MISSION AND PROGRAM INTEGRATION (MAPI) CONTRACT

NASA-STD-7012 Leak Test Requirements

Potential Reference for ASNT Nondestructive Testing Handbook for Leak Testing

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Outline

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Introduction

- NASA has many technical standards.
- Each NASA technical standard is assigned to a specific technical discipline.
- One of the disciplines is called “System and Subsystem Test, Analysis, Modeling, Evaluation”.
- There were four technical standards in this group, but not for LT.
- Therefore, last year Johnson Space Center (JSC) Requirements, Test and Verification Panel (RTVP) directed to draft a standard for LT requirements.
- Once the draft was completed, JSC Engineering initiated the standard through NASA Technical Standards Office.

Introduction (Cont.)

- Number for the standard was assigned as NASA-STD-7012 (hereinafter called Standard).
- Working Group (WG) was established for further Standard development.
- WG consisted of engineers qualified in aerospace hardware environmental test and verification.
- Two WG members had ASNT Level III in LT, five WG members had a Ph.D.
- Standard draft in its 10th revision was sent to all the NASA Centers for review and commenting.
- More than 300 comments were received, considered, and dispositioned.
- On March 5th of 2019, NASA Chief Engineer approved Standard that had thirty nine (39) requirements.

LT Methods Classification

- **The only section in NDT Handbook, Fourth Edition, Volume 2 LEAK TESTING (hereinafter called Handbook) that has the word ‘classification’ in its subtitle is “Classification Relative to Test Object”.**
- **However, nothing specific has been said regarding classification of the LT methods/techniques.**
- **Another valuable source, ASTM standard E432-91 “Standard Guide for Selection of a Leak Test Method”, has a guide where LT methods are divided on ‘leak location’ and ‘leak measurement’ methods that certainly required a further clarification.**
- **Standard has leak test methods classification put in a table format (hereinafter called Classification Table).**

LT Methods Classification (Cont.)

- **Classification Table has four columns:**
  - **Column 1 for LT Method Number (##1-14) and/or Technique Number (10 specified for 5 different methods), so total 19 Methods & Techniques**
  - **Column 2 for LT Method Name**
    - **I. Vacuum Chamber**
      - **I [1] Chamber technique**
      - **I [2] Bell Jar technique**
    - **II. Accumulation**
    - **III. Bombing**
    - **IV. Vacuum Exposure**
      - **IV [1] Mass Loss technique**
      - **IV [2] Pressure Loss technique**
    - **V. Pressure Change**
      - **V [1] Pressure Decay technique**

LT Methods Classification (Cont.)

- IX. Immersion
  - IX [2] Total Leakage Rate technique
- V. Pressure Change
  - V [2] Pressure Rise technique
- VI. Hood
- VII. Volumetric Displacement
- VIII. Leak Detector Direct Connection
- IX. Immersion
  - IX [1] Local Leakage Rate technique
- X. Ammonia Colorimetric
- XI. Detector Probe
  - XI [1] Joints technique
  - XI [2] Flex Hoses technique
- XII. Foam/Liquid Application
- XIII. Hydrostatic/Visual Inspection
- XIV. Tracer Probe

LT Methods Classification (Cont.)

- Column 3 for Minimum Leakage Rate Expected to Be Verifiable (specified for every LT Method/Technique within the range between $5x10^{-10}$ (Hood) and 10^{-3} (Hydrostatic/Visual Inspection) scc/sec
- Column 4 for Maximum Allowable Leakage Rate (MALR) Setting marked with Notes (A or 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

LT Methods Classification (Cont.)

- Classification Table has five rows with subtitles for different LT method categories:
  - Methods for Total Internal-to-External Leakage Rate Verification:
    - Methods I [1] & I [2], II, III, IV [1] & IV [2], V [1], VI, IX [2]
  - Methods for Total External-to-Internal Leakage Rate Verification
    - Methods V [2], VI
  - Methods for Total Internal-to-Internal Leakage Rate Verification
    - Methods VII, VIII
  - Methods for Local Internal-to-External Leakage Rate Verification
    - IX [1], X, XI [1] & XI [2], XII, XIII
  - Method for Local External-to-Internal Leakage Rate Verification

LT Methods Classification (Cont.)

- **Classification Table has a few general *Notes:***
  - ***Note 1: The selection of LT 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.***
  - ***Note 2: LT method employed should be demonstrated to have a sensitivity to detect leakage rates in accordance with this Standard*.**
  - ***Note 3: 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.***

LT Method to Ensure Allowed THL and SMAC

- **For the ISS hardware and payloads (hereinafter called Test Articles), the MALR together with the proper LT method/ technique shall ensure that the Maximum Working Fluid Amount (MWFA) that could leak over the spacecraft mission duration would prevent exceeding the allowed Toxicity Hazard Level (THL) or Spacecraft Maximum Allowable Concentration (SMAC) value, whichever is more conservative.**
- **MALR has to be identified in Test Article specifications.**
- **Proper LT method/technique has to be chosen from Classification Table.**
- **MWFA that could leak over the mission duration has to be calculated as**
  MWFA = MALR × Mission Duration × Safety Factor

LT Methods to Ensure Allowed THL and SMAC (Cont.)

- Table for THL and SMAC has two columns:
  - Column 1 for THL or Other Limitations
  - Column 2 for Recommended MALR to Be Verified: LT Methods
- Table for THL and SMAC has four rows:
  - Catastrophic
    - Method I (to verify pressure integrity)
    - Method IV may be used to verify pressure integrity only if MALR for Test Article is set to be >$5x10^{-5}$ scc/sec
    - Methods XI and XIV (to pinpoint local leaks)
  - Critical
    - Methods I and II (to verify pressure integrity)
    - Method IV may be used to verify pressure integrity only if MALR for Test Article is set to be >$5x10^{-5}$ scc/sec
    - Methods XI and XIV (to pinpoint local leaks)

LT Methods to Ensure Allowed THL and SMAC (Cont.)

- Fluid is not allowed or desired
  - Methods I, II, III, IV, and V [1] (to verify pressure integrity)
  - Methods IX, X, XI, XII, XIII, and XIV (to pinpoint local leaks)
- Not safety, just general concerns about leaks
  - 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 Test Article)

Leakage Rate Unit Conversion

- **For the ISS Test Articles, prior to conversion from a tracer gas (most frequently helium) leakage rate to a corresponding working fluid (gas or liquid) leakage rate, the measured tracer gas leakage rate shall be recalculated per Equation 1:**
  - **$Q_{100\%} = Q_{tg\%} \times 100\%/C_{tg\%}$ (Eq. 1) where**
    - **$Q_{100\%}$ = a tracer gas leakage rate recalculated to its 100% concentration**
    - **$Q_{tg\%}$ = a measured tracer gas leakage rate at its known or estimated concentration**
    - **$C_{tg\%}$ = a known or estimated concentration of a tracer gas inside the Test Article**
  - **Tracer gas concentration shall be greater than or equal to 5% at all the points of potential leak paths during LT**

Leakage Rate Unit Conversion (Cont.)

- Conversion factors to be used to determine working fluid are to be taken from Leakage Rate Unit Conversion Table with
  - Three columns
    - Column 1: To Convert Leakage Rate Measured with Helium as a Tracer Gas (Recalculated to its 100% Concentration)
    - Column 2: Gas Flow Convert per Equation 2 where Viscosity Factor (VF) is:
      - 1.076 for Air
      - 1.115 for Nitrogen
      - 0.971 for Oxygen
      - 2.226 for Hydrogen
      - 0.881 for Argon
      - 0.637 for Neon
    - Column 3: Liquid Flow Convert per Equation 3 where VF is:
      - 0.0202 for Water
      - 0.142 for Ammonia

Leakage Rate Unit Conversion (Cont.)

- **Equations for use in Leakage Rate Unit Conversion Table:**
  - $Q_F = Q_{He}\,[(P^2_{INT} - P^2_{EXT})_F]/\,P^2_{INT.He}\,VF$ (Eq. 2)
  - $Q_F = Q_{He}\,2P_0[(P_{INT} - P_{EXT})_F]/\,P^2_{INT.He}\,VF$ (Eq. 3), where
    - Q_F = 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 $_F$) and helium (shown with $_{He}$);
    - P_{EXT} = an external pressure for fluid (shown with $_F$) 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.

Leakage Rate Unit Conversion (Cont.)

- **Leakage Rate Unit Conversion Table has a few general Notes:**
  - **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.**
  - **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.**
  - **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.**

Leakage Rate Unit Conversion (Cont.)

- 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.
- 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.

Leakage Rate Unit Conversion (Cont.)

- **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)).**

Definitions

- **Definitions used in Standard but missing in 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**
  - **Semi-quantitative Leak Test Method/Technique**
  - **Test Article**

Conclusions

- **Standard and Handbook have specific technical details that differ from each other, in particular:**
  - **Classification of LT methods/techniques**
  - **Conversion from a tracer gas leakage rate to a corresponding working fluid (gas or liquid) leakage rate**
  - **Definitions**
- **ASNT may consider Standard as a reference when working on fifth edition of Handbook.**

Questions?