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(Baseline)**

**LEAK TEST REQUIREMENTS**

# NASA-STD-7012 W/CHANGE 1

## DOCUMENT HISTORY LOG

Status	Document Revision	Change Number	Approval Date	Description
Baseline			2019-03-05	Initial Release
Change		1	2020-11-13	Administrative Change: In section 5.11a(7), corrected from “A leak is indicated by any leak detector output above the established tracer gas background that in the aggregate does not exceed 40% of the tracer gas background ...” to “A leak is indicated by any leak detector output above the established tracer gas background that in the aggregate exceeds 40% of the tracer gas background ...”

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## FOREWORD

This NASA Technical Standard is published by the National Aeronautics and Space Administration (NASA) to provide uniform engineering and technical requirements for processes, procedures, practices, and methods that have been endorsed as standard for NASA programs and projects, including requirements for selection, application, and design criteria of an item.

This NASA Technical Standard is approved for use by NASA Headquarters and NASA Centers and Facilities, and applicable technical requirements may be cited in contract, program, and other Agency documents. It may also apply to the Jet Propulsion Laboratory (a Federally Funded Research and Development Center (FFRDC)), other contractors, recipients of grants and cooperative agreements, and parties to other agreements only to the extent specified or referenced in applicable contracts, grants, or agreements.

This NASA Technical Standard establishes uniform use of leak test requirements for NASA vehicles, subsystems and their components, and payloads.

This NASA Technical Standard was developed by the Johnson Space Center (JSC) Requirements, Test, and Verification Panel (RTVP) supported by JSC Engineering. To provide additional technical expert guidance, the RTVP established a Technical Discipline Working Group that involved many known space industry experts in leak testing from Glenn Research Center, Kennedy Space Center, Langley Research Center, and Marshall Space Flight Center (MSFC) in particular.

The references to perform leak testing per appropriate ASTM International standards and/or The American Society for Nondestructive Testing (ASNT) Handbook have been used and referred to correspondingly.

Requests for information should be submitted via “Feedback” at <https://standards.nasa.gov>. Requests for changes to this NASA Technical Standard should be submitted via MSFC Form 4657, Change Request for a NASA Engineering Standard.

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Original signed by  
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NASA Chief Engineer

\_\_\_\_\_  
03/05/2019  
Approval Date

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## **LEAK TEST REQUIREMENTS**

### **1. SCOPE**

#### **1.1 Purpose**

The purpose of this NASA Technical Standard is to provide an Agency-wide basis from which test programs and procedures are developed for NASA vehicles, subsystems and their components, and payloads. This NASA Technical Standard defines a standard set of flight hardware leak test requirements that provide the necessary verification of pressure integrity for NASA vehicles, subsystems and their components, and payloads (both pressurized and sealed). Compliance of qualification and acceptance test programs and procedures with this NASA Technical Standard will provide consistency across the Agency and its contractors, facilitating the sharing of hardware between Centers and programs.

This NASA Technical Standard has been developed for vehicles, subsystems and their components, and payloads that will operate in space environment (Earth's orbit and beyond) but may be tailored to include other operating environments. The leak test methods included are generally regarded as the most critical and the ones having the highest cost and schedule impact. This NASA Technical Standard specifies test levels, factors, margins, durations, and other parameters. In some cases, these specifics are expressed statistically or are referenced in other NASA standards.

#### **1.2 Applicability**

This NASA Technical Standard applies to all NASA flight programs, including vehicles, subsystems and their components, and payloads developed in-house or under contract. This NASA Technical Standard defines baseline leak test methodologies that are applicable to all NASA vehicles, subsystems and their components, and payloads regardless of mission risk classification as defined in particular for the payloads in NASA Procedural Requirements (NPR) 8705.4, Risk Classification for NASA Payloads. However, these test methodologies may be tailored (see section 1.3 of this NASA Technical Standard) based on risk classification following the Center's defined risk philosophy and with approval from the delegated Technical Authority. The levels of assembly for which this NASA Technical Standard applies are vehicles, subsystems and their components, and payloads. Small instruments may be treated as components.

This NASA Technical Standard is developed for the typical NASA flight hardware or payload wherein one qualification unit or article is built and serves to qualify the design, while other units undergo acceptance testing for workmanship screening purposes and are subsequently used for flight. If a protoflight approach is used, the qualification unit or article is also used for flight. Consistent and effective leak testing is a critical aspect of functional verification for all of these types of hardware and payload items.

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The major objective of leak testing is to verify proper assembly and workmanship during qualification and acceptance testing. The principal goal of the leak test method is to reliably verify the maximum allowable leakage rate (MALR) requirement set for the vehicles, subsystems and their components, and payloads in the applicable drawings and/or specifications. Tailoring the leak test method, with supplemental analysis, is appropriate in some cases.

This NASA Technical Standard is approved for use by NASA Headquarters and NASA Centers and Facilities, and applicable technical requirements may be cited in contract, program, and other Agency documents. It may also apply to the Jet Propulsion Laboratory (a Federally Funded Research and Development Center (FFRDC)), other contractors, recipients of grants and cooperative agreements, and parties to other agreements only to the extent specified or referenced in applicable contracts, grants, or agreements.

Verifiable requirement statements are designated by the acronym “LTR” (Leak Test Requirement), numbered, and indicated by the word “shall”; this NASA Technical Standard contains 39 requirements. Explanatory or guidance text is indicated in italics beginning in section 4. To facilitate requirements selection by NASA programs and projects, a Requirements Compliance Matrix is provided in Appendix A.

## 1.3 Tailoring

Tailoring of the requirements in this NASA Technical Standard for application to a specific program or project is acceptable when documented in program or project requirements and formally approved by the delegated Technical Authority in accordance with NPR 7120.10, Technical Standards for NASA Programs and Projects, and NPR 7120.5, NASA Space Flight Program and Project Management Requirements.

## 2. APPLICABLE DOCUMENTS

### 2.1 General

The documents listed in this section contain provisions that constitute requirements of this NASA Technical Standard as cited in the text.

**2.1.1** The latest issuances of cited documents apply unless specific versions are designated.

**2.1.2** Non-use of a specifically designated version is approved by the delegated Technical Authority.

Applicable documents may be accessed at <https://standards.nasa.gov> or obtained directly from the Standards Developing Body or other document distributors. When not available from these sources, information for obtaining the document is provided.

References are provided in Appendix B.

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## 2.2 Government Documents

### National Aeronautics and Space Administration (NASA)

NPR 7120.5	NASA Space Flight Program and Project Management Requirements
NPR 7120.10	Technical Standards for NASA Programs and Projects
NPR 8705.4	Risk Classification for NASA Payloads
NASA-STD-8709.20	Management of Safety and Mission Assurance Technical Authority (SMA TA) Requirements

## 2.3 Non-Government Documents

### ASTM International

ASTM E493/E493M (2011, Revalidated 2017)	Standard Practice for Leaks Using the Mass Spectrometer Leak Detector in the Inside-Out Testing Mode
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### The American Society of Nondestructive Testing (ASNT)

ANSI/ASNT CP-189	ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel
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## 2.4 Order of Precedence

**2.4.1** The requirements and standard practices established in this NASA Technical Standard do not supersede or waive existing requirements and standard practices found in other Agency documentation, or in applicable laws and regulations unless a specific exemption has been obtained by the Office of the NASA Chief Engineer.

**2.4.2** Conflicts between this NASA Technical Standard and other requirements documents are resolved by the delegated Technical Authority.



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## 3. ACRONYMS, ABBREVIATIONS, SYMBOLS, AND DEFINITIONS

### 3.1 Acronyms, Abbreviations, and Symbols

%	percent
±	plus or minus
°C	degrees of Celsius, metric unit of temperature
°F	degrees of Fahrenheit, English unit of temperature
μ	micro
μ <sub>He</sub>	dynamic viscosity of helium
μ <sub>F</sub>	dynamic viscosity of fluid
ASNT	The American Society for Nondestructive Testing
cc	metric unit of cubic centimeter
cm	metric unit of centimeter
ELT	element leak test
Eq.	equation
<i>F</i>	fluid
FFRDC	Federally Funded Research and Development Center
ft	foot
GLT	gross leak test
GSE	ground support equipment
He	helium
in	inch
JSC	Johnson Space Center
k	kilo, prefix in metric system
lbm/day	pounds-mass per day
LTR	Leak Test Requirement
lux	metric unit of illuminance
m	meter, metric unit of length
mm	millimeter, metric unit of length
MALR	maximum allowable leakage rate
MAWP	maximum allowable working pressure
MDP	maximum design pressure
MEOP	maximum expected operation pressure
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
NPR	NASA Procedural Requirements
Pa	Pascal, metric unit of pressure
P <sub>EXT</sub>	external pressure in consistent units
P <sub>INT</sub>	internal pressure in consistent units
P <sub>O</sub>	atmospheric pressure in consistent units
psi	pound-force per square inch, English unit of pressure
psig	pounds-force per square inch gauge, English unit of pressure

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Q	leakage rate
RTVP	Requirements, Test, and Verification Panel
scc	metric unit of standard cubic centimeter
sec	second
SMA	safety and mission assurance
SMAC	spacecraft maximum allowable concentration
STD	Standard
TA	Technical Authority
tg	tracer gas
THL	toxicity hazard level
VF	viscosity factor

## 3.2 Definitions

*Note: The many definitions specifically for leak testing are consistent with ASTM E1316, Standard Terminology for Nondestructive Examinations, while other definitions correspond to documentation currently used by NASA programs.*

**Acceptance Test:** A test performed to demonstrate that the test article is acceptable for its intended use. It also serves as a quality control screen to detect manufacturing, material, or workmanship defects in the flight build and to demonstrate compliance with specified requirements. This type of test is performed on previously qualified hardware to flight limit levels and durations for the purpose of functionality verification and workmanship screening.

**Background:** In leak testing, the steady or fluctuating output of a leak detector caused by the presence of residual tracer gas or other substance to which the detecting element responds.

**Calibration of Leak Test Setup:** The comparison or the adjustment of a leak test setup to a known reference called a calibrated or standard leak often traceable to the National Institute of Standards and Technology (NIST). For other leak test standard tools such as graduated flasks, columns, and pipettes purchased at standard scientific suppliers, the calibration of the graduations should be accepted. Tracer gas leak standards should bear a calibration certification sticker from metrology or the vendor and should be within the prescribed dates and, if equipped with a pressure gauge, within the appropriate pressure range. **Note:** See ASTM E908, Standard Practice for Calibrating Gaseous Reference Leaks, for details.

**Component:** A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples include pressure vessels, valves, pressure transducers, pressure gauges, quick disconnects, flex hoses. Synonymous with unit.

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Detector Probe: In leak testing, a device used to collect tracer gas from an area of the test article and feed it to the leak detector at the reduced pressure required. Synonymous with sniffing probe and/or sniffer wand.

Drift: In leak testing, the relatively slow change in the background output level of the leak detector due to the electronics rather than a change in the level of the tracer gas.

Element: An entire vehicle, spacecraft, or pressurized module, especially if crewed in flight or on-orbit.

External-to-Internal Total Leakage: The combined leakage rate of a fluid (most frequently tracer gas) through all the existing leaks from outside to inside of a test article being tested.

Internal-to-External Total Leakage: The combined leakage rate of a fluid (most frequently tracer gas) through all the existing leaks from inside of a test article being tested to outside.

Internal-to-Internal Total Leakage: The combined leakage rate of a fluid (most frequently tracer gas) through all the existing leaks across an internal barrier (static or moveable) within a test article.

Leak: A hole, void, path, or other defect (e.g., network of cracks in composite materials) in the wall of an enclosure or across a barrier that permits the passage of fluid (liquid or gas) from one side of the wall or barrier to the other under action of pressure or concentration differential existing across the wall or barrier independent of the quantity of fluid flowing.

Leak Detector: An instrument for detecting and locating leaks and/or measuring leakage rates.

Leak Detector Output Stabilization: Four consecutive readings taken no less than 5 minutes apart after three time constants have been exceeded with no more than a 10 percent (%) variation in the leak detector output from one measurement to the next, including the first and last measurements.

Leak Test Setup: The total end-to-end configuration of the ground support equipment (GSE) specific for each leak test method. For example, the test setup for tracer gas methods can include a leak detector connected to a vacuum chamber, bell jar, detector probe, hood, or enclosure.

Leak Testing: The process of verifying the total leakage rate (total leak testing) or pinpointing the local leak (local leak testing).

Leakage: The flow of fluid (liquid or gas) through a leak.

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Leakage Rate: The flow rate of a fluid (liquid or gas) through a leak at a given temperature as a result of a specified pressure difference across the leak. Standard conditions for gases are 25°C (77°F) and 100 kPa (14.50 psi). Leakage rates are expressed in various units such as Pascal cubic meters per second ( $\text{Pa m}^3/\text{sec}$ ), standard cubic centimeters per second (scc/sec), or pounds-mass per day (lbm/day). **Note**: Standard conditions for gases are not universally agreed to and accepted. For the purpose of this NASA Technical Standard, ASTM E1316 is chosen to be a reference where standard conditions are determined as 25°C (77°F) and 100 kPa (14.50 psi).

Maximum Allowable Working Pressure (MAWP): The maximum pressure at which a component, subsystem, vehicle, or element can continuously operate based on allowable stress values and functional capabilities. Synonymous with maximum design pressure (MDP), maximum operating pressure, and maximum expected operating pressure (MEOP). **Note**: See NASA-HDBK-8709.22, Safety and Mission Assurance Acronyms, Abbreviations, and Definitions.

Maximum Design Pressure (MDP): The highest possible operating pressure considering maximum temperature, maximum relief pressure, maximum regulator pressure, and, where applicable, transient pressure excursions. MDP for human-rated hardware is a two-failure tolerant pressure; i.e., MDP will not be exceeded for any combination of two credible failures that will affect pressure. For all other hardware, MDP is equivalent to MEOP. **Note**: See NASA-STD-5001, Structural Design and Test Factors of Safety for Spaceflight Hardware.

Maximum Expected Operating Pressure (MEOP): The maximum pressure which pressurized hardware is expected to experience during its service life, in association with its applicable operating environments. MEOP includes the effects of temperature, transient peaks, vehicle acceleration, and relief valve tolerance. **Note**: See NASA-STD-5001.

Payload: An integrated assemblage of subsystems designed to perform a specified mission in space. Other terms that may be used to designate this level of assembly are satellite, spacecraft, or observatory.

Pressurized Article: An article designed to retain its leak tightness at both standard atmospheric and positive differential internal pressure.

Proof Pressure: The product of maximum test pressure in accordance with the test article specifications (could be MAWP, MDP, or MEOP) and a proof factor accounting for the difference in material properties between the test and service environment (such as temperature). **Note**: See NASA-HDBK-8709.22.

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Proof Pressure Testing: The process of applying a proof pressure (hydrostatically by incompressible liquid or pneumatically by compressible gas) to a test article to detect material and workmanship defects, including excessive internal and/or external leakage, that could result in a failure during usage. **Note**: See NASA-STD-5001.

Qualification Test: A test intended to verify that the test article meets design requirements and will function within performance specifications during and/or after being exposed to levels that demonstrate margin over the expected flight environment. Both prototype and protoflight test approaches are considered to be valid for structural qualification purposes. **Note**: See NASA-STD-5001 that clarifies the differences between prototype and protoflight qualification test approaches.

Quantitative Leak Test Method/Technique: A test method/technique that, after proper calibration, provides the total leakage rate measurement for the test article or its part, but not intended to pinpoint an exact location of any specific leak.

Relative Sensitivity: A ratio calculated as a standard leak in leakage rate units (e.g., standard cubic centimeters per second) per a leak detector output in either scale divisions or the same leakage rate units (called “bag factor” for accumulation method). To be used for determining the test article leakage rate.

Sealed Article: An article designed to retain its leak tightness at both standard atmospheric and positive or negative differential internal pressure.

Semi-quantitative Leak Test Method/Technique: A test method/technique that, after proper calibration, provides the estimated local leakage rate measurement for a part of the test article, but not a total leakage rate measurement for the test article as a whole.

Sensitivity of Leak Detector/Leak Test Setup: The size of the smallest leakage rate that can be unambiguously detected by a leak detector/test setup.

Standard Leak: A device calibrated and maintained per NIST guidelines that permits a test gas either to be introduced into or leak out of a leak test setup at a known rate to facilitate its calibration. Synonymous with leak artifact. **Note**: See ASTM E908.

Subsystem: A specific set of hardware functional entities and their associated interconnections that perform a single category of functions. The functional level immediately below the system level. **Note**: For the purpose of this NASA Technical Standard, subassemblies are considered as subsystems.

Technical Authority: Part of NASA’s system of checks and balances that provides independent oversight of programs and projects in support of safety and mission success through the selection of individuals at delegated levels of authority. These individuals are the Technical Authorities. Technical Authority delegations are formal and traceable to the

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Administrator. Individuals with Technical Authority are funded independently of a program or project. **Note:** See NPR 7120.5.

Test Article: A space vehicle, its system, its subsystem or component, and/or payload that will be pressurized with any operational fluid (gas or liquid) or sealed with positive or negative operational fluid pressure inside it for flight.

Tracer gas: A gas that, passing through a leak, can then be detected by a specific leak detector and thus disclose the presence of a leak. Synonymous with search gas.

Vacuum Chamber: A container where an external vacuum can be created and applied to the test article that will be pressurized with a tracer gas and leak tested being placed completely or partially in a vacuum chamber. Synonymous with bell jar.

## 4. REQUIREMENTS

### 4.1 General Requirements for Leak Testing

**4.1.1** [LTR 1] Leak testing of the test articles **shall** be performed prior to initiation of and following the completion of each of the following applicable qualification, acceptance, and protoflight environmental tests:

- a. Thermal testing (vacuum, cycle).
- b. Vibration testing (random, sinusoidal, acoustic).
- c. Shock testing (pyrotechnic, mechanical).
- d. Acceleration testing.
- e. Life-cycle testing (pressure, actuation, etc.).

*Exceptions are space vehicles and elements, which may be subjected to leak testing only prior to initiation of environmental tests and at the end of all environmental tests.*

*[Rationale: Leak tests are used to verify proper assembly and workmanship during qualification, acceptance, or protoflight testing. Furthermore, leak tests demonstrate the capability of pressurized and/or sealed test articles to meet the leakage rate requirements specified in the test article specification or drawing.]*

**4.1.2** [LTR 2] Personnel performing leak testing in accordance with any of the leak test methods and/or techniques described in this NASA Technical Standard **shall** be, at a minimum, qualified and certified Level II qualification in accordance with ANSI/ASNT CP-189, ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel.

**4.1.3** [LTR 3] For the pressurized test articles, a proof pressure test **shall** be performed once prior to the first leak test.

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## NOTES:

1. Preliminary leak tests may be performed prior to the proof pressure test to establish a baseline.
2. Proof pressure tests can be performed in conjunction with the leak test.

**4.1.4** [LTR 4] Prior to initiating a leak test, the test article external and internal surfaces **shall** be prepared to meet the specific program or project cleanliness requirements to remove any foreign object debris and moisture from potential leaks.

**4.1.5** [LTR 5] When temperature affects the sealing materials or surfaces, the leak test **shall** be conducted at the minimum and maximum qualification, acceptance, or protoflight temperature limits.

*If it is determined from the evaluation that a leak test at temperature limits is warranted on a test article of a given level of assembly due solely to one or more lower tier components comprising the assembly, and it can be shown that all of those lower tier test articles receive an appropriate leak test at temperature limits as part of a lower level qualification, acceptance, or protoflight test, then the higher level of assembly such as space vehicle or element does not require leak testing at temperature extremes.*

## 4.2 Leak Test Methods

**4.2.1** [LTR 6] The leak test method **shall** detect leakage rates less than or equal to one-half of the MALR.

**4.2.1.1** [LTR 7] The sensitivity of the leak test setup used to implement any quantitative leak test method for total leak testing **shall** be verified through its calibration prior to and after the leak test.

**4.2.1.2** [LTR 8] The sensitivity of the leak test setup used to implement any semi-quantitative leak test method for local leak testing to pinpoint a specified single-point leakage rate **shall** be verified through its calibration prior to and after the leak test.

*The sensitivity of the leak test setup used to implement any semi-quantitative leak test method for local leak testing to pinpoint a non-specified single-point leakage rate may not be verified through its calibration.*

**4.2.2** [LTR 9] Leak testing of the test articles **shall** be performed using one of the following leak test methods/techniques as defined in Table 1, Leak Test Methods for Pressure Integrity Verification and Pinpointing Local Leaks, and in accordance with its related method/technique requirements specified in section 5 of this NASA Technical Standard:

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a. Method I [1]<sup>1</sup> and [2], II, IV [2], V [1], VII, VIII, IX [1] and [2], X, XI, XII, or XIII, as appropriate, for pressurized test articles.

b. Method III, IV [1] and [2], V [2], VI, or XIV, as appropriate, for sealed test articles.

*The leak test methods shown in Table 1 have five categories: (1) for total internal-to-external leakage rate verification; (2) for total external-to-internal leakage rate verification; (3) for total internal-to-internal leakage rate verification; (4) for local internal-to-external leakage rate verification, and (5) for local external-to-internal leakage rate verification.*

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<sup>1</sup> A number in brackets following a Roman numeral, e.g., V [1], refers to the technique number in a specific method. Also, see section 5.



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**Table 1—Leak Test Methods for Pressure Integrity Verification and Pinpointing Local Leaks**

Method No. and [Technique No.]	Leak Test Method <sup>1,2,4</sup>	Minimum Leakage Rate Expected to Be Verifiable (scc/sec) <sup>3</sup>	MALR Setting
<b>Methods for Total Internal-to-External Leakage Rate Verification</b>			<b>A</b>
I [1] and [2]	Vacuum Chamber [Chamber and Bell Jar techniques], quantitative	Down to 10 <sup>-9</sup>	
II	Accumulation, quantitative	Down to 10 <sup>-7</sup>	
III	Bombing, quantitative	Down to 10 <sup>-8</sup>	
IV [1] and [2]	Vacuum Exposure [Mass Loss and Pressure Loss techniques], quantitative	Down to 5×10 <sup>-5</sup>	
V [1]	Pressure Change [Pressure Decay technique], quantitative	Down to 10 <sup>-4</sup>	
IX [2]	Immersion [Total Leakage Rate technique], quantitative	Down to 10 <sup>-4</sup>	
<b>Methods for Total External-to-Internal Leakage Rate Verification</b>			<b>A</b>
V [2]	Pressure Change [Pressure Rise technique], quantitative	Down to 10 <sup>-5</sup>	
VI	Hood, quantitative	Down to 5×10 <sup>-10</sup>	
<b>Methods for Total Internal-to-Internal Leakage Rate Verification</b>			<b>A</b>
VII	Volumetric Displacement, quantitative	Down to 10 <sup>-3</sup>	
VIII	Leak Detector Direct Connection, quantitative	Down to 10 <sup>-8</sup>	
<b>Methods for Local Internal-to-External Leakage Rate Verification</b>			<b>B</b>
IX [1]	Immersion [Local Leakage Rate technique], semi-quantitative	Down to 10 <sup>-4</sup>	
X	Ammonia Colorimetric, semi-quantitative	Down to 5×10 <sup>-6</sup>	
XI [1] and [2]	Detector Probe [Joints and Flex Hoses techniques], semi-quantitative	Down to 10 <sup>-5</sup>	
XII	Foam/Liquid Application, semi-quantitative	Down to 10 <sup>-4</sup>	
XIII	Hydrostatic/Visual Inspection, semi-quantitative	Down to 10 <sup>-3</sup>	
<b>Method for Local External-to-Internal Leakage Rate Verification</b>			
XIV	Tracer Probe, semi-quantitative	Down to 10 <sup>-8</sup>	<b>B</b>
<p><b>A.</b> Use only methods for total leakage rate verification if the MALR is set as a total leakage rate.</p>			

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**B.** Use only methods for local leakage rate verification if the MALR is set as a single-point leakage rate.

### **NOTES:**

1. *The selection of a method to be chosen other than internal-to-external or external-to-internal leakage rate verification requires a special justification presented, for example, in a test article verification plan approved by the responsible safety organization.*
2. *The leak test method employed should be demonstrated to have a sensitivity to detect leakage rates, generally in accordance with section 4.2.1 of this NASA Technical Standard and specifically for tracer gas methods in accordance with section 5.19.3 of this NASA Technical Standard.*
3. *The minimum leakage rate that could be reliably verified is dependent on many technical details specific for each method, for example, on sensitivity of the leak detector with probe attached, free volume of a particular test arrangement, and time of accumulation for the accumulation method.*
4. *ASTM E432, Standard Guide for Selection of a Leak Testing Method, may also be used as a guide for selection of a leak test method.*

**4.2.3** [LTR 10] In general, the MALR (to be identified in the test article specifications or drawing) together with the leak test method (to be chosen from Table 1 to verify the MALR), **shall** ensure that the maximum amount of substance that could leak over the mission duration (calculated as MALR × mission duration × safety factor (assigned by a system engineer or payload developer and concurred with by the Safety and Mission Assurance (SMA) Technical Authority and Engineering Technical Authority) would prevent exceeding the allowed Toxicity Hazard Level (THL) or Spacecraft Maximum Allowable Concentration (SMAC) value (whichever is more conservative) shown in Table 2, Leak Test Methods to be Used to Ensure Allowed THL and SMAC Values (see NPR 7120.5 for Engineering Technical Authority responsibilities and NASA-STD-8709.20, Management of Safety and Mission Assurance Technical Authority (SMA TA) Requirements, for SMA Technical Authority responsibilities).

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**Table 2— Leak Test Methods to be Used to Ensure Allowed THL and SMAC Values**

THL or Other Limitations	Recommended MALR to Be Verified: Leak Test Methods
Catastrophic	Although no greater than $10^{-9}$ scc/sec is a prevalent value, the specific MALR calculated in accordance with section 4.2.3 of this NASA Technical Standard should take precedence: <ul style="list-style-type: none"> <li>• Method I (to verify pressure integrity);</li> <li>• Method IV may be used to verify pressure integrity only if MALR for the test article filled with the gas or liquid is set to be <math>5 \times 10^{-5}</math> scc/sec or more;</li> <li>• Methods XI, XIV (to pinpoint local leaks).</li> </ul>
Critical	Although no greater than $10^{-7}$ scc/sec is a prevalent value, the specific MALR calculated in accordance with section 4.2.3 of this NASA Technical Standard should take precedence: <ul style="list-style-type: none"> <li>• Methods I and II (to verify pressure integrity);</li> <li>• Method IV may be used to verify pressure integrity only if MALR for the test article filled with gas or liquid is set to be <math>5 \times 10^{-5}</math> scc/sec or more;</li> <li>• Methods XI, XIV (to pinpoint local leaks).</li> </ul>
Fluid is not allowed or desired	No greater than $10^{-4}$ scc/sec: <ul style="list-style-type: none"> <li>• Methods I, II, III, IV, and V [Technique No. 1] (to verify pressure integrity);</li> <li>• Methods IX, X, XI, XII, XIII, and XIV (to pinpoint local leaks).</li> </ul>
Not safety, just general concerns about leaks	No greater than $10^{-3}$ scc/sec: <ul style="list-style-type: none"> <li>• Methods I through XIV (selected to verify pressure integrity and/or pinpoint local leaks depending on a flow direction through leaks (out of or into the test article)).</li> </ul>

**4.2.4** [LTR 11] The test fluid (liquid or gas) used for leak testing **shall** be compatible with the test article’s materials and operational fluid.

### 4.3 Leakage Rate Unit Conversion

**4.3.1** [LTR 12] Prior to conversion from a tracer gas (most frequently helium) leakage rate to a corresponding leakage rate of a working fluid (gas or liquid), the measured tracer gas leakage rate **shall** be recalculated per equation (Eq.) 1:

$$Q_{100\%} = Q_{tg\%} \frac{100\%}{C_{tg\%}} \quad (\text{Eq. 1})$$

Where

$Q_{100\%}$  is a tracer gas leakage rate recalculated to its 100% concentration.

$Q_{tg\%}$  is a measured tracer gas leakage rate at its known or estimated concentration.

$C_{tg\%}$  is a known or estimated concentration of a tracer gas inside the test article.

**4.3.2** [LTR 13] Tracer gas concentration **shall** be greater than or equal to 5% at all the points of potential leak paths during leak tests.

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Conversion factors used to determine working fluid (gas or liquid) leakage rate from the measured tracer gas leakage rate may be based on the flow regime of the tracer gas and working fluid (gas or liquid) through the leak paths being tested and include the relevant pressure and thermal effects.

If the tracer gas used for leak testing is helium, conversion to a leakage rate of other fluids (most commonly used fluids (gas or liquid) are shown in the first column as an example) may be performed using Table 3, Chart for Conversion from Helium to Other Fluids. For fluids (gas or liquid) not listed in the chart, use Eq. 2 for gases or Eq. 3 for liquids to find the conversion factor.

**Table 3—Chart for Conversion from Helium to Other Fluids**

To Convert Leakage Rate Measured with Helium as a Tracer Gas (Recalculated to its 100% Concentration)	Gas Flow Convert per Equation 2 where Viscosity Factor (VF) is:	Liquid Flow Convert per Equation 3 where VF is:
$Q_{\text{Air}}$	1.076	-
$Q_{\text{Nitrogen}}$	1.115	-
$Q_{\text{Oxygen}}$	0.971	-
$Q_{\text{Hydrogen}}$	2.226	-
$Q_{\text{Argon}}$	0.881	-
$Q_{\text{Neon}}$	0.637	-
$Q_{\text{Water}}$	-	0.0202
$Q_{\text{Ammonia}}$	-	0.142

**NOTES:**

1. With viscous gas flow through a leak, the leakage rate is proportional to the difference in the squares of the pressures acting across the leak. The VF is calculated at 21°C (70°F). (Eq. 2)
2. With viscous liquid flow through a leak, the leakage rate is proportional to the pressure difference. The VF is calculated at 21°C (70°F). (Eq. 3)
3. If other than helium tracer gas was used, a new VF will be calculated as a ratio of the tracer gas and working fluid (gas or liquid) viscosities.
4. The conversion assumes laminar flow in the fluid leak path. Even though this is not always the physical case, making this assumption results in a conservative prediction of the leakage rate of the working fluid (gas or liquid) whether the flow of the helium (during leak testing) through the leak path and working fluid (gas or liquid while functioning on the ground or on orbit) is laminar, molecular, or in the transition region.
5. If the system engineers have a concern about the conservatism introduced by this approach, they may use a physics-based approach to conversion between the tracer gas and working fluid (gas or liquid) where the flow regime type (laminar, molecular, or transition) is determined for the test fluid and the working fluid and the appropriate conversions are made.
6. Conversion from measured helium leakage rate to water leakage rate for test articles that have hoses made of Teflon™ or similar material with high permeation rate for helium do not require a conversion factor provided that individual joints demonstrated not having any single-point leakage rate greater than  $1.0 \times 10^{-5}$  scc/sec (if tested via Method II (Accumulation)), and/or not having any single-point leakage above helium background in the

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test lab (if tested via Method XI (Joints technique), and/or not having any single-point leakage as evidenced by one or more bubbles formed by helium in the foam or liquid (if tested via Method XII (Foam/Liquid Application)).

Equations for use in Table 3:

$$Q_F = Q_{He} [(P_{INT}^2 - P_{EXT}^2)_F] / P_{INT, He}^2 VF \quad (Eq. 2)$$

$$Q_F = Q_{He} 2P_0 [(P_{INT} - P_{EXT})_F] / P_{INT, He}^2 VF \quad (Eq. 3)$$

Where

$Q_F$  is a fluid leakage rate in scc/sec (if fluid is a gas) and cubic centimeter (cc)/sec (if fluid is a liquid).

$Q_{He}$  is a helium leakage rate in scc/sec.

$P_{INT}$  is an internal pressure for fluid (shown with  $F$ ) and helium (shown with  $He$ ).

$P_{EXT}$  is an external pressure for fluid (shown with  $F$ ) and helium (shown with  $He$ ).

$VF$  is the ratio of the dynamic viscosities ( $\mu$ ) of the tracer gas and the working fluid, e.g., for helium  $VF = \mu_{He}/\mu_F$ .

$P_0$  is atmospheric pressure in consistent units.

Conversion between different leakage rate units is also provided in the *Leakage Testing Handbook*, ASTM E1316, and *ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing*.

## 5. LEAK TEST METHODS FOR QUALIFICATION OR ACCEPTANCE TESTING

Note that if the test article has unique design features, e.g., materials from which the test article is built, leak test methods described in this section may be modified and approved by the delegated Technical Authority (see section 1.3 in this NASA Technical Standard.)

### 5.1 Method I—Vacuum Chamber

[LTR 14] The following quantitative methods **shall** be used for total internal-to-external leak testing of pressurized test articles such as vehicles and/or spacecraft (technique [1]) and subsystem components such as electrical and/or fluid feedthroughs (technique [2]):

- a. Chamber Technique [1] for Spacecraft/Vehicle:
  - (1) Completely place the test article in a vacuum chamber and test for total leakage with a leak detector appropriate for the tracer gas used.
  - (2) Calibrate the leak test setup (vacuum chamber, all associated lines and fittings, and a leak detector) with the standard leak (see section 4.2.1.1 in this NASA Technical Standard) to determine the leak test setup relative sensitivity to be used to establish the test article leakage rate.
  - (3) Charge the test article with a known concentration of a tracer gas to the required pressure.

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- (4) Maintain the required pressure until stabilization (four consecutive readings no less than 5 minutes apart with no more than a 10% variation in the leak detector output from one measurement to the next, including the first and last measurements) of the leak detector output is achieved.

*If the leak detector outputs are decreasing over a 15-minute period rather than steadily increasing, or the leak detector output variations are more than 10% but occurred at a very low level (at least a factor of 10 lower than the MALR set for the test article), then this 10% stabilization may not be required.*

- (5) Record calibration data, leak detector initial and final readings, actual temperature of the test article (if leak test was performed at other than ambient temperature) and the four data points within a 15-minute duration demonstrating stabilization in accordance with the definition above.

b. Bell Jar Technique [2] for Feedthroughs:

- (1) Install the bell jar connected to the tracer gas leak detector on the test article area to undergo the leak test.
- (2) Calibrate the leak test setup (bell jar, all associated lines and fittings, and a leak detector) with the standard leak (see section 4.2.1.1 in this NASA Technical Standard) to determine the leak test setup relative sensitivity to be used to establish the test article leakage rate.
- (3) Charge the test article with a known concentration of a tracer gas to the required pressure.
- (4) Maintain the required pressure until stabilization (four consecutive readings no less than 5 minutes apart with no more than a 10% variation in the leak detector output from one measurement to the next, including the first and last measurements) of the leak detector output is achieved.

*If the leak detector outputs are decreasing over a 15-minute period rather than steadily increasing, or the leak detector output variations are more than 10% but occurred at a very low level (at least an order of magnitude lower than the MALR set for the test article), the stabilization requirement is not applicable.*

- (5) Record calibration data, leak detector initial and final readings, and the final test article leakage rate with four data points within a 15-minute duration to demonstrate stabilization in accordance with the definition above.

*ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, may be used as a reference to develop the leak test procedure to implement these techniques.*

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## 5.2 Method II—Accumulation

[LTR 15] The following quantitative method **shall** be used for total internal-to-external leak testing of pressurized test articles:

- a. Enclose the test article in a suitable enclosure.
- b. Calibrate the leak test setup (an enclosure and a leak detector) with the standard leak (see 4.2.1.1 of this NASA Technical Standard) that simulates the actual leak through the potentially existing defects placed in the enclosure for a predetermined period of time to determine the leak test setup relative sensitivity for use in establishing the test article leakage rate.

*In case of simultaneous leak testing of similar test articles such as quick disconnects, calibration of only three enclosures from the group of identical enclosures is allowed. If the sensitivity with these three enclosures is within  $\pm 20\%$  of each other, then the average sensitivity may be used for every other enclosure in the group of identical enclosures.*

- c. At the end of the time period, place a detector probe in the enclosure and record the maximum leak detector response.
- d. Purge the enclosure with air sufficiently to remove the tracer gas used for calibration.
- e. Charge the test article with a known concentration of a tracer gas to the required pressure.
- f. Prior to examination, perform the following:
  - (1) Hold the test pressure for a minimum duration of 30 minutes for joints with elastomeric seals and of 5 minutes for welds, fittings, or plugs with no elastomeric seals.
  - (2) Purge the enclosure with air until the tracer gas background inside it is equal to or less than the tracer gas concentration in the test facility and seal it.
  - (3) After the time period used for the calibration, place the detector probe in the enclosure at the same location it was placed during the calibration.
  - (4) Record calibration data, leak detector initial and final readings, and the final test article leakage rate.

*ASTM E499/E499M, Standard Practice for Leaks Using the Mass Spectrometer Leak Detector in the Detector Probe Mode, and ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, may be used as references to develop the leak test procedure to implement this method.*

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## 5.3 Method III—Bombing

[LTR 16] The following quantitative method **shall** be used for total internal-to-external leak testing of sealed test articles:

a. Place the test article in the pressure vessel and flush or backfill with tracer gas to the specified pressure.

b. Hold the test article at the specified external pressure as high as the test article can safely withstand for the time required to achieve the required test setup sensitivity but not less than five time constants.

*The time constant is the product of internal volume of the test article and the inverse of the conductance of the leak that corresponds to the MALR.*

c. After the dwell, release the tracer gas pressure at a considerable distance from the leak detector; remove the test article from the test setup pressure vessel; and flush with dry air or nitrogen to remove absorbed tracer gas from the test article surface.

d. After the flush, test the test article singly or in multiples in the vacuum chamber in accordance with Method I, including test setup (vacuum chamber and leak detector) calibration (see section 4.2.1.1 of this NASA Technical Standard).

e. To provide the necessary sensitivity and accuracy for the bombing leak test method, perform correlation studies on the parts to be tested to correlate actual leakage rates to the tracer gas leakage rate detected after bombing.

f. Limit the length of time between the bombing and actual leak test steps to the duration determined in correlation studies.

g. Calculate the actual leakage rate of the test article in accordance with ASTM E493/E493M, Standard Practice for Leaks Using the Mass Spectrometer Leak Detector in the Inside-Out Testing Mode.

*ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, may be used as a reference to develop the leak test procedure to implement this method.*

## 5.4 Method IV—Vacuum Exposure

[LTR 17] The following quantitative methods **shall** be used for total internal-to-external leak testing of liquid-filled (technique [1]) and gas-filled (technique [2]) sealed test articles:

a. Mass Loss Technique [1] for liquid-filled sealed test articles:

(1) Weigh the test article before the test.

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- (2) Completely place the test article in a vacuum chamber or bell jar and expose it to vacuum, the level and duration of which are dependent on the test article application and the MALR to be verified.
- (3) Weigh the test article after the test to confirm there is no calculated leakage rate above the MALR by the test article mass loss from the test.
- (4) Ensure that the weight balance has an accuracy adequate to measure the minimum weight change that corresponds to the MALR (see section 4.2.1.1 of this NASA Technical Standard).

b. Pressure Loss Technique [2] for gas-filled sealed test articles:

- (1) Pressurize the test article to the required pressure.
- (2) Completely place the test article in a vacuum chamber or bell jar to expose it to vacuum.

*Select the level and duration of dwell depending on the test article application.*

- (3) Measure the gas pressure inside the test article after the test and confirm there is no calculated leakage rate above the MALR by its internal gas pressure loss from the test.
- (4) Use a pressure gauge/transducer with accuracy adequate to measure the minimum allowed pressure change that corresponds to the MALR (see section 4.2.1.1 in this NASA Technical Standard).

*Note: ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, may be used as a reference to develop the leak test procedure to implement these techniques.*

### 5.5 Method V—Pressure Change

[LTR 18] The following quantitative methods **shall** be used for both pressurized (technique [1]) and sealed (technique [2]) test articles:

a. Pressure Decay Technique [1] for total internal-to-external leak testing of pressurized test articles:

- (1) Pressurize the test article to the required pressure.
- (2) Monitor the test article internal pressure, barometric pressure, and ambient temperature (or temperature of the test article) for the required time to determine the actual pressure drop and the corresponding leakage rate.
- (3) Use a pressure gauge/transducer with accuracy adequate to measure the minimum allowable pressure drop.
- (4) Verify test setup sensitivity by installing a standard leak in the test setup (see section 4.2.1.1 in this NASA Technical Standard).
- (5) While making leakage rate calculation based on a recorded pressure drop, take into account:

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- A. The test article and test fixture pressurized internal volumes, as well as volume tolerances at maximum positive values, and
- B. The test article and reference vessel (in case it was used) volumetric changes due to ambient temperature changes.

*To improve the accuracy of this technique, a reference vessel connected to the pressurized test article may be used (see section 4.2.1.1 in this NASA Technical Standard.)*

b. Pressure Rise Technique [2] for total external-to-internal leak testing of sealed test articles:

- (1) Reduce the pressure inside the test article to the required pressure.
- (2) Monitor the test article internal pressure, barometric pressure, and ambient temperature (or temperature of the test article) for the required time to determine the actual pressure rise and the corresponding leakage rate.
- (3) Use a pressure gauge/transducer with accuracy adequate to measure the minimum allowable pressure rise.
- (4) Verify test setup sensitivity by installing a standard leak in the test setup (see section 4.2.1.1 in this NASA Technical Standard).
- (5) While making leakage rate calculation based on a recorded pressure rise, take into account the total sealed internal volume of the test article and test fixture, as well as volume tolerances at maximum positive values.

*Note: ASTM E2930, Standard Practice for Pressure Decay Leak Test Method, and ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, may be used as references to develop the leak test procedure to implement these techniques.*

## 5.6 Method VI—Hood

[LTR 19] The following quantitative method **shall** be used for total external-to-internal leak testing of sealed test articles:

a. Evacuate the test article internal volume to a vacuum compatible with a tracer gas leak detector.

b. Calibrate the leak test setup (a hood and a leak detector) with the standard leak installed at the farthest possible point from the leak detector to determine the leak test setup relative sensitivity (see section 4.2.1.1 in this NASA Technical Standard) for use in establishing the test article leakage rate.

c. For the test articles that have only one leak test port, install a standard leak at this port.

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d. Expose the external surfaces of the test article to a verified concentration of a tracer gas at atmospheric pressure or slightly higher, maintaining pressure until stabilization (four consecutive readings no less than 5 minutes apart with no more than a 10% variation in the leak detector output from one measurement to the next, including the first and last measurements) of the leak detector output is achieved.

*If the leak detector outputs are decreasing over a 15-minute period rather than steadily increasing, or the leak detector output variations are more than 10% but occurred at a very low level (at least an order of magnitude lower than the MALR set for the test article), the stabilization requirement is not applicable.*

e. Record calibration data, leak detector initial and final readings, and the final test article leakage rate with four data points within a 15-minute duration to demonstrate stabilization in accordance with the definition above.

*Note: ASTM E1603/E1603M, Standard Practice for Leakage Measurement Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Hood Mode, and ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, may be used as references to develop the leak test procedure to implement this method.*

### 5.7 Method VII—Volumetric Displacement

[LTR 20] The following quantitative method **shall** be used for total internal-to-internal leak testing of pressurized test articles such as valves, pressure regulators, or heat exchangers:

a. Calibrate the leak test setup (see section 4.2.1.1 in this NASA Technical Standard) for volumetric displacement.

b. Pressurize one side of the test article to the required pressure while the other side across the internal barrier is sealed from the atmosphere and attached to the volumetric displacement measurement device.

c. Use the measured volume of leaked gas to establish the leakage rate and compare it to the MALR.

*Note: ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, may be used as a reference to develop the leak test procedure to implement this method.*

### 5.8 Method VIII—Leak Detector Direct Connection

[LTR 21] The following quantitative method **shall** be used for total internal-to-internal leak testing of pressurized test articles such as valves, pressure regulators, or heat exchangers:

a. Calibrate the leak test setup (a leak detector) with the standard leak installed at the farthest possible point from the leak detector (see section 4.2.1.1 of this NASA Technical

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Standard) to determine the leak test setup relative sensitivity for use in establishing the test article leakage rate.

b. Charge one side of the test article with a known concentration of a tracer gas to the required pressure while the other side across the internal barrier is sealed from the atmosphere and attached to the leak detector.

c. Maintain pressure until stabilization (four consecutive readings no less than 5 minutes apart with no more than a 10% variation in the leak detector output from one measurement to the next, including the first and last measurements) of the leak detector output is achieved.

*If the leak detector outputs are decreasing over a 15-minute period rather than steadily increasing, or the leak detector output variations are more than 10% but occurred at a very low level (at least an order of magnitude lower than the MALR set for the test article), the stabilization requirement is not applicable.*

d. Record calibration data, leak detector initial and final readings, and the final test article leakage rate with four data points within a 15-minute duration to demonstrate stabilization in accordance with the definition above.

*Note: ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, may be used as a reference to develop the leak test procedure to implement this method.*

## 5.9 Method IX—Immersion

[LTR 22] The following methods **shall** be used for local internal-to-external leak testing of pressurized test article purposes (technique [1]) and for total internal-to-external leak testing of pressurized test articles (technique [2]):

a. Semi-quantitative Local Leakage Rate Technique [1] to pinpoint local leaks and provide a rough estimate of their leakage rates (see section 4.2.1.2 of this NASA Technical Standard for calibration if required):

- (1) Apply internal gas pressure across the pressure boundary for a minimum duration of 15 minutes before the test liquid contacts the external surface.
- (2) Ensure lighting in the area to be examined is no less than 1000 lux or lumen/m<sup>2</sup> (100 foot-candles) in brightness, and illumination is free from shadows over the surface area under inspection.
- (3) Observe the surface to be examined with observer's eyes placed within 60 cm (2 ft) of the surface to be examined.

*Mirrors or magnifying glasses may be used to improve visibility of indications.*

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- (4) Completely immerse the test article in a liquid, ensuring that the critical side of interest of the test article is in a horizontal plane facing up, after which the appearance of gas bubbles indicates a leak.

b. Quantitative Total Leakage Rate Technique [2] that serves for total internal-to-external leak testing of pressurized test articles such as flex hoses (see section 4.2.1.1 of this NASA Technical Standard for calibration):

- (1) Apply internal gas pressure across the pressure boundary for a minimum duration of 15 minutes before the test liquid contacts the external surface.
- (2) Ensure lighting in the area to be examined is no less than 1000 lux or lumen/m<sup>2</sup> (100 foot-candles) in brightness, and illumination is free from shadows over the surface area under inspection.
- (3) Completely immerse the test article in a liquid.
- (4) Immerse the measuring cylinder in the bath with the test liquid.
- (5) Keep the measuring cylinder above the whole test article or its part to let leaking gas accumulate inside the measuring cylinder.
- (6) Use the measured volume of leaked gas to establish the leakage rate and compare it to the MALR to demonstrate a margin of at least five units of volumetric rate.

*Note: ASTM E515, Standard Practice for Leaks Using Bubble Emission Techniques, and ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, may be used as references to develop the leak test procedure to implement this method/technique.*

### 5.10 Method X— Ammonia Colorimetric

[LTR 23] The following semi-quantitative method **shall** be used to pinpoint the local leaks and provide a rough estimate of their leakage rates (see section 4.2.1.2 of this NASA Technical Standard for calibration if required):

a. Unless the test article already filled with working fluid (gas or liquid) such as ammonia, introduce an anhydrous ammonia or an ammonia-nitrogen mixture into the test article so that the final ammonia percentage achieved is between 1 and 100% by volume at a gauge pressure between 34.5 and 689.5 kPa (5 and 10 psig).

b. Apply a suitable indicator such as a dilute solution of phenolphthalein or other suitable color-change indicator such as colorimetric to all exterior seams, terminals, and pinch tubes of the test article subject to leakage of the working fluid (gas or liquid), after which a change in the color of the indicator indicates a leak.

c. After testing, remove the residual indicator from all exterior surfaces/features of the test article (e.g., with distilled water).

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## NOTES:

1. *The usefulness of this technique relies on the presence of ammonia within the test article; however, the compatibility of the test article with ammonia needs to be assessed carefully.*
2. *ASTM E1066/E1066M, Standard Practice for Ammonia Colorimetric Leak Testing, and ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, may be used as references to develop the leak test procedure to implement this method.*
3. *Other than ammonia colorimetric chemical indicator methods may be used, for example, leak indicating paints that change their color upon contact with liquid hydrazine or its derivatives (see Leakage Testing Handbook (1969) that may be used as a reference to develop the leak test procedure to implement this method).*

## 5.11 Method XI—Detector Probe

[LTR 24] The following semi-quantitative methods **shall** be used to pinpoint the local leaks and provide a rough estimate of their leakage rates for individual joints (e.g., welds, fittings, plugs) (technique [1]) and for the test articles built from materials that have a high permeation rate for a tracer gas (e.g., Teflon™ flex hoses) (technique [2]) (see section 4.2.1.2 of this NASA Technical Standard for calibration if required):

a. Joints Technique [1] for individual joints of pressurized test articles (e.g., for welds, fittings, plugs) single-point leakage rate verification:

- (1) Charge the test article with a known concentration of a tracer gas to the required pressure.
- (2) Prior to examination, hold the test pressure for a minimum duration of 30 minutes for joints with elastomeric seals and of 5 minutes for welds and fittings or plugs with no seal.
- (3) Prior to examination, measure the tracer gas background and calibrate the leak test setup (a detector probe attached to a leak detector) by passing the detector probe tip across the orifice of a standard leak to verify a sensitivity (see section 4.2.1.2 of this NASA Technical Standard for calibration if required).
- (4) Ensure the resulting leak detector output is at least 40% above the tracer gas background.
- (5) After the calibration, pass the detector probe tip over the test surface at the same scanning rate and distance used during the system calibration.
- (6) Repeat the leak test setup calibration every 60 minutes, any time test conductors/operators are changed, and after the test.
- (7) A leak is indicated by any leak detector output above the established tracer gas background that in the aggregate exceeds 40% of the tracer gas background (with allowance made for atmospheric tracer gas variations and leak detector drift).

b. Flex Hose Technique [2] for flex hoses:

- (1) Partially place the test article within a bore of the enclosure with the abutting lips that are able to be moved along the test article.

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- (2) Connect the detector probe to the enclosure hole to measure tracer gas background and implement the test setup calibration by using a standard leak connected to another enclosure hole to verify the test setup sensitivity (see section 4.2.1.2 of this NASA Technical Standard for calibration if required).
- (3) Ensure that the resulting leak detector output is detectable above the tracer gas background.
- (4) After the calibration, charge the test article with a known concentration of a tracer gas to the required pressure.
- (5) Hold the pressure for a minimum duration of 5 minutes.
- (6) Move the enclosure abutting lips, after the first portion of the test article has been tested, along the test article, portion by portion, to test its entire length for leaks.
- (7) Repeat the leak test setup calibration (see section 4.2.1.2 of this NASA Technical Standard for calibration if required) every 60 minutes, any time test conductors/operators are changed, and after the test, at which time any leak detector output above the allowable single-point leakage rate indicates a leak.

*Note: ASTM E499/E499M and ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, may be used as references to develop the leak test procedure to implement these techniques.*

### 5.12 Method XII—Foam/Liquid Application

[LTR 25] The following semi-quantitative method **shall** be used for local internal-to-external leak testing of individual joints (e.g., welds, fittings, plugs) of pressurized articles (see section 4.2.1.2 of this NASA Technical Standard for calibration if required):

- a. Clean the test article's internal and external surfaces and dry to remove any liquid and moisture from leakage paths.
- b. Prepare specially formulated bubble-forming solutions in accordance with existing standards or use available off-the-shelf bubble-forming liquids.
- c. Pressurize the test article to the required pressure with the test gas for more than 10 minutes before applying bubble-forming solution or liquid to prevent the clogging of small leaks.
- d. Apply the bubble-forming solution or liquid to the low-pressure side of the test article, such that the test article test areas are completely covered with a blanket of bubble-forming solution (3 to 7 mm (0.118 to 0.275 in) for foam application or uniformly for liquid application).
- e. Inspect the test article for bubbles.
- f. Ensure there is no observed leakage as evidenced by one or more bubbles formed by test gas in the foam or liquid.

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## NOTES:

1. *ASTM E515 and ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, may be used as references to develop the leak test procedure to implement this method.*
2. *A lamp and hinged mirror may be used to inspect the test article for bubbles.*

### 5.13 Method XIII—Hydrostatic/Visual Inspection

[LTR 26] The following semi-quantitative method **shall** be used for local internal-to-external leak testing of individual joints (e.g., welds, fittings, plugs) of pressurized articles (see section 4.2.1.2 in this NASA Technical Standard for calibration if required):

- a. Clean the test article's external surfaces and dry to remove any liquid and moisture from leakage paths.
- b. Use any appropriate test fluid compatible with the test article to be tested.
- c. Pressurize the test article to the required pressure with a test fluid (e.g., deionized or distilled water with or without visibility enhancer such as fluorescent dye tracer).
- d. Ensure lighting in the area to be examined is no less than 1000 lux or lumen/m<sup>2</sup> (100 foot-candles) in brightness, and illumination is free from shadows over the surface area under inspection.
- e. Observe the surface to be examined with observer's eyes placed within 60 cm (2 ft) of the surface to be examined.
- f. Visually inspect the test article's leak paths for an absence of test fluid droplets every 30 minutes during the test using a lamp and hinged mirror to meticulously observe areas.
- g. Use absorbent wipes, blotting paper, or other products such as water developer that changes color in contact with moisture to enhance the visibility of leaking test fluid.
- h. Ensure there is no observed leakage as evidenced by one or more test fluid droplets of any diameter.

*Surface tension and viscosity effects (wicking) may affect droplet size/shape and overall visual appearance.*

*Note: ASTM E1003, Standard Practice for Hydrostatic Leak Testing, and ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, may be used as references to develop the leak test procedure to implement this method.*

### 5.14 Method XIV—Tracer Probe

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[LTR 27] The following semi-quantitative method **shall** be used for local external-to-internal leak testing of sealed test articles (see section 4.2.1.2 of this NASA Technical Standard for calibration if required):

- a. Evacuate the test article internal volume to a vacuum compatible with a tracer gas leak detector.
- b. If the calibration is required, calibrate the leak test setup (a tracer probe and a leak detector) with the standard leak installed at the farthest possible point from the leak detector.
- c. Connect the tracer probe to a source of 100% tracer gas with a valve opening at the other end for directing a stream of tracer gas over the test article starting at the location closest to the connection to the leak detector on the upper side of the test article.
- d. Proceed along the test article, and any indication of tracer gas above the background by the leak detector indicates a leak.

*Note: ASTM E498/E498M, Standard Practice for Leaks Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Tracer Probe Mode, and ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, may be used as references to develop the leak test procedure to implement this method.*

## 5.15 Supplementary Provisions for Seal Verification

**5.15.1** [LTR 28] The leak tests **shall** be performed with the test article pressurized at the minimum (if the seals are dependent upon pressure for proper sealing) and the maximum test pressure required in the test article design specifications.

*The maximum test pressure in the test article design specifications may be chosen based on MAWP, MDP, or MEOP depending on the test article specifics.*

**5.15.2** [LTR 29] Evidence of the test article seal redundancy and proper seal installation for each seal **shall** be provided by using any means that have been demonstrated to be capable of confirming the integrity of independent seals in a redundant seal installation.

**5.15.2.1** [LTR 30] For the test articles not equipped with the leak check ports between the redundant seals, the leak detector output **shall** be characterized in two steps: first during test article development testing to set a baseline leakage rate recorded during a predetermined time period, and second during test article qualification or acceptance testing to verify that the leakage rate through the seals does not rise above the baseline leakage rate after tracer gas exposure for the same predetermined time period.

*It may be done in addition to verifying total steady state leakage rate at the end of leak test while using one of the quantitative leak test methods such as bell jar technique (see 5.1 [2] in this NASA Technical Standard).*

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## 5.16 Supplementary Provisions for Elements

**5.16.1** [LTR 31] If the test article is an element, the leak test **shall** be performed via total Element Leak Test (ELT) at the test pressure required in the test article specifications.

*The test pressure in specifications may be chosen based on MAWP, MDP, or MEOP depending on the test article specifics.*

**5.16.1.1** [LTR 32] The ELT **shall** be performed as close to launch as practical after the element has successfully passed the ELT test readiness review.

*Only two methods are recommended for the ELT, i.e., Chamber technique (see section 5.1, technique [1]) and Accumulation (see section 5.2) in this NASA Technical Standard.*

**5.16.2** [LTR 33] Pressure integrity of the element final configuration **shall** be verified via prelaunch Gross Leak Test (GLT) at allowed delta pressure as part of a final element pressurization for launch.

*The GLT is recommended to be performed as a final confidence test to confirm the proper positioning of valves, hatches, and feedthroughs that provide seals to space vacuum. Only one method is recommended for the GLT, i.e., Pressure Decay technique (see section 5.5, technique [1] in this NASA Technical Standard).*

## 5.17 Supplementary Provisions for Test Fixtures

[LTR 34] For the test articles in their final flight configuration, the test fixtures used for leak testing **shall** have the fluid (gas or liquid) interfaces to the test article equivalent to flight interfaces (including seals).

## 5.18 Supplementary Provisions for Leak Test Procedures and Failures Reporting

**5.18.1** [LTR 35] Leak test procedures **shall** have pass/fail criteria established to reflect the test article performance either by design assessment or historical performance experience, but in no case may the pass/fail criteria be less stringent than the MALR shown in the specification requirements.

**5.18.2** [LTR 36] The actual measured leakage rate **shall** be recorded in the as-run leak test procedure or leak test log book (i.e., no recording of simply “pass” or “fail”).

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### 5.19 Supplementary Provisions for Tracer Gas Concentration and Leak Detector/Leak Test Setup Sensitivity

**5.19.1** [LTR 37] For the leak test methods that use a tracer gas (most frequently helium), tracer gas concentration at all the points of potential leak paths **shall** be greater than or equal to 5%.

**5.19.2** [LTR 38] Tracer gas (most frequently helium) leak detector **shall** provide a sensitivity of 10% or less of the intended leakage rate to be measured.

**5.19.3** [LTR 39] Test setup that includes a leak detector **shall** provide a sensitivity of at least one-half of the intended leakage rate to be measured.

*For example, if the allowable leakage rate is  $10^{-4}$  scc/sec, the method (actually the leak test setup employed by the method) used should be demonstrated by use of a standard leak source to be capable of detecting at least  $5.0 \times 10^{-5}$  scc/sec.*

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## APPENDIX A

### REQUIREMENTS COMPLIANCE MATRIX

#### A.1 Purpose

Due to the complexity and uniqueness of space flight, it is unlikely that all of the requirements in a NASA technical standard will apply. The Requirements Compliance Matrix below contains this NASA Technical Standard’s technical authority requirements and may be used by programs and projects to indicate requirements that are applicable or not applicable to help minimize costs. Enter “Yes” in the “Applicable” column if the requirement is applicable to the program or project or “No” if the requirement is not applicable to the program or project. The “Comments” column may be used to provide specific instructions on how to apply the requirement or to specify proposed tailoring.

NASA-STD-7012				
Section	Description	Requirement in this Standard	Applicable (Enter Yes or No)	Comments
4.1.1	General Requirements for Leak Testing	[LTR 1] Leak testing of the test articles <b>shall</b> be performed prior to initiation of and following the completion of each of the following applicable qualification, acceptance, and protoflight environmental tests: <ul style="list-style-type: none"> <li>a. Thermal testing (vacuum, cycle).</li> <li>b. Vibration testing (random, sinusoidal, acoustic).</li> <li>c. Shock testing (pyrotechnic, mechanical).</li> <li>d. Acceleration testing.</li> <li>e. Life-cycle testing (pressure, actuation, etc.).</li> </ul>		
4.1.2	General Requirements for Leak Testing	[LTR 2] Personnel performing leak testing in accordance with any of the leak test methods and/or techniques described in this NASA Technical Standard <b>shall</b> be, at a minimum, qualified and certified Level II qualification in accordance with ANSI/ASNT CP-189, ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel.		
4.1.3	General Requirements for Leak Testing	[LTR 3] For the pressurized test articles, a proof pressure test <b>shall</b> be performed once prior to the first leak test.  <i>NOTES:</i> <i>1. Preliminary leak tests may be performed prior to the proof pressure test to establish a baseline.</i>		

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Section	Description	Requirement in this Standard	Applicable (Enter Yes or No)	Comments
		<i>2. Proof pressure tests can be performed in conjunction with the leak test.</i>		
4.1.4	General Requirements for Leak Testing	[LTR 4] Prior to initiating a leak test, the test article external and internal surfaces <b>shall</b> be prepared to meet the specific program or project cleanliness requirements to remove any foreign object debris and moisture from potential leaks.		
4.1.5	General Requirements for Leak Testing	[LTR 5] When temperature affects the sealing materials or surfaces, the leak test <b>shall</b> be conducted at the minimum and maximum qualification, acceptance, or protoflight temperature limits.		
4.2.1	Leak Test Methods	[LTR 6] The leak test method <b>shall</b> detect leakage rates less than or equal to one-half of the MALR.		
4.2.1.1	Leak Test Methods	[LTR 7] The sensitivity of the leak test setup used to implement any quantitative leak test method for total leak testing <b>shall</b> be verified through its calibration prior to and after the leak test.		
4.2.1.2	Leak Test Methods	[LTR 8] The sensitivity of the leak test setup used to implement any semi-quantitative leak test method for local leak testing to pinpoint a specified single-point leakage rate <b>shall</b> be verified through its calibration prior to and after the leak test.		
4.2.2	Leak Test Methods	<p>[LTR 9] Leak testing of the test articles <b>shall</b> be performed using one of the following leak test methods/techniques as defined in Table 1, Leak Test Methods for Pressure Integrity Verification and Pinpointing Local Leaks, and in accordance with its related method/technique requirements specified in section 5 of this NASA Technical Standard:</p> <ul style="list-style-type: none"> <li>a. Method I [1]<sup>1</sup> and [2], II, IV [2], V [1], VII, VIII, IX [1] and [2], X, XI, XII, or XIII, as appropriate, for pressurized test articles.</li> <li>c. Method III, IV [1] and [2], V [2], VI, or XIV, as appropriate, for sealed test articles.</li> </ul> <p><sup>1</sup>A number in brackets following a Roman numeral, e.g., V [1], refers to the technique number in a specific method. Also, see section 5.</p>		

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Section	Description	Requirement in this Standard			Applicable (Enter Yes or No)	Comments
		XI [1] and [2]	Detector Probe [Joints and Flex Hoses techniques], semi-quantitative	Down to 10 <sup>-5</sup>		
		XII	Foam/Liquid Application, semi-quantitative	Down to 10 <sup>-4</sup>		
		XIII	Hydrostatic/Visual Inspection, semi-quantitative	Down to 10 <sup>-3</sup>		
		<b>Method for Local External-to-Internal Leakage Rate Verification</b>				
		XIV	Tracer Probe, semi-quantitative	Down to 10 <sup>-8</sup>	<b>B</b>	
		<p><b>A.</b> Use only methods for total leakage rate verification if the MALR is set as a total leakage rate.</p> <p><b>B.</b> Use only methods for local leakage rate verification if the MALR is set as a single-point leakage rate.</p>				
		<p><b>NOTES:</b></p> <ol style="list-style-type: none"> <li>1. <i>The selection of a method to be chosen other than internal-to-external or external-to-internal leakage rate verification requires a special justification presented, for example, in a test article verification plan approved by the responsible safety organization.</i></li> <li>2. <i>The leak test method employed should be demonstrated to have a sensitivity to detect leakage rates, generally in accordance with section 4.2.1 of this NASA Technical Standard and specifically for tracer gas methods in accordance with section 5.19.3 of this NASA Technical Standard.</i></li> <li>3. <i>The minimum leakage rate that could be reliably verified is dependent on many technical details specific for each method, for example, on sensitivity of the leak detector with probe attached, free volume of a particular test arrangement, and time of accumulation for the accumulation method.</i></li> <li>4. <i>ASTM E432, Standard Guide for Selection of a Leak Testing Method, may also be used as a guide for selection of a leak test method.</i></li> </ol>				
4.2.3	Leak Test Methods	<p>[LTR 10] In general, the MALR (to be identified in the test article specifications or drawing) together with the leak test method (to be chosen from Table 1 to verify the MALR), <b>shall</b> ensure that the maximum amount of substance that could leak over the mission duration (calculated as MALR × mission duration × safety factor (assigned by a system engineer or payload developer and concurred with by the Safety and Mission Assurance (SMA) Technical Authority and Engineering Technical Authority) would prevent exceeding the allowed Toxicity Hazard Level (THL) or Spacecraft Maximum Allowable Concentration (SMAC) value (whichever is more conservative) shown in Table 2, Leak Test Methods to be Used to Ensure Allowed THL and SMAC Values (see NPR 7120.5 for Engineering Technical Authority responsibilities and NASA-STD-8709.20, Management of Safety and Mission Assurance Technical Authority (SMA TA) Requirements, for SMA Technical Authority responsibilities).</p>				

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		<p><b>Table 2— Leak Test Methods to be Used to Ensure Allowed THL and SMAC Values</b></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 25%;">THL or Other Limitations</th> <th>Recommended MALR to Be Verified: Leak Test Methods</th> </tr> </thead> <tbody> <tr> <td>Catastrophic</td> <td>Although no greater than <math>10^{-9}</math> scc/sec is a prevalent value, the specific MALR calculated in accordance with section 4.2.3 of this NASA Technical Standard should take precedence:                             <ul style="list-style-type: none"> <li>• Method I (to verify pressure integrity);</li> <li>• Method IV may be used to verify pressure integrity only if MALR for the test article filled with the gas or liquid is set to be <math>5 \times 10^{-5}</math> scc/sec or more;</li> <li>• Methods XI, XIV (to pinpoint local leaks).</li> </ul> </td> </tr> <tr> <td>Critical</td> <td>Although no greater than <math>10^{-7}</math> scc/sec is a prevalent value, the specific MALR calculated in accordance with section 4.2.3 of this NASA Technical Standard should take precedence:                             <ul style="list-style-type: none"> <li>• Methods I and II (to verify pressure integrity);</li> <li>• Method IV may be used to verify pressure integrity only if MALR for the test article filled with gas or liquid is set to be <math>5 \times 10^{-5}</math> scc/sec or more;</li> <li>• Methods XI, XIV (to pinpoint local leaks).</li> </ul> </td> </tr> <tr> <td>Fluid is not allowed or desired</td> <td>No greater than <math>10^{-4}</math> scc/sec:                             <ul style="list-style-type: none"> <li>• Methods I, II, III, IV, and V [Technique No. 1] (to verify pressure integrity);</li> <li>• Methods IX, X, XI, XII, XIII, and XIV (to pinpoint local leaks).</li> </ul> </td> </tr> <tr> <td>Not safety, just general concerns about leaks</td> <td>No greater than <math>10^{-3}</math> scc/sec:                             <ul style="list-style-type: none"> <li>• Methods I through XIV (selected to verify pressure integrity and/or pinpoint local leaks depending on a flow direction through leaks (out of or into the test article)).</li> </ul> </td> </tr> </tbody> </table>	THL or Other Limitations	Recommended MALR to Be Verified: Leak Test Methods	Catastrophic	Although no greater than $10^{-9}$ scc/sec is a prevalent value, the specific MALR calculated in accordance with section 4.2.3 of this NASA Technical Standard should take precedence: <ul style="list-style-type: none"> <li>• Method I (to verify pressure integrity);</li> <li>• Method IV may be used to verify pressure integrity only if MALR for the test article filled with the gas or liquid is set to be <math>5 \times 10^{-5}</math> scc/sec or more;</li> <li>• Methods XI, XIV (to pinpoint local leaks).</li> </ul>	Critical	Although no greater than $10^{-7}$ scc/sec is a prevalent value, the specific MALR calculated in accordance with section 4.2.3 of this NASA Technical Standard should take precedence: <ul style="list-style-type: none"> <li>• Methods I and II (to verify pressure integrity);</li> <li>• Method IV may be used to verify pressure integrity only if MALR for the test article filled with gas or liquid is set to be <math>5 \times 10^{-5}</math> scc/sec or more;</li> <li>• Methods XI, XIV (to pinpoint local leaks).</li> </ul>	Fluid is not allowed or desired	No greater than $10^{-4}$ scc/sec: <ul style="list-style-type: none"> <li>• Methods I, II, III, IV, and V [Technique No. 1] (to verify pressure integrity);</li> <li>• Methods IX, X, XI, XII, XIII, and XIV (to pinpoint local leaks).</li> </ul>	Not safety, just general concerns about leaks	No greater than $10^{-3}$ scc/sec: <ul style="list-style-type: none"> <li>• Methods I through XIV (selected to verify pressure integrity and/or pinpoint local leaks depending on a flow direction through leaks (out of or into the test article)).</li> </ul>		
THL or Other Limitations	Recommended MALR to Be Verified: Leak Test Methods													
Catastrophic	Although no greater than $10^{-9}$ scc/sec is a prevalent value, the specific MALR calculated in accordance with section 4.2.3 of this NASA Technical Standard should take precedence: <ul style="list-style-type: none"> <li>• Method I (to verify pressure integrity);</li> <li>• Method IV may be used to verify pressure integrity only if MALR for the test article filled with the gas or liquid is set to be <math>5 \times 10^{-5}</math> scc/sec or more;</li> <li>• Methods XI, XIV (to pinpoint local leaks).</li> </ul>													
Critical	Although no greater than $10^{-7}$ scc/sec is a prevalent value, the specific MALR calculated in accordance with section 4.2.3 of this NASA Technical Standard should take precedence: <ul style="list-style-type: none"> <li>• Methods I and II (to verify pressure integrity);</li> <li>• Method IV may be used to verify pressure integrity only if MALR for the test article filled with gas or liquid is set to be <math>5 \times 10^{-5}</math> scc/sec or more;</li> <li>• Methods XI, XIV (to pinpoint local leaks).</li> </ul>													
Fluid is not allowed or desired	No greater than $10^{-4}$ scc/sec: <ul style="list-style-type: none"> <li>• Methods I, II, III, IV, and V [Technique No. 1] (to verify pressure integrity);</li> <li>• Methods IX, X, XI, XII, XIII, and XIV (to pinpoint local leaks).</li> </ul>													
Not safety, just general concerns about leaks	No greater than $10^{-3}$ scc/sec: <ul style="list-style-type: none"> <li>• Methods I through XIV (selected to verify pressure integrity and/or pinpoint local leaks depending on a flow direction through leaks (out of or into the test article)).</li> </ul>													
4.2.4	Leak Test Methods	[LTR 11] The test fluid (liquid or gas) used for leak testing shall be compatible with the test article's materials and operational fluid.												
4.3.1	Leakage Rate Unit Conversion	<p>[LTR 12] Prior to conversion from tracer gas (most frequently helium) leakage rate to a corresponding leakage rate of a working fluid (gas or liquid), the measured tracer gas leakage rate <b>shall</b> be recalculated per equation (Eq. 1):</p> $Q_{100\%} = Q_{tg\%} \frac{100\%}{C_{tg\%}} \quad (\text{Eq. 1})$ <p>Where</p> <ul style="list-style-type: none"> <li><math>Q_{100\%}</math> is a tracer gas leakage rate recalculated to its 100% concentration.</li> <li><math>Q_{tg\%}</math> is a measured tracer gas leakage rate at its known or estimated concentration.</li> <li><math>C_{tg\%}</math> is a known or estimated concentration of a tracer gas inside the test article.</li> </ul>												

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Section	Description	Requirement in this Standard	Applicable (Enter Yes or No)	Comments
4.3.2	Leakage Rate Unit Conversion	[LTR 13] Tracer gas concentration <b>shall</b> be greater than or equal to 5% at all the points of potential leak paths during leak tests		
<b>5. LEAK TEST METHODS FOR QUALIFICATION OR ACCEPTANCE TESTING</b>				
5.1	Method I— Vacuum Chamber	<p>[LTR 14] The following quantitative methods <b>shall</b> be used for total internal-to-external leak testing of pressurized test articles such as vehicles and/or spacecraft (technique [1]) and subsystem components such as electrical and/or fluid feedthroughs (technique [2]):</p> <p style="margin-left: 40px;">a. Chamber Technique [1] for Spacecraft/Vehicle:</p> <ol style="list-style-type: none"> <li>(1) Completely place the test article in a vacuum chamber and test for total leakage with a leak detector appropriate for the tracer gas used.</li> <li>(2) Calibrate the leak test setup (vacuum chamber, all associated lines and fittings, and a leak detector) with the standard leak (see section 4.2.1.1 in this NASA Technical Standard) to determine the leak test setup relative sensitivity to be used to establish the test article leakage rate.</li> <li>(3) Charge the test article with a known concentration of a tracer gas to the required pressure.</li> <li>(4) Maintain the required pressure until stabilization (four consecutive readings no less than 5 minutes apart with no more than a 10% variation in the leak detector output from one measurement to the next, including the first and last measurements) of the leak detector output is achieved.</li> </ol> <p style="margin-left: 80px;"><i>If the leak detector outputs are decreasing over a 15-minute period rather than steadily increasing, or the leak detector output variations are more than 10% but occurred at a very low level (at least a factor of 10 lower than the MALR set for the test article), then this 10% stabilization may not be required.</i></p> <ol style="list-style-type: none"> <li>(5) Record calibration data, leak detector initial and final readings, actual temperature of the test article (if leak test was performed at other than ambient temperature) and the four data points within a 15-minute duration demonstrating stabilization in accordance with the definition above.</li> </ol> <p style="margin-left: 40px;">b. Bell Jar Technique [2] for Feedthroughs:</p> <ol style="list-style-type: none"> <li>(1) Install the bell jar connected to the tracer gas leak detector on the test article area to undergo the leak test.</li> </ol>		

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		<p>(2) Calibrate the leak test setup (bell jar, all associated lines and fittings, and a leak detector) with the standard leak (see section 4.2.1.1 in this NASA Technical Standard) to determine the leak test setup relative sensitivity to be used to establish the test article leakage rate.</p> <p>(3) Charge the test article with a known concentration of a tracer gas to the required pressure.</p> <p>(4) Maintain the required pressure until stabilization (four consecutive readings no less than 5 minutes apart with no more than a 10% variation in the leak detector output from one measurement to the next, including the first and last measurements) of the leak detector output is achieved.</p> <p><i>If the leak detector outputs are decreasing over a 15-minute period rather than steadily increasing, or the leak detector output variations are more than 10% but occurred at a very low level (at least an order of magnitude lower than the MALR set for the test article), the stabilization requirement is not applicable).</i></p> <p>(5) Record calibration data, leak detector initial and final readings, and the final test article leakage rate with four data points within a 15-minute duration to demonstrate stabilization in accordance with the definition above.</p>		
5.2	Method II— Accumulation	<p>[LTR 15] The following quantitative method <b>shall</b> be used for total internal-to-external leak testing of pressurized test articles:</p> <p>a. Enclose the test article in a suitable enclosure.</p> <p>b. Calibrate the leak test setup (an enclosure and a leak detector) with the standard leak (see 4.2.1.1 of this NASA Technical Standard) that simulates the actual leak through the potentially existing defects placed in the enclosure for a predetermined period of time to determine the leak test setup relative sensitivity for use in establishing the test article leakage rate.</p> <p>c. At the end of the time period, place a detector probe in the enclosure and record the maximum leak detector response.</p> <p>d. Purge the enclosure with air sufficiently to remove the tracer gas used for calibration.</p> <p>e. Charge the test article with a known concentration of a tracer gas to the required pressure.</p> <p>f. Prior to examination, perform the following:</p>		

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		<ul style="list-style-type: none"> <li>(1) Hold the test pressure for a minimum duration of 30 minutes for joints with elastomeric seals and of 5 minutes for welds, fittings, or plugs with no elastomeric seals.</li> <li>(2) Purge the enclosure with air until the tracer gas background inside it is equal to or less than the tracer gas concentration in the test facility and seal it.</li> <li>(3) After the time period used for the calibration, place the detector probe in the enclosure at the same location it was placed during calibration.</li> <li>(4) Record calibration data, leak detector initial and final readings, and the final test article leakage rate.</li> </ul>		
5.3	Method III— Bombing	<p>[LTR 16] The following quantitative method <b>shall</b> be used for total internal-to-external leak testing of sealed test articles:</p> <ul style="list-style-type: none"> <li>a. Place the test article in the pressure vessel and flush or backfill with tracer gas to the specified pressure.</li> <li>b. Hold the test article at the specified external pressure as high as the test article can safely withstand for the time required to achieve the required test setup sensitivity but not less than five time constants.</li> <li>c. After the dwell, release the tracer gas pressure at a considerable distance from the leak detector; remove the test article from the test setup pressure vessel; and flush with dry air or nitrogen to remove absorbed tracer gas from the test article surface.</li> <li>d. After the flush, test the test article singly or in multiples in the vacuum chamber in accordance with Method I, including test setup (vacuum chamber and leak detector) calibration (see section 4.2.1.1 of this NASA Technical Standard).</li> <li>e. To provide the necessary sensitivity and accuracy for the bombing leak test method, perform correlation studies on the parts to be tested to correlate actual leakage rates to the tracer gas leakage rate detected after bombing.</li> <li>f. Limit the length of time between the bombing and actual leak test steps to the duration determined in correlation studies.</li> <li>g. Calculate the actual leakage rate of the test article in accordance with ASTM E493/E493M, Standard Practice for Leaks Using the Mass Spectrometer Leak Detector in the Inside-Out Testing Mode.</li> </ul>		
5.4	Method IV— Vacuum Exposure	<p>[LTR 17] The following quantitative methods <b>shall</b> be used for total internal-to-external leak testing of liquid-filled (technique [1]) and gas-filled (technique [2]) sealed test articles:</p>		

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		<p>a. Mass Loss Technique [1] for liquid-filled sealed test articles:</p> <ol style="list-style-type: none"> <li>(1) Weigh the test article before the test.</li> <li>(2) Completely place the test article in a vacuum chamber or bell jar and expose it to vacuum, the level and duration of which are dependent on the test article application and the MALR to be verified.</li> <li>(3) Weigh the test article after the test to confirm there is no calculated leakage rate above the MALR by the test article mass loss from the test.</li> <li>(4) Ensure that the weight balance has an accuracy adequate to measure the minimum weight change that corresponds to the MALR (see section 4.2.1.1 of this NASA Technical Standard).</li> </ol> <p>b. Pressure Loss Technique [2] for gas-filled sealed test articles:</p> <ol style="list-style-type: none"> <li>(1) Pressurize the test article to the required pressure.</li> <li>(2) Completely place the test article in a vacuum chamber or bell jar to expose it to vacuum.</li> <li>(3) Measure the gas pressure inside the test article after the test and confirm there is no calculated leakage rate above the MALR by its internal gas pressure loss from the test.</li> <li>(4) Use a pressure gauge/transducer with accuracy adequate to measure the minimum allowed pressure change that corresponds to the MALR (see section 4.2.1.1 in this NASA Technical Standard).</li> </ol>		
5.5	Method V— Pressure Change	<p>[LTR 18] The following quantitative methods <b>shall</b> be used for both pressurized (technique [1]) and sealed (technique [2]) test articles:</p> <p>a. Pressure Decay Technique [1] for total internal-to-external leak testing of pressurized test articles:</p> <ol style="list-style-type: none"> <li>(1) Pressurize the test article to the required pressure.</li> <li>(2) Monitor the test article internal pressure, barometric pressure, and ambient temperature (or temperature of the test article) for the required time to determine the actual pressure drop and the corresponding leakage rate.</li> <li>(3) Use a pressure gauge/transducer with accuracy adequate to measure the minimum allowable pressure drop.</li> <li>(4) Verify test setup sensitivity by installing a standard leak in the test setup (see section 4.2.1.1 in this NASA Technical Standard).</li> <li>(5) While making leakage rate calculation based on a recorded pressure drop, take into account:                             <ol style="list-style-type: none"> <li>A. The test article and test fixture pressurized internal volumes, as well as volume tolerances at maximum positive values, and</li> </ol> </li> </ol>		

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		<p style="text-align: center;">B. The test article and reference vessel (in case it was used) volumetric changes due to ambient temperature changes.</p> <p>b. Pressure Rise Technique [2] for total external-to-internal leak testing of sealed test articles:</p> <ol style="list-style-type: none"> <li>(1) Reduce the pressure inside the test article to the required pressure.</li> <li>(2) Monitor the test article internal pressure, barometric pressure, and ambient temperature (or temperature of the test article) for the required time to determine the actual pressure rise and the corresponding leakage rate.</li> <li>(3) Use a pressure gauge/transducer with accuracy adequate to measure the minimum allowable pressure rise.</li> <li>(4) Verify test setup sensitivity by installing a standard leak in the test setup (see section 4.2.1.1 in this NASA Technical Standard).</li> <li>(5) While making leakage rate calculation based on a recorded pressure rise, take into account the total sealed internal volume of the test article and test fixture, as well as volume tolerances at maximum positive values.</li> </ol>		
5.6	Method VI—Hood	<p>[LTR 19] The following quantitative method <b>shall</b> be used for total external-to-internal leak testing of sealed test articles:</p> <ol style="list-style-type: none"> <li>a. Evacuate the test article internal volume to a vacuum compatible with a tracer gas leak detector.</li> <li>b. Calibrate the leak test setup (a hood and a leak detector) with the standard leak installed at the farthest possible point from the leak detector to determine the leak test setup relative sensitivity (see section 4.2.1.1 in this NASA Technical Standard) for use in establishing the test article leakage rate.</li> <li>c. For the test articles that have only one leak test port, install a standard leak at this port.</li> <li>d. Expose the external surfaces of the test article to a verified concentration of a tracer gas at atmospheric pressure or slightly higher, maintaining pressure until stabilization (four consecutive readings no less than 5 minutes apart with no more than a 10% variation in the leak detector output from one measurement to the next, including the first and last measurements) of the leak detector output is achieved.</li> <li>e. Record calibration data, leak detector initial and final readings, and the final test article leakage rate with four data points within a 15-minute duration to demonstrate stabilization in accordance with the definition above.</li> </ol>		

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5.7	Method VII— Volumetric Displacement	<p>[LTR 20] The following quantitative method <b>shall</b> be used for total internal-to-internal leak testing of pressurized test articles such as valves, pressure regulators, or heat exchangers:</p> <ul style="list-style-type: none"> <li>a. Calibrate the leak test setup (see section 4.2.1.1 in this NASA Technical Standard) for volumetric displacement.</li> <li>b. Pressurize one side of the test article to the required pressure while the other side across the internal barrier is sealed from the atmosphere and attached to the volumetric displacement measurement device.</li> <li>c. Use the measured volume of leaked gas to establish the leakage rate and compare it to the MALR.</li> </ul>		
5.8	Method VIII— Leak Detector Direct Connection	<p>[LTR 21] The following quantitative method <b>shall</b> be used for total internal-to-internal leak testing of pressurized test articles such as valves, pressure regulators, or heat exchangers:</p> <ul style="list-style-type: none"> <li>a. Calibrate the leak test setup (a leak detector) with the standard leak installed at the farthest possible point from the leak detector (see section 4.2.1.1 of this NASA Technical Standard) to determine the leak test setup relative sensitivity for use in establishing the test article leakage rate.</li> <li>b. Charge one side of the test article with a known concentration of a tracer gas to the required pressure while the other side across the internal barrier is sealed from the atmosphere and attached to the leak detector.</li> <li>c. Maintain pressure until stabilization (four consecutive readings no less than 5 minutes apart with no more than a 10% variation in the leak detector output from one measurement to the next, including the first and last measurements) of the leak detector output is achieved.</li> <li>d. Record calibration data, leak detector initial and final readings, and the final test article leakage rate with four data points within a 15-minute duration to demonstrate stabilization in accordance with the definition above.</li> </ul>		
5.9	Method IX— Immersion	<p>[LTR 22] The following methods <b>shall</b> be used for local internal-to-external leak testing of pressurized test article purposes (technique [1]) and for total internal-to-external leak testing of pressurized test articles (technique [2]):</p> <ul style="list-style-type: none"> <li>a. Semi-quantitative Local Leakage Rate Technique [1] to pinpoint the local leaks and provide a rough estimate of their leakage rates (see section 4.2.1.2 of this NASA Technical Standard for calibration if required): <ul style="list-style-type: none"> <li>(1) Apply internal gas pressure across the pressure boundary for a minimum duration of 15 minutes before the test liquid contacts the external surface.</li> </ul> </li> </ul>		

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		<p>(2) Ensure lighting in the area to be examined is no less than 1000 lux or lumen/m<sup>2</sup> (100 foot-candles) in brightness, and illumination is free from shadows over the surface area under inspection.</p> <p>(3) Observe the surface to be examined with observer's eyes placed within 60 cm (2 ft) of the surface to be examined.</p> <p>(4) Completely immerse the test article in a liquid, ensuring that the critical side of interest of the test article is in a horizontal plane facing up, after which the appearance of gas bubbles indicates a leak.</p> <p>b. Quantitative Total Leakage Rate Technique [2] that serves for total internal-to-external leak testing of pressurized test articles such as flex hoses (see section 4.2.1.1 of this NASA Technical Standard for calibration):</p> <p>(1) Apply internal gas pressure across the pressure boundary for a minimum duration of 15 minutes before the test liquid contacts the external surface.</p> <p>(2) Ensure lighting in the area to be examined is no less than 1000 lux or lumen/m<sup>2</sup> (100 foot-candles) in brightness, and illumination is free from shadows over the surface area under inspection.</p> <p>(3) Completely immerse the test article in a liquid.</p> <p>(4) Immerse the measuring cylinder in the bath with the test liquid.</p> <p>(5) Keep the measuring cylinder above the whole test article or its part to let leaking gas accumulate inside the measuring cylinder.</p> <p>(6) Use the measured volume of leaked gas to establish the leakage rate and compare it to the MALR to demonstrate a margin of at least five units of volumetric rate.</p>		
5.10	Method X— Ammonia Colorimetric	<p>[LTR 23] The following semi-quantitative method <b>shall</b> be used to pinpoint the local leaks and provide a rough estimate of their leakage rates (see section 4.2.1.2 of this NASA Technical Standard for calibration if required):</p> <p>a. Unless the test article already filled with working fluid (gas or liquid) such as ammonia, introduce an anhydrous ammonia or an ammonia-nitrogen mixture into the test article so that the final ammonia percentage achieved is between 1 and 100% by volume at a gauge pressure between 34.5 and 689.5 kPa (5 and 10 psig).</p> <p>b. Apply a suitable indicator such as a dilute solution of phenolphthalein or other suitable color-change indicator such as colorimetric to all exterior seams, terminals, and pinch tubes of the test article subject to leakage of the working fluid (gas or liquid), after which a change in the color of the indicator indicates a leak.</p> <p>c. After testing, remove the residual indicator from all exterior surfaces/features of the test article (e.g., with distilled water).</p>		

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5.11	Method XI— Detector Probe	<p>[LTR 24] The following semi-quantitative methods <b>shall</b> be used to pinpoint the local leaks and provide a rough estimate of their leakage rates for individual joints (e.g., welds, fittings, plugs) (technique [1]) and for the test articles built from materials that have a high permeation rate for a tracer gas (e.g., Teflon™ flex hoses) (technique [2]) (see section 4.2.1.2 of this NASA Technical Standard for calibration if required):</p> <p style="margin-left: 20px;">a. Joints Technique [1] for individual joints of pressurized test articles (e.g., for welds, fittings, plugs) single-point leakage rate verification:</p> <ol style="list-style-type: none"> <li>(1) Charge the test article with a known concentration of a tracer gas to the required pressure.</li> <li>(2) Prior to examination, hold the test pressure for a minimum duration of 30 minutes for joints with elastomeric seals and of 5 minutes for welds and fittings or plugs with no seal.</li> <li>(3) Prior to examination, measure the tracer gas background and calibrate the leak test setup (a detector probe attached to a leak detector) by passing the detector probe tip across the orifice of a standard leak to verify a sensitivity (see section 4.2.1.2 of this NASA Technical Standard for calibration if required).</li> <li>(4) Ensure the resulting leak detector output is at least 40% above the tracer gas background.</li> <li>(5) After the calibration, pass the detector probe tip over the test surface at the same scanning rate and distance used during the system calibration.</li> <li>(6) Repeat the leak test setup calibration every 60 minutes, any time test conductors/operators are changed, and after the test.</li> <li>(7) A leak is indicated by any leak detector output above the established tracer gas background that in the aggregate exceeds 40% of the tracer gas background (with allowance made for atmospheric tracer gas variations and leak detector drift).</li> </ol> <p style="margin-left: 20px;">b. Flex Hose Technique [2] for flex hoses:</p> <ol style="list-style-type: none"> <li>(1) Partially place the test article within a bore of the enclosure with the abutting lips that are able to be moved along the test article.</li> <li>(2) Connect the detector probe to the enclosure hole to measure tracer gas background and implement the test setup calibration by using a standard leak connected to another enclosure hole to verify the test setup sensitivity (see section 4.2.1.2 of this NASA Technical Standard for calibration if required).</li> <li>(3) Ensure that the resulting leak detector output is detectable above the tracer gas background.</li> <li>(4) After the calibration, charge the test article with a known concentration of a tracer gas to the required pressure.</li> <li>(5) Hold the pressure for a minimum duration of 5 minutes.</li> </ol>		

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		<p>(6) Move the enclosure abutting lips, after the first portion of the test article has been tested, along the test article, portion by portion, to test its entire length for leaks.</p> <p>(7) Repeat the leak test setup calibration (see section 4.2.1.2 of this NASA Technical Standard for calibration if required) every 60 minutes, any time test conductors/operators are changed, and after the test, at which time any leak detector output above the allowable single-point leakage rate indicates a leak.</p>		
5.12	Method XII— Foam/Liquid Application	<p>[LTR 25] The following semi-quantitative method <b>shall</b> be used for local internal-to-external leak testing of individual joints (e.g., welds, fittings, plugs) of pressurized articles (see section 4.2.1.2 of this NASA Technical Standard for calibration if required):</p> <p>a. Clean the test article’s internal and external surfaces and dry to remove any liquid and moisture from leakage paths.</p> <p>b. Prepare specially formulated bubble-forming solutions in accordance with existing standards or use available off-the-shelf bubble-forming liquids.</p> <p>c. Pressurize the test article to the required pressure with the test gas for more than 10 minutes before applying bubble-forming solution or liquid to prevent the clogging of small leaks.</p> <p>d. Apply the bubble-forming solution or liquid to the low-pressure side of the test article, such that the test article test areas are completely covered with a blanket of bubble-forming solution (3 to 7 mm (0.118 to 0.275 in) for foam application or uniformly for liquid application).</p> <p>e. Inspect the test article for bubbles.</p> <p>f. Ensure there is no observed leakage as evidenced by one or more bubbles formed by test gas in the foam or liquid.</p>		
5.13	Method XIII— Hydrostatic/Visual Inspection	<p>[LTR 26] The following semi-quantitative method <b>shall</b> be used for local internal-to-external leak testing of individual joints (e.g., welds, fittings, plugs) of pressurized articles (see section 4.2.1.2 in this NASA Technical Standard for calibration if required):</p> <p>a. Clean the test article’s external surfaces and dry to remove any liquid and moisture from leakage paths.</p> <p>b. Use any appropriate test fluid compatible with the test article to be tested.</p>		

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		<p>c. Pressurize the test article to the required pressure with a test fluid (e.g., deionized or distilled water with or without visibility enhancer such as fluorescent dye tracer).</p> <p>d. Ensure lighting in the area to be examined is no less than 1000 lux or lumen/m<sup>2</sup> (100 foot-candles) in brightness, and illumination is free from shadows over the surface area under inspection.</p> <p>e. Observe the surface to be examined with observer's eyes placed within 60 cm (2 ft) of the surface to be examined.</p> <p>f. Visually inspect the test article's leak paths for an absence of test fluid droplets every 30 minutes during the test using a lamp and hinged mirror to meticulously observe areas.</p> <p>g. Use absorbent wipes, blotting paper, or other products such as water developer that changes color in contact with moisture to enhance the visibility of leaking test fluid.</p> <p>h. Ensure there is no observed leakage as evidenced by one or more test fluid droplets of any diameter.</p>		
5.14	Method XIV— Tracer Probe	<p>[LTR 27] The following semi-quantitative method <b>shall</b> be used for local external-to-internal leak testing of sealed test articles (see section 4.2.1.2 of this NASA Technical Standard for calibration if required):</p> <p>a. Evacuate the test article internal volume to a vacuum compatible with a tracer gas leak detector.</p> <p>b. If the calibration is required, calibrate the leak test setup (a tracer probe and a leak detector) with the standard leak installed at the farthest possible point from the leak detector.</p> <p>c. Connect the tracer probe to a source of 100% tracer gas with a valve opening at the other end for directing a stream of tracer gas over the test article starting at the location closest to the connection to the leak detector on the upper side of the test article.</p> <p>d. Proceed along the test article, and any indication of tracer gas above the background by the leak detector indicates a leak.</p>		
5.15.1	Supplementary Provisions for Seal Verification	<p>[LTR 28] The leak tests <b>shall</b> be performed with the test article pressurized at the minimum (if the seals are dependent upon pressure for proper sealing) and the maximum test pressure required in the test article design specifications.</p>		

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5.15.2	Supplementary Provisions for Seal Verification	[LTR 29] Evidence of the test article seal redundancy and proper seal installation for each seal <b>shall</b> be provided by using any means that have been demonstrated to be capable of confirming the integrity of independent seals in a redundant seal installation.		
5.15.2.1	Supplementary Provisions for Seal Verification	[LTR 30] For the test articles not equipped with the leak check ports between the redundant seals, the leak detector output <b>shall</b> be characterized in two steps: first during test article development testing to set a baseline leakage rate recorded during a predetermined time period, and second during test article qualification or acceptance testing to verify that the leakage rate through the seals does not rise above the baseline leakage rate after tracer gas exposure for the same predetermined time period		
5.16.1	Supplementary Provisions for Elements	[LTR 31] If the test article is an element, the leak test <b>shall</b> be performed via total Element Leak Test (ELT) at the test pressure required in the test article specifications.		
5.16.1.1	Supplementary Provisions for Elements	[LTR 32] The ELT <b>shall</b> be performed as close to launch as practical after the element has successfully passed the ELT test readiness review.		
5.16.2	Supplementary Provisions for Elements	[LTR 33] Pressure integrity of the element final configuration <b>shall</b> be verified via prelaunch Gross Leak Test (GLT) at allowed delta pressure as part of a final element pressurization for launch.		
5.17	Supplementary Provisions for Test Fixtures	[LTR 34] For the test articles in their final flight configuration, the test fixtures used for leak testing <b>shall</b> have the fluid (gas or liquid) interfaces to the test article equivalent to flight interfaces (including seals).		
5.18.1	Supplementary Provisions for Leak Test Procedures and Failures Reporting	[LTR 35] Leak test procedures <b>shall</b> have pass/fail criteria established to reflect the test article performance either by design assessment or historical performance experience, but in no case may the pass/fail criteria be less stringent than the MALR shown in the specification requirements.		
5.18.2	Supplementary Provisions for Leak Test Procedures and Failures Reporting	[LTR 36] The actual measured leakage rate <b>shall</b> be recorded in the as-run leak test procedure or leak test log book (i.e., no recording of simply “pass” or “fail”).		
5.19.1	Supplementary Provisions for Tracer Gas Concentration and	[LTR 37] For the leak test methods that use a tracer gas (most frequently helium), tracer gas concentration at all the points of potential leak paths <b>shall</b> be greater than or equal to 5%.		

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Section	Description	Requirement in this Standard	Applicable (Enter Yes or No)	Comments
	Leak Detector/Leak Test Setup Sensitivity			
5.19.2	Supplementary Provisions for Tracer Gas Concentration and Leak Detector/Leak Test Setup Sensitivity	[LTR 38] Tracer gas (most frequently helium) leak detector <b>shall</b> provide a sensitivity of 10% or less of the intended leakage rate to be measured.		
5.19.3	Supplementary Provisions for Tracer Gas Concentration and Leak Detector/Leak Test Setup Sensitivity	[LTR 39] Test setup that includes a leak detector <b>shall</b> provide a sensitivity of at least one-half of the intended leakage rate to be measured.  <i>For example, if the allowable leakage rate is <math>10^{-4}</math> scc/sec, the method (actually the leak test set-up employed by the method) used should be demonstrated by use of a standard leak source to be capable of detecting at least <math>5.0 \times 10^{-5}</math> scc/sec.</i>		

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## APPENDIX B

### REFERENCES

#### B.1 Purpose/Scope

This Appendix provides reference information that may be helpful to the user.

#### B.2 Reference Documents

	ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing
	Leakage Testing Handbook. Prepared by General Electric for the Liquid Propulsion Section, Jet Propulsion Laboratory (July 1969)
ASTM E432 (2017)	Standard Guide for Selection of a Leak Testing Method
ASTM E498/E498M (2011, Revalidated 2017)	Standard Practice for Leaks Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Tracer Probe Mode
ASTM E499/E499M	Standard Practice for Leaks Using the Mass Spectrometer Leak Detector in the Detector Probe Mode
ASTM E515	Standard Practice for Leaks Using Bubble Emission Techniques
ASTM E908	Standard Practice for Calibrating Gaseous Reference Leaks
ASTM E1003	Standard Practice for Hydrostatic Leak Testing
ASTM E1066/E1066M (2012)	Standard Practice for Ammonia Colorimetric Leak Testing
ASTM E1316 (2018)	Standard Terminology for Nondestructive Examinations
ASTM E1603/E1603M (2011, Revalidated 2017)	Standard Practice for Leakage Measurement Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Hood Mode
ASTM E2930 (2013)	Standard Practice for Pressure Decay Leak Test Method

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## **NASA-STD-7012 W/CHANGE 1**

NASA-STD-5001	Structural Design and Test Factors of Safety for Spaceflight Hardware
NASA-HDBK-8709.22	Safety and Mission Assurance Acronyms, Abbreviations, and Definitions