum Design Pressure |
| MEOP | Maximum Expected Operating Pressure |
| MMA | Moving Mechanical Assembly |
| MS | Margin of Safety |
| MSFC | Marshall Space Flight Center |
| NASA | National Aeronautics and Space Administration |
| PSD | Power Spectrum Density |
| psia | Pounds per Square Inch (absolute) |
| SAE | Society of Automotive Engineers |
| sccs | Standard Cubic Centimeters per Second |
| scim | Standard Cubic Centimeters per Minute |
| “T” | Test (used in Table 7) |
| TBD | To Be Determined |
| TBR | To Be Reviewed |
| TBS | To Be Selected |

3 COMPONENT REQUIREMENTS

3.1 Item Description

The low leakage relief valve (referred to from this point forward as the “valve”) will be a pressure activated device to vent gas pressure from the cryogenic propellant tank.

3.2 Performance Requirements

3.2.1 Operating Fluid

The valve shall meet the performance requirements of section 3.2 during exposure to the following fluids:

- GH2 per MIL-PRF-27201

3.2.2 Pressure

3.2.2.1 Operating Pressure Range

The valve operating pressure range will be 0 to TBD psig.

3.2.2.2 Maximum Expected Operating Pressure (MEOP)

The maximum expected operating pressure will be TBD psig.

3.2.2.3 Maximum Design Pressure (MDP)

The maximum design pressure will be TBD psig.

3.2.2.4 Proof Pressure

The valve shall meet the performance requirements of section 3.2 after exposing the pressure boundary to a proof pressure differential of $1.5 \times \text{MDP}$ for a minimum of five (5) minutes without detrimental yielding.

3.2.2.5 Burst Pressure

The valve shall not rupture when exposed to a burst pressure of $4 \times \text{MDP}$ for a minimum of one (1) minute. Permanent deformation is acceptable.

3.2.3 Leakage

3.2.3.1 External Leakage

The valve shall have an external leakage rate less than or equal to 1×10^{-6} sccs GHe over the operating pressures in paragraph 3.2.2.1.

3.2.3.2 Internal Leakage

The valve shall have an internal leakage rate less than or equal to 1 scim GHe over the minimum operating pressure specified in paragraph 3.2.2.1 up to 15 psig supplied to the inlet of the valve. Internal leakage is defined as flow from the inlet to outlet port of the valve.

3.2.4 Flow Capacity

The valve shall have a flow capacity (CdA) of: $3.0 \text{ in}^2 \leq \text{CdA} \leq 4.0 \text{ in}^2$.

3.2.5 Operating Characteristics

3.2.5.1 Reseat Pressure

The valve reseat pressure shall be 17 psig minimum, based on the pressure differential between the valve inlet and outlet interfaces. Reseat pressure is defined as the pressure where the flow rate is less than **TBD** after the valve has been opened and pressure is reduced.

3.2.5.2 Cracking Pressure

The valve cracking pressure shall be 21 psig maximum, based on the pressure differential between the valve inlet and outlet interfaces. Cracking pressure is defined as the pressure where the flow rate is greater than **TBD** after the valve has been closed and pressure is increased.

3.2.5.3 Full Flow Pressure

The valve full flow pressure shall be 21 psig maximum, based on the pressure differential between the valve inlet and outlet interfaces. Full flow pressure is defined as the pressure where the valve meets the flow capacity requirement specified in paragraph 3.2.4.

3.2.5.4 Response Time

3.2.5.4.1 Opening Response Time

The valve shall achieve the flow capacity specified in paragraph 3.2.4 in less than or equal to one (1) second when the valve is exposed to an instantaneous pressure of 21 psig at the inlet port of the valve.

3.2.5.4.2 Closing Response Time

The valve shall achieve the reseat pressure specified in paragraph 3.2.5.1 in less than or equal to one (1) second when the valve is initially fully open with a pressure of 21 psig at the inlet port of the valve, then an instantaneous pressure reduction to the reseat pressure specified in paragraph 3.2.5.1.

3.2.6 Physical Characteristics

3.2.6.1 Envelope Dimensions

The valve shall occupy a physical envelope no larger than specified in Figure 1 and Figure 2. All dimensions shown are in inches.

Figure 1: Envelope (Side View)

Figure 2: Envelope (End View)

3.2.6.2 Mass

The valve shall have a mass of equal to or less than **TBD** lbm.

3.2.6.3 Lifting Point

The valve shall contain lifting features to allow moving of the valve by lifting equipment if the mass of the valve exceeds **TBD** lbm.

3.2.7 Life

3.2.7.1 Shelf Life

The valve shall meet the performance requirements of section 3.2 for a minimum of five (5) years after hardware delivery and prior to removal from packaging.

3.2.7.2 Service Life

The valve shall meet the performance requirements of section 3.2 for a minimum of five (5) years after removal from packaging.

3.2.7.3 Cycle Life

3.2.7.3.1 Actuation Cycles

The valve shall meet the performance requirements of section 3.2 for a minimum of 50 operating close/open/close cycles after delivery.

3.2.7.3.2 Proof Pressure Cycles

The valve shall meet the performance requirements of section 3.2 after exposure to a minimum of five (5) proof pressure cycles. A proof pressure cycle is defined as 0 psia to proof pressure to 0 psia.

3.3 Component Interfaces

3.3.1 Fluid Interfaces

3.3.1.1 Inlet Interface

The valve inlet interface shall be a bolted joint interface per Figure 3. All dimensions shown are in inches.

Figure 3: Inlet Interface

3.3.1.2 Outlet Interface

The valve outlet interface shall be a bolted joint interface per Figure 3. All dimensions shown are in inches.

Figure 4: Outlet Interface

3.3.2 Mounting

The valve shall be mounted using the inlet and outlet port interfaces, with no other support attaching the valve to vehicle structure.

3.3.3 Orientation

The valve shall meet the performance requirements of section 3.2 while mounted in any orientation.

3.4 Environments

3.4.1 Operating Temperature

The valve shall meet the leakage requirements of paragraph 3.2.3.4 during and after exposure to an operating temperature ranging from -423°F to +104°F. Note, the temperatures shown are “Allowable Flight Temperatures” and do not include acceptance and qualification test margin, which is addressed in section 4 of this specification.

3.4.2 Non-Operating Temperature

The valve shall meet the performance requirements of section 3.2 after exposure to a non-operating temperature ranging from -65°F to +140°F. Note, the temperatures shown are “Allowable Flight Temperatures” and do not include acceptance and qualification test margin, which is addressed in section 4 of this specification.

3.4.3 Humidity

The valve shall meet all performance requirements after exposure to humidity levels between 0 and 100%.

3.4.4 Random Vibration

While in the closed position, the valve shall meet the leakage requirement specified in paragraph 3.2.3.2 during and all performance requirements after exposure to the random vibration levels specified in Table 1 for three minutes minimum in each of the three orthogonal axes.

Table 1: Random Vibration Levels

| Qualification Level | | | Acceptance Level | |
|---------------------|--------------------------|--|------------------|--------------------------|
| Frequency (Hz) | PSD (g ² /Hz) | | Frequency (Hz) | PSD (g ² /Hz) |
| 20 | 0.026 | | 20 | 0.013 |
| 50 | 0.16 | | 50 | 0.08 |
| 800 | 0.16 | | 375 | 0.08 |
| 2000 | 0.026 | | 2000 | 0.026 |
| Overall | 14.1 g _{rms} | | Overall | 10.0 g _{rms} |

3.4.5 Inertial Loads

While in the closed position, the valve shall meet the structural requirements specified in paragraph 3.5.3 during exposure to the inertial loads of ± 85.8 g's.

3.5 Design and Construction

3.5.1 Material and Construction Standards

The valve shall comply with NASA-STD-6016 requirements regarding materials and construction for a non-human-rated mission.

3.5.2 Fluid Compatibility

The valve shall be compatible with the following fluids:

- GN2 per MIL-PRF-27401
- GHe per MIL-PRF-27407, Type 1, Grade A
- Isopropyl Alcohol per TT-I-735, Grade A
- Operating fluids per paragraph 3.2.1

3.5.3 Structural Design and Test Factors of Safety

The valve shall have a positive Margin of Safety (MS) for all yield and ultimate limit loads using the Factor of Safety (FS) defined in NASA-STD-5001 “Structural Design and Test Factors of Safety for Spaceflight Hardware”.

3.5.4 Threaded Joints

Threaded joints within the valve shall meet the requirements of NASA-STD-5020 “Requirements for Threaded Fastening Systems in Spaceflight Hardware”, with the exception that fastener preload does not require testing to substantiate.

3.5.5 Mechanisms

The valve shall meet the requirements of NASA-STD-5017 “Design and Development Requirements for Mechanisms”.

3.5.6 Electrical Bonding

The valve shall meet NASA-STD-4003 “Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment”, Class S, measured between the valve housing and mounting interface.

3.5.7 Fasteners

Fasteners shall comply with NASA-STD-6008 and MSFC-STD-486.

3.5.8 External Cleanliness

The valve external cleanliness shall meet the requirements of IEST-STD-CC1246E “Product Cleanliness Levels –Applications, Requirements, and Determination”, Level VC-0.5-1000 Particulate Cleanliness.

3.5.9 Internal Cleanliness

The valve internal cleanliness shall meet the requirements of IEST-STD-CC1246E “Product Cleanliness Levels –Applications, Requirements, and Determination”, Level 100 Particulate Cleanliness.

3.5.10 Interchangeability

The valve shall be directly interchangeable in form, fit, and function with other valves of the same part number.

3.6 Part Marking and Identification

The valve shall be identified per MIL-STD-130 “Identification Marking of U.S. Military Property” and, at a minimum, include the following:

- Manufacturer
- Manufacturer Part Number
- Serial Number

3.7 Traceability

3.7.1 Serialization

All non-standard parts shall be serialized with a unique serial number.

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4 VERIFICATION

Supplier shall conduct a verification program that demonstrates the hardware design is qualified and meets all requirements contained in this document.

Supplier shall provide documentation showing conformance to this specification.

4.1 Inspection

Verification by inspection includes visual inspection of the physical hardware, a physical measurement of a property of the hardware, or the documentation search demonstrating hardware of an identical design has demonstrated fulfillment of a requirement.

4.1.1 Visual Inspection

Visual inspection of the physical component shall be performed by a qualified inspector to certify that the component has the properties/configuration specified in the requirement.

4.1.2 Physical Measurement

Physical measurement of hardware property (i.e. mass, dimensions, etc.) demonstrating the hardware meets specific requirement.

4.1.3 Documentation Search

Verification of requirements based on similarity shall include supporting rationale and documentation and shall be approved by the purchaser.

4.2 Analysis

Verification by analysis involves the use of engineering analysis, qualitative assessment, computer modeling and/or simulation to ensure compliance to requirement(s). If necessary, analysis combined with test results may be used to provide this evidence.

4.3 Test

Verification by test (e.g., functional, environmental) is the actual operation to ensure that the performance characteristics of the valve are in accordance with the requirement(s). Testing will also include methods to verify requirements such as material compatibility which may or may not be performed with an end item. All acceptance and qualification testing shall be performed in accordance with SMC-S-016 and NASA-STD-5017, using the bounding test criteria for each test. For determining SMC-S-016 required testing, the valve would be categorized as a Moving Mechanical Assembly (MMA) and pressure component.

4.3.1 Test Restrictions

Any deviation from SMC-S-016 or NASA-STD-5017 must be approved by the purchaser.

4.3.2 Equipment Failure During Testing

The test will be stopped if equipment fails during testing in cases where this failure will result in damage to the valve. A complete record shall be maintained and included in the test report.

4.3.3 Valve Failure During Testing

In the event of a valve failure during test, the test will be stopped, the configuration made safe and maintained to the extent practical, and the purchaser notified. A complete record shall be maintained and included in the test report.

4.3.4 Modification of Valve

Modification of the valve shall not be permitted once acceptance and/or qualification testing has started.

4.3.5 Acceptance Testing

Perform acceptance testing on each valve per paragraph 4.3, with tailoring and clarification to test requirements defined below.

4.3.5.1 Proof Pressure

The proof test shall include the required environmental correction factor if performed at room temperature.

4.3.5.2 Thermal

Thermal cycle test shall be performed in lieu of thermal vacuum testing. Non-operating temperature, one cycle, to be performed prior to operating temperature testing. Hot and cold temperature plateaus shall be held for a minimum of four (4) hours at the acceptance temperature levels. Pressurization of the valve when not performing leakage tests is not required.

4.3.6 Qualification Testing

Perform qualification testing on each valve per paragraph 4.3, with tailoring and clarification to test requirements defined below.

4.3.6.1 Proof Cycle Life

The proof cycle life test shall include the required environmental correction factor if performed at room temperature.

4.3.6.2 Thermal

Thermal cycle test shall be performed in lieu of thermal vacuum testing. Non-operating temperature, one cycle, to be performed prior to operating temperature testing. Hot and cold temperature plateaus shall be held for a minimum of four (4) hours at the qualification temperature levels. The “hot and cold temperature plateaus” are 18 °F beyond the operating and non-operating temperatures shown in paragraphs 3.4.1 & 3.4.2, except the minimum operating temperature test does not require margin. Performance testing shall be performed at the first, third and last thermal cycles as part of the minimum and maximum temperature dwells in order to detect performance degradation. Pressurization of the valve when not performing leakage tests is not required.

4.3.6.3 Actuation Cycle Life

The valve application is a non-manned system for determining qualification margin requirements per NASA-STD-5017. Performance tests shall be conducted every 25% of the total qualified cycles to provide trending data.

4.3.6.4 Burst Pressure

The burst pressure test shall include the required environmental correction factor if performed at room temperature.

4.4 Verification Matrix

Verification shall be accomplished per Table 2.

Table 2: Verification Cross Reference Matrix Requirements

| Section 3 Requirement Paragraph No. | Title | Verification | | |
|--|--|--------------|------------|---------------|
| | | Development | Acceptance | Qualification |
| 3.2 | Performance Requirements | | | |
| 3.2.1 | Operating Fluid | | I | A |
| 3.2.2 | Pressure | | | |
| 3.2.2.1 | Operating Pressure Range | | — | — |
| 3.2.2.2 | Maximum Expected Operating Pressure (MEOP) | | — | — |
| 3.2.2.3 | Maximum Design Pressure (MDP) | | — | — |
| 3.2.2.4 | Proof Pressure | | T | A,T |
| 3.2.2.5 | Burst Pressure | | I | A,T |
| 3.2.3 | Leakage | | | |
| 3.2.3.1 | External Leakage | | T | T |
| 3.2.3.2 | Internal Leakage | | T | T |
| 3.2.4 | Flow Capacity | | T | A,T |
| 3.2.5 | Operating Characteristics | | | |
| 3.2.5.1 | Reseat Pressure | | T | A,T |
| 3.2.5.2 | Cracking Pressure | | T | A,T |
| 3.2.5.3 | Full Flow Pressure | | T | A,T |
| 3.2.5.4 | Response Time | | | |
| 3.2.5.4.1 | Opening Response Time | | T | A,T |
| 3.2.5.4.2 | Closing Response Time | | T | A,T |
| 3.2.6 | Physical Characteristics | | | |
| 3.2.6.1 | Envelope Dimensions | | I | I |
| 3.2.6.2 | Mass | | I | I |
| 3.2.6.3 | Lifting Provisions | | I | I |
| 3.2.7 | Life | | | |
| 3.2.7.1 | Shelf Life | | I | A |
| 3.2.7.2 | Service Life | | I | A |
| 3.2.7.3 | Cycle Life | | | |
| 3.2.7.3.1 | Actuation Cycles | | I | A,T |
| 3.2.7.3.2 | Proof Pressure Cycles | | I | A,T |

| Section 3 Requirement Paragraph No. | Title | Verification | | |
|--|---|--------------|------------|---------------|
| | | Development | Acceptance | Qualification |
| 3.3 | Component Interfaces | | | |
| 3.3.1 | Fluid Interfaces | | | |
| 3.3.1.1 | Inlet Interface | | I | I |
| 3.3.1.2 | Outlet Interface | | I | I |
| 3.3.2 | Mounting | | I | I |
| 3.3.3 | Orientation | | I | A |
| 3.4 | Environments | | | |
| 3.4.1 | Operating Temperature | | T | A,T |
| 3.4.2 | Non-Operating Temperature | | T | A,T |
| 3.4.3 | Humidity | | I | A |
| 3.4.4 | Random Vibration | | T | A,T |
| 3.4.5 | Inertial Loads | | I | A |
| 3.5 | Design and Construction | | | |
| 3.5.1 | Material and Construction Standards | | I | A,I |
| 3.5.2 | Fluid Compatibility | | I | A,I |
| 3.5.3 | Structural Design and Test Factor of Safety | | I | A |
| 3.5.4 | Threaded Joints | | I | A |
| 3.5.5 | Mechanisms | | T | A,T |
| 3.5.6 | Electrical Bonding | | T | T |
| 3.5.7 | Fasteners | | I | A,I |
| 3.5.8 | External Cleanliness | | T | T |
| 3.5.9 | Internal Cleanliness | | T | T |
| 3.5.10 | Interchangeability | | I | I |
| 3.6 | Part Marking and Identification | | I | I |
| 3.7 | Traceability | | | |
| 3.7.1 | Serialization | | I | I |
| 3.8 | Reliability | | I | A |

5 PREPARATION FOR DELIVERY

5.1 Methods of Preservation and Packaging

Unless otherwise specified in the contract or purchasing order, valves procured to this specification shall be packaged, packed, and marked for shipment as specified herein.

A copy of the supplier's handling/transportation and safety procedures and cleanliness certification of compliance shall be included with the valve.

5.1.1 Retention of Cleanliness

After cleaning, and while the valve is still in a controlled clean room area, the vehicle interface tube shall be capped off or enclosed using antistatic Nylon material conforming to **TBS**.

The valve should then be secured in place with clean-room tape to a specification approved by the purchaser.

The valve shall then be bagged using a 2 mil minimum antistatic Nylon inner bag cleaned to Cleanliness Level **100** or better per IEST-STD-CC1246E. This inner bag shall be evacuated and the bag ends heat sealed closed. It shall then be outer-bagged with 4 mil minimum Nylon or Polyethylene transparent antistatic material cleaned to Cleanliness Level **100** or better per IEST-STD-CC1246E.

A non-shedding identification tag shall be placed between the inner and outer bags and it shall display the following caution note as a minimum: 'Open in Clean Room Environment only.'

A humidity indicator shall also be placed between the inner and outer bags.

5.1.2 Storage

The valve shall be capable of being stored for a minimum of that stated in paragraph 3.2.7.1 without requiring repair, maintenance, or retesting at the end of storage.

5.1.3 Protective Coverings

The valve shall be provided with protective covering to prevent contamination during transportation outside clean areas and where necessary to protect against damage in handling, tube caps shall be fitted at the inlet and outlet ports of the valve.