NASA-STD-7012 Leak Test Requirements: Potential Reference for ASNT Nondestructive Testing Handbook for Leak Testing

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ABSTRACT

Keywords

INTRODUCTION

, one of which is called “ ”. There were

, but now it’s Volume 2

CLASSIFICATION OF LEAK TEST METHODS

The word ‘classification’ was not mentioned in
The only section in
word ‘classification’ in its subtitle is “Classification Relative to Test Object”, bu
91 “Standard Guide for
lection of a Leak Test Method” (
methods are divided on ‘leak location’ and ‘leak
nt’

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

Method No. and [Technique No.]	Leak Test Method[1,2]	Minimum Leakage Rate Expected to Be Verifiable (scc/sec)[3]	Maximum Allowable Leakage Rate (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	**Volumetric Displacement, 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 LT method employed should be demonstrated to have a sensitivity to detect leakage rates in accordance with 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.*

MAXIMUM ALLOWABLE LEAKAGE RATE

For the ISS hardware and payloads (hereinafter called test articles), the MALR (to be identified in the test article specifications or drawing) together with the LT method/technique (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 would prevent exceeding the allowed Toxicity Hazard Level (THL) or Spacecraft Maximum Allowable Concentration (SMAC) value, whichever is more conservative (see Table 2).

Table 2: Leak Test Methods to Be Used to Ensure Allowed THL and SMAC Values

THL or Other Limitations	Recommended MALR to Be Verified: Leak Test Method/Technique
	• Method I (• Method IV may be used to verify pressure integrity only if MALR for the test article • Methods XI, XIV (to
	• Methods I and II (• Method IV may be used to verify pressure integrity only if MALR for the test article • Methods XI, XIV (to
	• Methods I, II, III, IV, and V [Technique No. 1] (• Methods IX, X, XI, XII, XIII, and XIV (to
	• Methods I through XIV (selected t

LEAKAGE RATE UNIT CONVERSION

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

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:

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

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

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

where

Q = a fluid leakage rate in scc/sec (if fluid is a gas) and cubic centimeter (cc)/sec (if fluid is a liquid).
Q_{He} = a helium leakage rate in scc/sec.
P_{INT} = an internal pressure for fluid (shown with) and helium (shown with $_{He}$).
P_{EXT} = an external pressure for fluid (shown with) and helium (shown with $_{He}$).
VF = the ratio of the dynamic viscosities (μ) of the tracer gas and the working fluid.
P_0 = atmospheric pressure in consistent units.

DEFINITIONS

Table 4. Definitions used in the Standard but missing in the Handbook

Definitions in the Standard	Definitions in the Handbook
Calibration of Leak Test Setup	
External-to-Internal Total Leakage	
Internal-to-External Total Leakage	
Internal-to-Internal Total Leakage	
Leak Detector Output Stabilization	
Leak Test Setup	
Quantitative Leak Test Method/Technique	
Relative Sensitivity "bag factor"	
Semi-quantitative Leak Test Method/Technique	
Test Article: A system, its subsystem or component that will be pressurized with any operational fluid (gas or liquid) or sealed with positive or negative operational fluid pressure inside it for operation.	

CONCLUSIONS

ACKNOWLEDGEMENTS

REFERENCES

Nondestructive Testing Handbook, *Leak Testing*

Nondestructive Testing Handbook 2, *Leak Testing*

, Standard Guide for Selection of a Leak Testing Method,

Leak Test Requirements,
"*Aerospace Payloads Leak Test Methodology*", *Proceedings ASNT Fall Conference,*

Lvovsky, O.M., "*Optimizing and Standardizing Leak Test Methodology: Step toward NASA Standard for Leak* Testing", Proceedings 31^{s} *Aerospace Testing Seminar,*
Leakage Testing Handbook, revised edition,

– *Standard Terminology for Nondestructive Examinations,*