INGRESS LEAK TESTING
Protecting Products from Their Environment

JP De Luca
Sales Manager | Leak Detection Product Manager

LACO TECHNOLOGIES
Overview

• Why Do You Need to Leak Test?
• Ingression Leak Testing Standards and Guidelines
• Establishing a Leak Rate
• Overview of Leak Testing Methods
  • Helium leak testing
  • Air/Nitrogen Leak Testing
• Selecting a Leak Test Method
• Examples of Ingress Leak Testing Solutions
• Conclusion
Why Do You Need to Leak Test?
Why Leak Test?

• Production leak testing is implemented to verify the integrity of a manufactured part. It can involve 100% testing or sample inspection.

• The goal of production leak testing is to prevent “leaky” parts from getting to the customer. Because manufacturing processes and materials are not “perfect”, leak testing is often implemented.
Why Leak Test?

Prevent **OUT Leakage**

- Depletion of Gas in a Sealed Device or System
  - A/C System
  - Pressurized Airbag Inflator
  - Gas Storage Cylinder

- Leaking of Liquids in a Sealed Device or System
  - 55-gallon Drum
  - Liquid Cooling System
  - Drug Delivery System
Why Leak Test?

Prevent **IN Leakage** (Ingress)

- Ingression of Water or Dust
  - Handheld Electronic Device
  - Exterior Lighting
- Ingression of Water Vapor
  - Engine Control Module
  - Pyrotechnic Airbag Inflator
  - Electronic Sensors
Why Leak Test?

Prevent IN Leakage (Ingress)

• Ingression of Other Gases
  • Packaged Food Products
  • Pharmaceutical Products

• Ingression of Bacteria
  • Sterile Bioprocess Bags
  • Sterile Packaging
Ingression Leak Testing Guidelines & Standards
Ingression Leak Testing Standards & Guidelines

• International Electrotechnical Commission (IEC)
  • IEC 60529, International Protection (IP) Rating (also called Ingress Protection)
    • Dust and Water Ingression Protection for Electrical Enclosures
### IPXX Code – Int’l Protection Marking, IEC Std 605329 (Ingress Protection Marking)

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<thead>
<tr>
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<th>Second digit</th>
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<td>6K</td>
<td>Powerful high temperature water jets</td>
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<tr>
<td></td>
<td></td>
<td>7</td>
<td>Immersion, up to 1 m depth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
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Ingression Leak Testing Standards & Guidelines

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• MIL-STD-883K
  • Hermeticity of Microelectronic Devices
    • Humidity Ingression Protection — MIL-STD-883K
MIL-STD-883K Test Method Standard
Microcircuits
Ingression Leak Testing Standards & Guidelines

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  - IEC 60529, International Protection (IP) Rating (also called Ingress Protection)
    - Dust and Water Ingression Protection for Electrical Enclosures
- MIL-STD-883K
  - Hermeticity of Microelectronic Devices
    - Humidity Ingression Protection — MIL-STD-883K
- Integrity Testing for Pharmaceutical Industry
  - ASTM, USP, ISO, PDA, and others
  - Both Out-leakage and Bacteria Ingress
- ASTM
  - Multiple Standards
Ingression Leak Testing Standards & Guidelines

• For many applications there may exist no standards or guidelines for determining a leak rate criteria that will ensure appropriate ingress protection for your product

• **Example 1:** Parts, under 15 psig of pressure, should not leak more than 1 small drop of liquid within 1 hour

• **Example 2:** No moisture ingress after 1 hour of liquid exposure under a pressure of 30 psig

• **Example 3:** No leak!
Establishing a Leak Rate
Establishing a Leak Rate

• Understanding the operating conditions of the product
  • Will the product be submerged?
  • Will the product be implanted in a person?
  • Will the product be exposed to weather?
  • Will the product see different altitudes?
  • What is the internal operating pressure of the product?
  • What is the nature of the ingress?
  • What conditions might drive a contaminant into the product?

• Other Criteria
  • What is the expected life time of the product or its content?
Establishing a Leak Rate

- Empirical studies may be necessary to determine what an ideal leak rate might be for a given product.
  - LACO has conducted many studies duplicating operating conditions, measuring ingress leakage (moisture ingress for instance)
  - LACO has extensive experience running tests using our built-in calibrated leak standards – Micro Tube Capillary (MTC) – in mockup parts to replicate various environmental conditions. Data collected is a great reference database to help our customers determine the required leak rate
Common Production Leak Testing Methods

- **HELIUM**
  - Hydrogen
  - Refrigerants
  - Others

- **AIR/NITROGEN**
  - Vacuum

**TRACER GAS**
- Sniffing
  - Manual
  - Automated
  - Robotic
- Hard Vacuum Chamber
  - Bombed
  - Clamshell
- Prefilled
- Apply Gas at Test
  - Atmospheric
  - Vacuum
- Visual Detection
  - Bubble Testing
- Direct Flow
  - Mass Flow
  - Mass Flow - Chamber
- Pressure Change
  - Vacuum/Pressure Decay
  - Vacuum/Pressure Decay - Chamber

Helium Leak Testing

Hard Vacuum / Sniffing Methods
Hard Vacuum Test Outside-In: Helium Spray
Hard Vacuum Test Inside-Out
Helium Sniffing Test Principle

Helium Management Module

Helium Pressure
Accumulation Test Inside-Out: Helium Charged Part

Helium Management Module

Helium Pressure

Atmosphere

Helium
Air/Nitrogen Leak Test Testing

Pressure Decay / Mass Flow
Air Pressure Decay Leak Testing – OPEN Part

2-WAY LEAK ISOLATION VALVE

3-WAY ISOLATION/VENT VALVE

2-WAY FILL VALVE

REGULATED, CLEAN AIR SOURCE

AIR VENT

LACO CALIBRATED LEAK STANDARD

PRESSURE TRANSDUCER

TEST PART
Air Pressure Decay Leak Test Basic Steps

1. **Fill**: Achieve test pressure and isolate test volume.
2. **Settle**: Allow air pressure to stabilize (temperature and volume).
3. **Measure**: Monitor pressure drop. Determine PASS/FAIL.
4. **Vent**: Allow air to vent from test volume.
Basic Principle of Air Pressure Decay Leak Test

Typical Air Pressure Decay Leak Test Profile

- Fill
- Settle
- Measure
- Vent

Reject Limit

Pressure (psi) vs. Test Time (sec)

Pressure (psi) and Pressure Change (psi) graph
Direct Air Mass Flow Test – OPEN Part

2-WAY LEAK ISOLATION VALVE

PRESSURE TRANSDUCER

FLOW SENSOR

3-WAY BYPASS VALVE

3-WAY VENT/ISOLATION VALVE

LACO CALIBRATED LEAK STANDARD

REGULATED, CLEAN AIR SOURCE

AIR VENT

TEST PART
Direct Mass Flow Test – Basic Steps

 Fill — Bypass fill, then direct fill the test part

 Settle — Allow air pressure to stabilize (temperature and volume)

 Measure — Measure Leak Rate (Flow) Determine PASS/FAIL

 Vent — Allow air to vent from test volume
Basic Principle of Air Mass Flow Leak Test

Typical Air Mass Flow Leak Test Profile

<table>
<thead>
<tr>
<th>Fill</th>
<th>Settle</th>
<th>Measure</th>
<th>Vent</th>
</tr>
</thead>
</table>

- **Fill**: Pressure build-up
- **Settle**: Pressure stabilize
- **Measure**: Pressure measurement
- **Vent**: Pressure release

Test Time (sec)

---

- **Fill Pressure**: Blue line
- **Flow - No Leak**: Orange line
- **Flow - Leak**: Dotted orange line

Reject Limit
Common Production Leak Test Methods with Associated Characteristics

<table>
<thead>
<tr>
<th>Method</th>
<th>Quantify</th>
<th>Locate</th>
<th>Global 1</th>
<th>Go / No Go</th>
<th>Test Media</th>
<th>Test Volume Dep.</th>
<th>Relative Cost</th>
<th>Typical Sensitivity (atmcc/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Pressure (Vacuum) Decay</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Air</td>
<td>Yes</td>
<td>Medium</td>
<td>0.01</td>
</tr>
<tr>
<td>Mass Flow</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Air</td>
<td>Yes</td>
<td>Medium</td>
<td>0.01</td>
</tr>
<tr>
<td>Dye Liquid Tracers</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Liquid</td>
<td>No</td>
<td>Low</td>
<td>0.001</td>
</tr>
<tr>
<td>Bubble Immersion</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Air</td>
<td>No</td>
<td>Low</td>
<td>$10^{-4}$</td>
</tr>
<tr>
<td>Thermal Conductivity Sniffing</td>
<td>Limited</td>
<td>Yes</td>
<td>No</td>
<td>Yes³</td>
<td>Helium</td>
<td>No</td>
<td>Low</td>
<td>$10^{-5}$</td>
</tr>
<tr>
<td>SF6 Sniffing</td>
<td>Limited</td>
<td>Yes</td>
<td>No</td>
<td>Yes³</td>
<td>SF6</td>
<td>No</td>
<td>Low-Med</td>
<td>$10^{-3}$ to $10^{-9}$</td>
</tr>
<tr>
<td>Halogen Sniffing</td>
<td>Limited</td>
<td>Yes</td>
<td>No</td>
<td>Yes³</td>
<td>Halogens</td>
<td>No</td>
<td>Low-Med</td>
<td>$10^{-4}$ to $10^{-2}$</td>
</tr>
<tr>
<td>Helium Mass Spec Sniffing</td>
<td>Limited</td>
<td>Yes</td>
<td>No</td>
<td>Yes³</td>
<td>Helium</td>
<td>No</td>
<td>Med-High</td>
<td>$10^{-7}$</td>
</tr>
<tr>
<td>Helium Mass Spec Atmosphere Accumulation</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Helium</td>
<td>Yes</td>
<td>High</td>
<td>Approx. 10-4</td>
</tr>
<tr>
<td>Helium Mass Spec Hard Vacuum</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Helium</td>
<td>No</td>
<td>High</td>
<td>10-9</td>
</tr>
<tr>
<td>Trace Gas Mass Spec Hard Vacuum</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>R134a, SF6, Air, H2, NO2, CO2</td>
<td>No</td>
<td>High</td>
<td>10-7 gas dependent</td>
</tr>
</tbody>
</table>

1. The test method measures the global leak rate of the part, versus individual leaks.
2. The test volume significantly affects the test cycle time and/or sensitivity.
3. Result may be operator dependent.
Selecting a Leak Test Method
Selecting a Leak Test Method

Many of these requirements and characteristics have a direct impact on the available leak test method.
# Example of Method Selection

<table>
<thead>
<tr>
<th>Method</th>
<th>Leak Rate Sensitivity (atmcc/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; 0.01</td>
</tr>
<tr>
<td>Tracer Gas Leak Testing</td>
<td></td>
</tr>
<tr>
<td>Helium Sniffing - Manual</td>
<td></td>
</tr>
<tr>
<td>Helium Sniffing - Robotic</td>
<td></td>
</tr>
<tr>
<td>Helium Sniffing - Chamber/Clamshell</td>
<td></td>
</tr>
<tr>
<td>Hard Vacuum Helium - Bombed</td>
<td></td>
</tr>
<tr>
<td>Hard Vacuum Helium - Prefilled</td>
<td></td>
</tr>
<tr>
<td>Hard Vacuum Helium - Gas Inside Part</td>
<td></td>
</tr>
<tr>
<td>Hard Vacuum Helium - Gas Outside Part</td>
<td></td>
</tr>
<tr>
<td>Helium Accumulation (Atm/Vac)</td>
<td></td>
</tr>
</tbody>
</table>

| Compatibility Levels                            |          |                |                   |                   |           |
|-----------------------------------------------|-----------------------------------|
| C = Compatible                                |          |                |                   |                   |           |
| P = Possibly Compatible, but not Ideal        |          |                |                   |                   |           |
| X = Not Compatible                            |          |                |                   |                   |           |

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Examples of Ingress Leak Testing Solutions
Example of Ingress Leak Testing: Application #1

- **Part Description**: Sealed Pharmaceutical Packages
- **Leak Rate Requirement**: Comply with ASTM F2096 and ASTM D3078
  
  Bubble Testing to Assess Package Integrity
- **Test Pressure**: Vacuum
- **Selected Leak Testing Method**: Bubble Leak Testing
Bubble Leak Tester

- Part is submerged under water
- A vacuum is generated above the water
- A pressure differential is created between the inside and the outside of the part
- Bubbles will form at leaking point(s)

Note: Size and stream of bubbles will vary based on the part leakage level
Example of Ingress Leak Testing: Application #2

- **Part Description:** Sealed Electrical Enclosure
- **Leak Rate Requirement:** Comply with the IP67 Standard
- **Leak Rate Specification:** 1 SCCM (typical) CM
- **Test Pressure:** 1.5 psig
- **Selected Leak Testing Method:** Pressure Decay
Air Pressure Decay Chamber Test – SEALED Part

- SEALED TEST PART
- TEST CHAMBER
- PRESSURE TRANSUDCER
- 2-WAY LEAK ISOLATION VALVE
- LACO CALIBRATED LEAK STANDARD
- 3-WAY ISOLATION/VENT VALVE
- PRESSURE TRANSUDCER
- AIR VENT
- REFERENCE VOLUME
- 2-WAY FILL VALVE
- REGULATED AIR OR VACUUM SOURCE
Chamber Air Pressure Decay Leak Test Basic Steps

1. **Volume Equalize**
   - Pre-fill test chamber with reference volume and check pressure for gross leak

2. **Fill**
   - Continue fill to achieve test pressure and isolate test volume

3. **Settle**
   - Allow air pressure to stabilize (temperature and volume)

4. **Measure**
   - Monitor pressure drop. Determine PASS/FAIL

5. **Vent**
   - Allow air to vent from test volume
Basic Principle of CHAMBER Air Pressure Decay Leak Test

Typical Air Chamber Pressure Decay Leak Test Profile with Gross Leak Volume Equalization

- PreFill Volume
- Equalize Volumes
- Final Fill
- Settle
- Measure
- Vent

Pressure (psi) vs. Test Time (sec)

Reject Limit

Gross Leak

(ΔP/Δt)

Pressure Change (psi)
Example of Ingress Leak Testing: Application #3

- **Leak Testing Application**: Hermetically Sealed Device
- **Part Description**: Small Sealed Part
- **Leak Rate Requirement**: $1 \times 10^{-8}$ atm.cc/sec
- **Leak Testing Method**: Helium Bombing Method
- **Using the MIL-STD-883K Standard**
  - Helium is forced into the part prior to the helium leak test process
  - Bombing Pressure: 90 psig
  - Pressurization Time: 5 hours
  - Dwell Time: 30 min.

Step 1: Helium bombing process (several parts at a time)

Step 2: Helium leak testing process

Helium Management Module

Bombing Chamber

Vacuum

Helium Leak Detector
Alternative Solution To Helium Bombing Method

- The Bombing Method Requires
  - One or more bombing chambers
  - A helium management system (to evacuate, pressurize with helium and then vent the helium out of the bombing chamber)
  - The bombing time can be quite long – hours - (based on the leak rate requirements, the part internal dead space and the maximum bombing pressure the parts can withstand)
  - The bombing method has limitations in terms of leak rate sensitivity (MIL-STD-883K)

- The Alternative
  - Whenever possible, seal the parts within a helium controlled environment. This alternative is a good economical solution (App # 4)
Example of Ingress Leak Testing: Application #4

- **Leak Testing Application**: Sealed Part
- **Part Description**: Medical Implant
- **Leak Rate Requirement**: $1 \times 10^{-9}$ atm.cc/sec
- **Leak Testing Method**: Helium Hard Vacuum with Test Chamber
  - Part is welded in a controlled environment with a specific % of helium
  - Helium is present in the part prior to the helium leak test

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Hard Vacuum Test Inside-Out

Pre-filled Part

Vacuum Chamber
Conclusion
Conclusion

• More and more applications are for ingress leak testing.
• The ingress can be of different nature and size, depending on the product, application requirements, standards, etc.
• Defining the correct leak rate for some applications can be challenging and require empirical studies, LACO has extensive experiences in running such studies and helping customers defining the correct leak rates.
• LACO is unique with offering the widest range of leak testing methods to all ingress leak testing requirements.
THANK YOU!

• Stop By Our Booth (#1438) to Validate Your Coupon for a FREE Calibrated Leak Standard
• Contact Us to Review Your Current Calibration and Validation Strategy
• LinkedIn Group: Production Leak Testing
• Blog: www.lacotech.com/posts
• Website: www.lacotech.com
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MIL-STD-883K Test Method Standard Microcircuits