NASA TECHNICAL STANDARD

Office of the NASA Chief Engineer

NASA-STD-7012A
Approved: 2023-02-22

Superseding NASA-STD-7012 (Baseline) w/Change 1

METRIC/SI

LEAK TEST REQUIREMENTS

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 …"
Revision	A		2023-02-22	Significant changes were made to this NASA Technical Standard. It is recommended that it be reviewed in its entirety before implementation. Key changes were: In section 4.2, Leak Test Methods, the major change is the modified Method VII that now has four techniques—not one method; section 4.2.2a was modified to include VII [1], [2], [3], and [4]. Table 1 was modified from VII (Volumetric Displacement, quantitative) to VII [1], [2], [3], and [4] (Leaked Gas Parameters Measurement [Volumetric Displacement, Delta Pressure, Bubbles Volume, and Mass Replacement], quantitative); In section 5.1, Method I—Vacuum Chamber, [LTR 14) was changed to "The following quantitative methods shall be used for total internal-to-external leak testing of pressurized test articles such as spacecraft/vehicles and/or spacecraft pressurized equipment/pressure vessels (technique [1]) and subsystem components such as electrical and/or fluid feedthroughs (technique [2]): a. Chamber Technique [1] for Spacecraft/Vehicles and Pressurized Equipment/Pressure Vessels." In section 5.7, Method VII—Volumetric Displacement, [LTR 20] was renamed to Leaked Gas Parameters Measurement and sectioned into "a. Volumetric Displacement

				Technique [1]", "b. Delta Pressure Technique [2]", "c. Bubbles Volume Technique [3]", and "d. Mass Replacement Technique; in section 5.11, Method XI—Detector Probe, a. Joints Technique [1], was changed from "(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)." to "(7) Investigate further any leak detector output of 40% or more above the established tracer gas background with an appropriate quantitative technique such as accumulation (see Method II) to determine if unacceptable leakage exists."

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 endorsed as standard for NASA programs and projects, including requirements for selection, application, and design criteria of an item.

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

This 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 in accordance with appropriate ASTM International standards and/or The American Society for Nondestructive Testing (ASNT) Handbook have been used and referred to correspondingly.

Submit requests for information via "Email Feedback" at https://standards.nasa.gov. Submit requests for changes to this Standard via Marshall Space Flight Center (MSFC) Form 4657, Change Request for a NASA Engineering Standard, or the "Suggest a Change to this Standard" link on the Standard's Summary Page at https://standards.nasa.gov.

Original Signed By	02-22-2023
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Joseph W. Pellicciotti NASA Chief Engineer	Approval Date

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LEAK TEST REQUIREMENTS

1. SCOPE

1.1 Purpose

This NASA Technical Standard provides an Agency-wide basis from which test programs and procedures are developed for NASA vehicles, subsystems and their components, and payloads. This Standard defines a set of space 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 Standard will provide consistency across the Agency and its contractors, facilitating the sharing of hardware between Centers and programs.

This 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 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

1.2.1 This Standard is approved for use by all NASA space flight programs, including vehicles, subsystems and their components, and payloads developed in-house or under contract. This 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 Standard) based on risk classification following the Center's defined risk philosophy and with approval from the delegated NASA Technical Authority. The levels of assembly for which this Standard applies are vehicles, subsystems and their components, and payloads. Small instruments may be treated as components.

This Standard is developed for the typical NASA space 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.

The major objective of leak testing is to verify proper assembly and workmanship during qualification and acceptance testing and to reveal possible design deficiencies relative to pressure integrity during hardware qualification. The principal goal of the leak test method is to reliably verify the maximum allowable leakage rate (MALR) requirement (see section 3.2 in this Standard for Leakage Rate Verification definition). Tailoring the leak test method, with supplemental analysis, is appropriate in some cases (see section 1.3 in this Standard).

1.2.2 This 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. This language applies to the Jet Propulsion Laboratory (a Federally Funded Research and Development Center), other contractors, recipients of grants, cooperative agreements, or other agreements only to the extent specified or referenced in the applicable contracts, grants, or agreements.

1.2.3 References to "this Standard" refer to NASA-STD-7012A; references to other documents state the specific document information.

1.2.4 Verifiable requirement statements are designated by the acronym "LTR" (Leak Test Requirement), numbered, and indicated by the word "shall." This Standard contains 39 requirements. To facilitate requirements selection by NASA programs and projects, a Requirements Identification Matrix is provided in Appendix A.

1.2.5 Explanatory or guidance text is indicated in italics beginning in section 4. The terms "may" or "can" denote discretionary privilege or permission, "should" denotes a good practice and is recommended but not required, "will" denotes expected outcome, and "is/are" denotes descriptive material or a statement of fact.

1.3 Tailoring

Tailoring of the requirements in this Standard for application to a specific program or project is acceptable when formally approved by the delegated NASA 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, and documented in program or project requirements.

2. APPLICABLE DOCUMENTS

2.1 General

2.1.1 Documents listed in this section contain provisions constituting requirements of this Standard as cited in the text. Latest issuances of cited documents apply unless specific versions are designated. Obtain approval from the delegated NASA Technical Authority to use a version other than as designated.

2.1.2 Access applicable documents at https://standards.nasa.gov or obtain documents directly from the Standards Developing Body or other document distributors.

Note: References are provided in Appendix B.

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

NPR 8715.3, NASA General Safety Program Requirements

2.3 Non-Government Documents

ASTM International

ASTM E493/E493M-11 (2022), Standard Practice for Leaks Using the Mass Spectrometer Leak Detector in the Inside-Out Testing Mode

The American Society of Nondestructive Testing (ASNT)

ANSI/ASNT CP-189, ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel

2.4 Order of Precedence

2.4.1 The requirements and standard practices established in this 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 Standard and other requirements documents will be resolved by the delegated NASA Technical Authority.

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_{He}	dynamic viscosity of helium
μ_F	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
$_F$	fluid
ft	foot
GLT	gross leak test
GSE	ground support equipment
He	helium
in	inch
ISS	International Space Station
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_{EXT}	external pressure in consistent units
P_{INT}	internal pressure in consistent units
P_O	atmospheric pressure in consistent units
psia	pound-force per square inch absolute, English unit of pressure
psig	pounds-force per square inch gauge, English unit of pressure
Q	leakage rate
RTVP	Requirements, Test, and Verification Panel
scc	metric unit of standard cubic centimeter
sec	second
SI	Système Internationale or metric system of measurement
SMA	safety and mission assurance
SMAC	spacecraft maximum allowable concentration
STD	standard
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 E1316-22a, 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.

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.

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 Rate: 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 Rate: 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 Rate: 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 Test Setup Calibration: 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 E908-98 (2022), Standard Practice for Calibrating Gaseous Reference Leaks, for details.

Leak Testing: Nondestructive testing method for detecting and locating leaks and/or measuring leakage rate through leaks in pressurized or evacuated systems or components. **Note**: If leak testing is used to measure the total leakage rate, it will be called 'total leak testing'); if it is used to pinpoint local leaks, it will be called 'local leak testing'.

Leakage: The measurable quantity of fluid (liquid or gas) escaping from a leak.

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 psia). Leakage rates are expressed in various units such as Pascal cubic meters per second (Pa m^3/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 Standard, ASTM E1316-22a is chosen to be a reference where standard conditions are determined as 25°C (77°F) and 100 kPa (14.50 psia).

Leakage Rate Verification: Verification (by test) that the test article can meet the specified maximum allowable leakage rate (MALR) requirement defined by the applicable specification, test plan, and/or test procedure.

Maximum Allowable Leakage Rate (MALR): The leakage rate specified in the pressurized or sealed test article documentation (specifications, drawings, test plans, etc.) that at a given operating conditions may not be exceeded, and for which consideration is given to factors such as mission duration, safety factor, and allowed toxicity hazard level (THL) and spacecraft maximum allowable concentration (SMAC) values.

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 Test Articles: Articles such as spacecraft/vehicles or pressurized equipment (valves, pressure regulators, heat exchangers, etc.)/pressure vessels required to retain leak tightness under positive differential internal pressure conditions.

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

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.

Proof Test Factor: A multiplying factor to be applied to the maximum test pressure (could be MAWP, MDP, or MEOP) to define the proof test pressure.

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 E908-98 (2022) and ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing, Chapter 4, for calibrated (standard) leaks.

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 Standard, subassemblies are considered as subsystems.

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 in which 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.) coupled with any specialty testing such as radiation or commodity exposure.

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.

Note:
Leak test may be skipped as a stand-alone test if it is a part of a functional or performance test that also should be done before and after each environmental test listed above.

[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 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 during the qualification, acceptance, and protoflight testing.

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 cleaned to meet the specific program and/or project cleanliness requirements with the dual purpose of removing any foreign object debris and moisture from potential leaks, and protecting test personnel from potentially toxic and/or hazardous fluid.

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

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 Standard:

a. Method I [1][1] and [2], II, V [1], VII [1] [2], [3], and [4], 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.

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[1] 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.

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.

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

Method No. and [Technique No.]	Leak Test Method [1,2,4]	Leakage Rate Expected to Be Verifiable (scc/sec)[3]	MALR Setting
Methods for Total Internal-to-External Leakage Rate Verification			**A**
I [1] and [2]	Vacuum Chamber [Chamber and Bell Jar techniques], quantitative	Down to 10^{-9}	
II	Accumulation, quantitative	Down to 10^{-7}	
III	Bombing, quantitative	Down to 10^{-8}	
IV [1] and [2]	Vacuum Exposure [Mass Loss and Pressure Loss techniques], quantitative	Down to 5×10^{-5}	
V [1]	Pressure Change [Pressure Decay technique], quantitative	Down to 10^{-4}	
IX [2]	Immersion [Total Leakage Rate technique], quantitative	Down to 10^{-4}	
Methods for Total External-to-Internal Leakage Rate Verification			**A**
V [2]	Pressure Change [Pressure Rise technique], quantitative	Down to 10^{-5}	
VI	Hood, quantitative	Down to 5×10^{-10}	
Methods for Total Internal-to-Internal Leakage Rate Verification			**A**
VII [1], [2], [3], and [4]	Leaked Gas Parameters Measurement [Volumetric Displacement, Delta Pressure, Bubbles Volume, and Mass Replacement], quantitative	Down to 10^{-3}	
VIII	Leak Detector Direct Connection, quantitative	Down to 10^{-8}	
Methods for Local Internal-to-External Leakage Rate Verification			**B**
IX [1]	Immersion [Local Leakage Rate technique], semi-quantitative	Down to 10^{-4}	
X	Ammonia Colorimetric, semi-quantitative	Down to 5×10^{-6}	
XI [1] and [2]	Detector Probe [Joints and Flex Hoses techniques], semi-quantitative	Down to 10^{-5}	
XII	Foam/Liquid Application, semi-quantitative	Down to 10^{-4}	
XIII	Hydrostatic/Visual Inspection, semi-quantitative	Down to 10^{-3}	

Method for Local External-to-Internal Leakage Rate Verification			
XIV	Tracer Probe, semi-quantitative	Down to 10^{-8}	**B**
A. Use only methods for total leakage rate verification if the MALR is set as a total leakage rate.			
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 Standard and specifically for tracer gas methods in accordance with section 5.19.3 of this 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 E432-91 (2022), 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 NPR 8715.3, NASA General Safety Program Requirements, for SMA Technical Authority responsibilities).

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

THL or SMAC 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 Standard should take precedence: • Method I (to verify pressure integrity); • 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 5×10^{-5} scc/sec or more; • Methods XI, XIV (to pinpoint local leaks).
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 Standard should take precedence: • Methods I and II (to verify pressure integrity); • 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 5×10^{-5} scc/sec or more; • Methods XI, XIV (to pinpoint local leaks).
Fluid is not allowed or desired	No greater than 10^{-4} scc/sec: • Methods I, II, III, IV, and V [Technique No. 1] (to verify pressure integrity); • Methods IX, X, XI, XII, XIII, and XIV (to pinpoint local leaks).
Not safety, just general concerns about leaks	No greater than 10^{-3} scc/sec: • 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]).

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.

Note*: See NASA-STD-6016, Standard Materials and Processes Requirements for Spacecraft, for compatibility requirements*

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:

$$Q_{100\%} = Qtg\% \ \frac{100\%}{Ctg\%} \qquad \text{(Eq. 1)}$$

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 at least 5% by volume at all the points of potential leak paths during leak tests.

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, conversions 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_{Air}	1.076	-
$Q_{Nitrogen}$	1.115	-
Q_{Oxygen}	0.971	-
$Q_{Hydrogen}$	2.226	-
Q_{Argon}	0.881	-
Q_{Neon}	0.637	-
Q_{Water}	-	0.0202
$Q_{Ammonia}$	-	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. This assumption results in a linear trend which breaks down when the flow becomes transitional and/or molecular, but may still be relatively accurate to the first order.*

5. *If the system engineers have a concern about the conservatism introduced by this approach, they may use a physics-based approach to convert 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 1.0×10^{-5} scc/sec (if tested via Method II [Accumulation]), and/or not having any single-point leakage above helium background in the 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:

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

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 (μ) 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 E1316-22a*, 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 NASA Technical Authority (see section 1.3 in this 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 spacecraft/vehicles and pressurized equipment/pressure vessels (technique [1]) and subsystem components such as electrical and/or fluid feedthroughs (technique [2]):

a. Chamber Technique [1] for Spacecraft/Vehicles and Pressurized Equipment/Pressure Vessels:

(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 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 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 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.

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 such as spacecraft/vehicles and pressurized equipment/pressure vessels:

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 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 ± 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-11 (2017), 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.

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 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-11 (2022), 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.
(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 Standard).

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

(1) Verify that the test article is pressurized 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 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 such as spacecraft/vehicle or pressurized equipment/pressure vessels:

(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 the test setup sensitivity by installing a standard leak in the test setup (see section 4.2.1.1 in this Standard).

If the test article has pressure transducers and temperature sensors that could be used instead of the test setup, this step is not required.

(5) While making leakage rate calculation based on a recorded pressure drop, take into account:

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 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 the test setup sensitivity by installing a standard leak in the test setup (see section 4.2.1.1 in this 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 E2930-13 (2021), 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 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.

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-11 (2022), 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—Leaked Gas Parameters Measurement

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

a. Volumetric Displacement Technique [1]:

(1) Calibrate the leak test setup (see section 4.2.1.1 in this Standard) for volumetric displacement.
(2) 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.

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

b. Delta Pressure Technique [2]:

(1) Calibrate the leak test setup (see section 4.2.1.1 in this Standard) for delta pressure measurement.
(2) 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 a suitable device for the purposes of measuring pressure increase.
(3) Calculate the leakage rate based on the measured pressure increase and pressurized volume into which gas leaked and compare it to the MALR.
(4) While making leakage rate calculation, take into account the test article sealed part:

A. Internal volume tolerance at maximum positive value, and
B. Volumetric change due to ambient temperature change.

c. Bubbles Volume Technique [3]:

(1) Calibrate the leak test setup (see section 4.2.1.1 in this Standard) for bubbles volume measurement.
(2) 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 via tubing, flexible or firm, to the volumetric apparatus filled with fluid, preferably deionized water or alcohol.
(3) Use the measured volume of leaked gas to establish the leakage rate and compare it to the MALR.

d. Mass Replacement Technique [4]:

(1) Calibrate the leak test setup (see section 4.2.1.1 in this Standard) for mass flow measurement.
(2) Pressurize the test article volume to be tested (called wetted volume) to the required pressure while attached secondary volumes are vented such that the wetted volume boundary is referenced to atmosphere or a specified reference condition (i.e., positive over ambient pressure or vacuum).
(3) Measure mass flow rate required to maintain the specified pressure using a mass flow meter/controller.

Consider the following with respect to the measurement:

A. The reference condition should be stable during the measurement.
B. The uncertainty of the measurement is limited by the uncertainty of the mass flow meter and pressure measurement.

(4) Calculate the leakage rate based on the measured mass flow rate and compare it to the MALR.

Notes:

1. *Volumetric apparatus mentioned in the Bubbles Volume Technique [3] may have a brand name Bubble-O-Meter™ that should be calibrated per ASTM E694-18, Standard Specification for Laboratory Glass Volumetric Apparatus.*
2. *The Mass Replacement Technique [4] can also be used for total internal-to-external testing of pressurized test articles.*
3. *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 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 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^2 (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.

(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 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^2 (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) Calculate the actual leakage rate of the test article dividing the measured volume of leaked gas by the immersion time and compare it to the MALR to demonstrate a margin of at least five divisions of the measuring cylinder.

Note*: ASTM E515-11 (2022), 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 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 100 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).

***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-19, 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 Marr [1969], Leakage Testing Handbook) 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 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 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) Investigate further any leak detector output of 40% or more above the established tracer gas background with an appropriate quantitative technique such as accumulation (see Method II) to determine if unacceptable leakage exists.

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.
(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 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 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**: US Patent 9,116,069, Apparatus for Leak Testing Pressurized Hoses; ASTM E499/E499M-11 (2017), 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 such as pressurized equipment (see section 4.2.1.2 of this 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.

Notes:
1. *ASTM E515-11 (2022) 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 such as pressurized equipment (see section 4.2.1.2 in this 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^2 (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 E1003-03 (2022), *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

[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 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-11 (2022), 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 differential pressure (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: (1) during test article development testing to set a baseline leakage rate recorded during a predetermined time period, and (2) 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 Standard).

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 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 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”).

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 set-up employed by the method) used should be demonstrated by use of a standard leak source to be capable of detecting at least 5.0×10^{-5} scc/sec.

APPENDIX A: REQUIREMENTS IDENTIFICATION MATRIX

A.1 PURPOSE

Due to the complexity and uniqueness of space flight, it is unlikely that all the requirements in a Standard will apply. The Requirements Identification Matrix below contains this Standard's technical authority requirements and may be used by programs and projects to indicate requirements that are applicable or not applicable. 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, specify proposed tailoring, or provide an explanation/justification when not applicable.

Table 4—Requirements Identification Matrix

<table>
<tr><th colspan="5">NASA-STD-7012A</th></tr>
<tr><th>Section</th><th>Description</th><th>Requirement in this Standard</th><th>Applicable (Enter Yes or No)</th><th>Comments</th></tr>
<tr><td>4.1.1</td><td>General Requirements for Leak Testing</td><td>[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.) coupled with any specialty testing such as radiation or commodity exposure.

Note: Leak test may be skipped as a stand-alone test if it is a part of a functional or performance test that also should be done before and after each environmental test listed above.</td><td></td><td></td></tr>
<tr><td>4.1.2</td><td>General Requirements for Leak Testing</td><td>[LTR 2] Personnel performing leak testing in accordance with any of the leak test methods and/or techniques described in this 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.</td><td></td><td></td></tr>
</table>

NASA-STD-7012A				
Section	**Description**	**Requirement in this Standard**	**Applicable (Enter Yes or No)**	**Comments**
4.1.3	General Requirements for Leak Testing	[LTR 3] For the pressurized test articles, a proof pressure test **shall** be performed once prior to the first leak test during the qualification, acceptance, and protoflight testing. ***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	General Requirements for Leak Testing	[LTR 4] Prior to initiating a leak test, the test article external and internal surfaces **shall** be cleaned to meet the specific program and/or project cleanliness requirements with the dual purpose of removing any foreign object debris and moisture from potential leaks, and protecting test personnel from potentially toxic and/or hazardous fluid.		
4.1.5	General Requirements for Leak Testing	[LTR 5] When temperature affects the sealing materials or surfaces, the leak test **shall** be conducted at the minimum and maximum temperature limits at least once during qualification, acceptance, or protoflight testing.		
4.2.1	Leak Test Methods	[LTR 6] The leak test method **shall** 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 **shall** 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 **shall** be verified through its calibration prior to and after the leak test.		
4.2.2	Leak Test Methods	[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 Standard: a. Method I [1][1] and [2], II, V [1], VII [1], [2], [3], and [4,] 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. [1]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.		

NASA-STD-7012A				
Section	**Description**	**Requirement in this Standard**	**Applicable (Enter Yes or No)**	**Comments**
		Table 1—Leak Test Methods for Pressure Integrity Verification and Pinpointing Local Leaks		

Method No. and [Technique No.]	**Leak Test Method [1,2,4]**	**Leakage Rate Expected to Be Verifiable (scc/sec)[3]**	**MALR Setting**
Methods for Total Internal-to-External Leakage Rate Verification			**A**
I [1] and [2]	Vacuum Chamber [Chamber and Bell Jar techniques], quantitative	Down to 10^{-9}	
II	Accumulation, quantitative	Down to 10^{-7}	
III	Bombing, quantitative	Down to 10^{-8}	
IV [1] and [2]	Vacuum Exposure [Mass Loss and Pressure Loss techniques], quantitative	Down to 5×10^{-5}	
V [1]	Pressure Change [Pressure Decay technique], quantitative	Down to 10^{-4}	
IX [2]	Immersion [Total Leakage Rate technique], quantitative	Down to 10^{-4}	
Methods for Total External-to-Internal Leakage Rate Verification			**A**
V [2]	Pressure Change [Pressure Rise technique], quantitative	Down to 10^{-5}	
VI	Hood, quantitative	Down to 5×10^{-10}	
Methods for Total Internal-to-Internal Leakage Rate Verification			**A**
VII [1], [2], [3], and [4]	Leaked Gas Parameters Measurement [Volumetric Displacement, Delta Pressure, Bubbles Volume, and Mass Replacement], quantitative	Down to 10^{-3}	
VIII	Leak Detector Direct Connection, quantitative	Down to 10^{-8}	
Methods for Local Internal-to-External Leakage Rate Verification			**B**

NASA-STD-7012A				
Section	**Description**	**Requirement in this Standard**	**Applicable (Enter Yes or No)**	**Comments**

IX [1]	Immersion [Local Leakage Rate technique], semi-quantitative	Down to 10^{-4}	
X	Ammonia Colorimetric, semi-quantitative	Down to 5×10^{-6}	
XI [1] and [2]	Detector Probe [Joints and Flex Hoses techniques], semi-quantitative	Down to 10^{-5}	
XII	Foam/Liquid Application, semi-quantitative	Down to 10^{-4}	
XIII	Hydrostatic/Visual Inspection, semi-quantitative	Down to 10^{-3}	
Method for Local External-to-Internal Leakage Rate Verification			
XIV	Tracer Probe, semi-quantitative	Down to 10^{-8}	**B**
A. Use only methods for total leakage rate verification if the MALR is set as a total leakage rate.			
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 Standard and specifically for tracer gas methods in accordance with section 5.19.3 of this 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 E432-91 (2022), Standard Guide for Selection of a Leak Testing Method, may also be used as a guide for selection of a leak test method.*

Section	Description	Requirement in this Standard	Applicable (Enter Yes or No)	Comments
4.2.3	Leak Test Methods	[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 NPR 8715.3, NASA General Safety Program Requirements, for SMA Technical Authority responsibilities).		

<table>
<tr><th colspan="5">NASA-STD-7012A</th></tr>
<tr><th>Section</th><th>Description</th><th>Requirement in this Standard</th><th>Applicable (Enter Yes or No)</th><th>Comments</th></tr>
<tr><td></td><td></td><td>Table 2— Leak Test Methods to be Used to Ensure Allowed THL or SMAC Values
<table>
<tr><th>THL or SMAC Limitations</th><th>Recommended MALR to Be Verified: Leak Test Methods</th></tr>
<tr><td>Catastrophic</td><td>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 Standard should take precedence:
• Method I (to verify pressure integrity);
• 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 5×10^{-5} scc/sec or more;
• Methods XI, XIV (to pinpoint local leaks).</td></tr>
<tr><td>Critical</td><td>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 Standard should take precedence:
• Methods I and II (to verify pressure integrity);
• 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 5×10^{-5} scc/sec or more;
• Methods XI, XIV (to pinpoint local leaks).</td></tr>
<tr><td>Fluid is not allowed or desired</td><td>No greater than 10^{-4} scc/sec:
• Methods I, II, III, IV, and V [Technique No. 1] (to verify pressure integrity);
• Methods IX, X, XI, XII, XIII, and XIV (to pinpoint local leaks).</td></tr>
<tr><td>Not safety, just general concerns about leaks</td><td>No greater than 10^{-3} scc/sec:
• 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]).</td></tr>
</table></td><td></td><td></td></tr>
<tr><td>4.2.4</td><td>Leak Test Methods</td><td>[LTR 11] The test fluid (liquid or gas) used for leak testing shall be compatible with the test article’s materials and operational fluid.
Note: See NASA-STD-6016, Standard Materials and Processes Requirements for Spacecraft, for compatibility requirements.</td><td></td><td></td></tr>
<tr><td>4.3.1</td><td>Leakage Rate Unit Conversion</td><td>[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 shall be recalculated per equation (Eq.) 1:

$$Q_{100\%} = Qtg\% \frac{100\%}{Ctg\%} \quad \text{(Eq. 1)}$$
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.</td><td></td><td></td></tr>
</table>

NASA-STD-7012A				
Section	**Description**	**Requirement in this Standard**	**Applicable (Enter Yes or No)**	**Comments**
4.3.2	Leakage Rate Unit Conversion	[LTR 13] Tracer gas concentration **shall** be at least 5% by volume at all the points of potential leak paths during leak tests.		
5. LEAK TEST METHODS FOR QUALIFICATION OR ACCEPTANCE TESTING				
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 spacecraft/vehicles and pressurized equipment/pressure vessels (technique [1]) and subsystem components such as electrical and/or fluid feedthroughs (technique [2]): a. Chamber Technique [1] for Spacecraft/Vehicles and Pressurized Equipment/Pressure Vessels: (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 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 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 Standard) to determine the leak test setup relative sensitivity to be used to establish the test article leakage rate.		

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Section	**Description**	**Requirement in this Standard**	**Applicable (Enter Yes or No)**	**Comments**
		(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.		
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 such as spacecraft/vehicles and pressurized equipment/pressure vessels: 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 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. 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.		

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Section	**Description**	**Requirement in this Standard**	**Applicable (Enter Yes or No)**	**Comments**
		(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.		
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. 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 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-11 (2022), Standard Practice for Leaks Using the Mass Spectrometer Leak Detector in the Inside-Out Testing Mode.		
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. (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.		

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Section	**Description**	**Requirement in this Standard**	**Applicable (Enter Yes or No)**	**Comments**
		(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 Standard). b. Pressure Loss Technique [2] for gas-filled sealed test articles: (1) Verify that the test article is pressurized to the required pressure. (2) Completely place the test article in a vacuum chamber or bell jar to expose it to vacuum. (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 Standard).		
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 such as spacecraft/vehicle or pressurized equipment/pressure vessels: (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 the test setup sensitivity by installing a standard leak in the test setup (see section 4.2.1.1 in this Standard). *If the test article has pressure transducers and temperature sensors that could be used instead of the test setup, this step is not required.* (5) While making leakage rate calculation based on a recorded pressure drop, take into account: A. The test article and test fixture pressurized internal volumes, as well as volume tolerances at maximum positive values, and		

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Section	**Description**	**Requirement in this Standard**	**Applicable (Enter Yes or No)**	**Comments**
		B. The test article and reference vessel (in case it was used) volumetric changes due to ambient temperature changes. 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 the test setup sensitivity by installing a standard leak in the test setup (see section 4.2.1.1 in this 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.		
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 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. 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. 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.		

NASA-STD-7012A				
Section	**Description**	**Requirement in this Standard**	**Applicable (Enter Yes or No)**	**Comments**
5.7	Method VII—Leaked Gas Parameters Measurement	[LTR 20] The following quantitative methods **shall** be used for total internal-to-internal leak testing of pressurized test articles such as valves, pressure regulators, heat exchangers, or space suits: a. Volumetric Displacement Technique (1) Calibrate the leak test setup (see section 4.2.1.1 in this Standard) for volumetric displacement. (2) 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. (3) Use the measured volume of leaked gas to establish the leakage rate and compare it to the MALR. b. Delta Pressure Technique [2]: (1) Calibrate the leak test setup (see section 4.2.1.1 in this Standard) for delta pressure measurement. (2) 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 a suitable device for the purposes of measuring pressure increase. (3) Calculate the leakage rate based on the measured pressure increase and pressurized volume into which gas leaked and compare it to the MALR. (4) While making leakage rate calculation, take into account the test article sealed part: A. Internal volume tolerance at maximum positive value, and B. Volumetric change due to ambient temperature change. c. Bubbles Volume Technique [3]: (1) Calibrate the leak test setup (see section 4.2.1.1 in this Standard) for bubbles volume measurement. (2) 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 via tubing, flexible or firm, to the volumetric apparatus filled with fluid, preferably deionized water or alcohol. (3) Use the measured volume of leaked gas to establish the leakage rate and compare it to the MALR. d. Mass Replacement Technique [4]: (1) Calibrate the leak test setup (see section 4.2.1.1 in this Standard) for mass flow measurement.		

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Section	**Description**	**Requirement in this Standard**	**Applicable (Enter Yes or No)**	**Comments**
		(2) Pressurize the test article volume to be tested (called wetted volume) to the required pressure while attached secondary volumes are vented such that the wetted volume boundary is referenced to atmosphere or a specified reference condition (i.e., positive over ambient pressure or vacuum). (3) Measure mass flow rate required to maintain the specified pressure using a mass flow meter/controller. *Consider the following with respect to the measurement:* *A. The reference condition should be stable during the measurement.* *B. The uncertainty of the measurement is limited by the uncertainty of the mass flow meter and pressure measurement.* (4) Calculate the leakage rate based on the measured mass flow rate and compare it to the MALR.		
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 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. 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.		
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 the local leaks and provide a rough estimate of their leakage rates (see section 4.2.1.2 of this Standard for calibration if required):		

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		(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^2 (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. (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 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^2 (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) Calculate the actual leakage rate of the test article dividing the measured volume of leaked gas by the immersion time and compare it to the MALR to demonstrate a margin of at least five divisions of the measuring cylinder.		
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 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 100 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.		

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		c. After testing, remove the residual indicator from all exterior surfaces/features of the test article (e.g., with distilled water).		
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 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 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) Investigate further any leak detector output of 40% or more above the established tracer gas background with an appropriate quantitative technique such as accumulation (see Method II) to determine if unacceptable leakage exists. 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. (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 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.		

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		(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 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.		
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 such as pressurized equipment (see section 4.2.1.2 of this 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.		
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 such as pressurized equipment (see section 4.2.1.2 in this 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.		

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		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^2 (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.		
5.14	Method XIV—Tracer Probe	[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 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.		
5.15.1	Supplementary Provisions for Seal Verification	[LTR 28] The leak tests **shall** be performed with the test article pressurized at the minimum differential pressure (if the seals are dependent upon pressure for proper sealing) and the maximum test pressure required in the test article design specifications.		

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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 **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	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 **shall** be characterized in two steps: (1) during test article development testing to set a baseline leakage rate recorded during a predetermined time period, and (2) 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 **shall** 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 **shall** 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 **shall** 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 **shall** 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 **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	Supplementary Provisions for Leak Test Procedures and Failures Reporting	[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”).		
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 **shall** be greater than or equal to 5%.		

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	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 **shall** 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 **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 set-up employed by the method) used should be demonstrated by use of a standard leak source to be capable of detecting at least 5.0×10^{-5} scc/sec.*		

APPENDIX B: REFERENCES

B.1 PURPOSE

This Appendix contains information of a general or explanatory nature but does not contain requirements. The latest issuances of reference documents apply unless specific versions are designated. Access reference documents at https://standards.nasa.gov or obtain documents directly from the Standards Developing Body, other document distributors, or by contacting the office of primary responsibility designee for this Standard.

B.2 REFERENCE DOCUMENTS

ASNT Nondestructive Testing Handbook, Fourth Edition: Volume 2, Leak Testing

Marr, J.W. 1969. Report CR 952, *Leakage Testing Handbook, revised edition*. Springfield, VA: National Technical Information Service

ASTM E432-91 (2022), Standard Guide for Selection of a Leak Testing Method

ASTM E498/E498M-11 (2022), Standard Practice for Leaks Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Tracer Probe Mode

ASTM E499/E499M-11 (2017), Standard Practice for Leaks Using the Mass Spectrometer Leak Detector in the Detector Probe Mode

ASTM E515-11 (2022), Standard Practice for Leaks Using Bubble Emission Techniques

ASTM E694-18, Standard Specification for Laboratory Glass Volumetric Apparatus

ASTM E908-98 (2022), Standard Practice for Calibrating Gaseous Reference Leaks

ASTM E1003-03 (2022), Standard Practice for Hydrostatic Leak Testing

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ASTM E1316-22a, Standard Terminology for Nondestructive Examinations

ASTM E1603/E1603M-11 (2022), Standard Practice for Leakage Measurement Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Hood Mode

ASTM E2930-13 (2021), Standard Practice for Pressure Decay Leak Test Method

NASA-STD-5001, Structural Design and Test Factors of Safety for Spaceflight Hardware

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NASA-HDBK-8709.22, Safety and Mission Assurance Acronyms, Abbreviations, and Definitions

Underwood, et al. (Aug. 25, 2015). Apparatus for Leak Testing Pressurized Hoses, United States Patent No.: US 9,116,069 B2