Succeeding with Production Air Leak Testing Methods

Paul Chamberlain
President, CEO
Overview

- Air Leak Testing Overview
- Pressure Decay Air Leak Testing
  - Factors impacting leak rate measurement
  - Test Data: Test Pressure, Materials
- Measurement Error: Summary of Contributing Factors
Overview of Air Leak Testing

Basic air leak testing methods
What do you expect from your air leak testing process?

1. Test Reliability (Trust the Results)
2. Test Quickly (High Production Rates)
3. Equipment Reliability (High Up-Time)
4. High Sensitivity (Detect Smaller & Smaller Leaks)
Many Users of Air Leak Test Instruments Experience Some Degree of **Frustration**

- May not trust the results
- May not have the understanding to troubleshoot the issues
Air Leak Testing Fundamentals

- Air is the test medium
- A pressure differential is created
- Flow is detected across the part boundary
Flow Detection Methods
FOR AIR LEAK TESTING

Visual

- Pressure Change (Pressure Decay)
- Direct Flow Measurement (Mass Flow)

Electronic/Sensor

Emission of bubbles from a leak (Bubble Immersion)
Air Leak Testing Methods

“What is the best method to find leaks?”

Test Part

Bubble Immersion

Pressure Decay

Mass Flow

Air

www.lacotech.com
© 2016 LACO Technologies. All Rights Reserved.
Air Leak Testing Methods

- Electric/Sensor (Pressure Change & Mass Flow)
  - Operator Independent
  - Automated
  - Does Not Require a Liquid
  - Fast and Repeatable
  - Can Be Calibrated
  - **BUT**...Many Possible Contributors to Measurement Error
Factors Influencing Leak Rate (Q) Measurement Error
Pressure Decay Air Leak Testing

Factors that can impact leak rate measurement
Part Configuration Influences Test Method & Tooling

“What type of part do you have?”

Open Parts

- Can connect to or seal to the part to supply test air
  - Requires connectors or a test fixture

Sealed Parts

- No way to connect to the internal volume of the part
  - Requires a test chamber
OPEN Part Examples
SEALED Part Examples
Pressure Change Air Leak Testing

- Pressure Decay
- Vacuum Decay
- Chamber Pressure Decay
- Chamber Vacuum Decay
- Differential Pressure Decay

“Open” Parts

“Sealed” Parts
Air Pressure Decay Leak Testing – OPEN Part

- 2-WAY LEAK ISOLATION VALVE
- CALIBRATED LEAK STANDARD
- PRESSURE TRANSDUCER
- 3-WAY ISOLATION/VENT VALVE
- 2-WAY FILL VALVE
- REGULATED, CLEAN AIR SOURCE
- AIR VENT

TEST PART

Air Pressure Decay Leak Test Basic Steps

1. Fill: Achieve test pressure and isolate test volume
2. Settle: All 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)
Pressure Change (psi)

Test Time (sec)

(ΔP/Δt)
Air Pressure/Vacuum Decay Chamber Test – Sealed Part

[Diagram showing a sealed test part, test chamber, pressure transducer, air vent, reference volume, regulated air or vacuum source, 2-way fill valve, 3-way isolation/vent valve, 2-way leak isolation valve, and calibrated leak standard.]

SEATED TEST PART

TEST CHAMBER

PRESSURE TRANSDUCER

2-WAY FILL VALVE

AIR VENT

REFERENCE VOLUME

REGULATED AIR OR VACUUM SOURCE

2-WAY LEAK ISOLATION VALVE

CALIBRATED LEAK STANDARD

PRESSURE TRANSDUCER

3-WAY ISOLATION/VENT VALVE
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

Gross Leak Reject Limit

Reject Limit

Pressure (psi)

Pressure Change (psi)
Keys to Success

- Minimize the source of measurement errors – impact on pressure change ($\Delta P$) for “other” sources
- Maximize the contribution of the Leak (Q_{leak}) to the pressure change ($\Delta P$)
Reality of Pressure Decay Leak Measurement

Measure

Reject Limit

No Leak

Leak

Vent
What Affects Pressure Change Measurement?

\[ \Delta P = \Delta T + \Delta V + Q_{\text{gas}} + Q_{\text{sys}} + Q_{\text{leak}} \]
Pressure Decay Leak Test Theory

\[ Q_{\text{leak}} \text{ (sccm)} = \left( \frac{\Delta P}{\Delta t} \right) V \]

\[ \Delta P = Q_{\text{leak}} \cdot \Delta t / V \]

\[ \Delta P = (Q_{\text{leak}} + Q(\Delta V) + Q(\Delta T) + Q_{\text{sys}} + Q_{\text{gas}}) \cdot \Delta t / V \]
What Affects Pressure Change Measurement?

- Temperature instabilities during measurement
- Volume instabilities during measurement
- Leaks in the system or tooling – not from the part
- Gas adsorbing or desorbing inside the test volume
- Flow measured from a leak in the test part

\[ \Delta P = \Delta T + \Delta V + Q_{\text{gas}} + Q_{\text{sys}} + Q_{\text{leak}} \]
Factors Influencing Leak Rate (Q) Measurement Error

- Test Conditions (pressure, leak rate, cycle time)
- Part Characteristics (size, materials, construction)
- Fixture Design (seal, size, materials, etc.)
- Test Instrument (manifold, sensor, resolution, S/W features)
- Test Environment (part temp, cleanliness, environ. temp, air quality)

$Q_{sys}$

$\Delta T$

$\Delta V$

$Q_{gas}$
Temperature Instabilities During Measurement

Under constant volume, the absolute pressure of a gas will change as a function of the change in gas absolute temperature:

\[ P_2 = P_1 \times \left( \frac{T_2}{T_1} \right) \]

Air at 24.7 psia (10 psig) cools 0.2 K from 298 K (24.85 C) to 297.8 K (24.65 C) in 10 seconds resulting in a pressure drop of 0.0166 psi. (equivalent to a 0.36 sccm leak in a 50 cc volume)
Temperature Instabilities During Measurement

• Test Conditions
  • Fill Pressure: Adiabatic Heating caused by gas compression causes the air and part temperature to rise. Higher pressure = more compression = more heat.
  • Short Test Times: Don’t allow for temperature stabilization.

• Part Characteristics
  • Materials: Thermal conductivity affects heat dissipation rates.
  • Size: Larger volumes create more heat (more gas is compressed) due to Adiabatic Heating.
Part Temperature During Pressure Decay Test

Typical Air Pressure Decay Leak Test Profile - Showing Part Temperature

Fill  Settle  Measure  Vent

More Adiabatic Heating

Less Adiabatic Heating

Test Time (sec)

Pressure (psi)  Part Temp  Pressure Change (psi)
Temperature Instabilities During Measurement

• Environmental Conditions
  • Prior Operations: Welding, cleaning, drying, etc., can heat the test part above ambient temperature causing the part to cool during measurement.
  • Ambient Temperature: The difference between the ambient temperature and part temperature can create heating or cooling during measurement.
  • Part Handling: Transfer of heat from the operator to the test part during part loading.
Temperature Instabilities During Measurement

- **Fixture Design**
  - **Materials**: Thermal conductivity affects heat dissipation rates.
  - **Size**: Larger volumes create more heat due to Adiabatic Heating.

- **Test Instrument**
  - **Manifold Design**: Stability of temperature from filling/venting and valve coils.
  - **Software**: Ability of the software to monitor and subtract out temperature effects.
Test Data For Pressure Decay Air Leak Testing

Test Pressure and Materials Influences
What impact will the fill (test) pressure have on the robustness of the test?

- 10 psig versus 100 psig
- Same Equivalent Leak Rate
- Same Part
- Same Test Parameters (timers)
Signal to Noise Ratio (S/N)

• A key indicator of the capability of a test.

• Larger the signal to noise ratio the more capable or robust the test is.

• $S/N = (\Delta P_{\text{leak}} - \Delta P_{\text{no leak}}) / \Delta P_{\text{no leak}} \geq 1$
What impact will the part or test fixture materials have on the robustness of the test?

- Aluminum part versus Stainless Steel Part
- Same equivalent leak rate
- Same test pressure
- Same test parameters (timers)
ADIABATIC HEATING DISSIPATION FOR DIFFERENT MATERIALS

100 psig fill, 50 cc volume, 0.08 sccm Calibrated Leak

Aluminum
No Leak

Aluminum
W/ Leak

Stainless Steel
No Leak

Stainless Steel
W/ Leak

Pressure Drop (PSI)

Signal / Noise = 0.5

Signal / Noise = 0.07
Volume Instabilities During Measurement

Under constant temperature, the absolute pressure of a gas will change as a function of the change in gas volume:

$$P_2 = P_1 \times \left(\frac{V_1}{V_2}\right)$$

A flexible part with 50 cc volume at 24.7 psia (10 psig) stretches to 50.1 cc (0.2%) in 10 seconds resulting in a pressure drop of 0.0493 psi.

(equivalent to a 1.0 sccm leak in a 50 cc volume)
Volume Instabilities During Measurement

• Test Conditions
  • Fill Pressure: Higher pressures can create more volume change on flexible parts.
  • Short Test Times: Don’t allow for volume stabilization.

• Intrinsic Part Characteristics
  • Materials: Flexibility of materials can create stretching or elastic behavior.
  • Construction/Design: Testing some parts near or above their design pressure can cause volume changes.
Volume Instabilities During Measurement

• Environmental Conditions
  • Environmental Pressure: For flexible or "soft" wall parts, changes in room pressure during measurement can cause volume changes.
  • Part Handling: Stressing flexible parts during handling can cause them to relax and move during test.
Volume Instabilities During Measurement

• Fixture Design
  • Materials: Use of non-rigid or unstable materials can cause volume creep.
  • Seal Design: Elastomer seals improperly designed can cause volume creep.

• Test Instrument
  • Software: Ability of the software to monitor, minimize, or subtract out volume effects.
System Leaks During Measurement

- Environmental Conditions
  - Production Contamination: Particles and other contamination from production processes and environment affect sealing to test part.
  - Poor Air Quality: Dirty air can cause premature valve leakage in the instrument.

- Fixture Design
  - Seal Design: Seals prematurely wear or cannot accommodate part variability or production contamination.
Gas Adsorption/De-sorption During Measurement

• Intrinsic Part Characteristics
  • Internal cavities or porous materials that may adsorb air that is pressurized inside the part.
  • For Vacuum Decay – High internal surface area may trap humidity and “outgas” or desorb during measurement.

• Environmental Conditions
  • For Vacuum Decay – Volatile residues from previous operations like water, lubricants, or solvents will “outgas” or desorb during measurement.
Summary of Contributors to Error – Pressure Decay Air Leak Testing
Summary of Contributors to Measurement Error

- **Temperature Change**
  - Part filling – large volumes, high pressures are worse.
  - Hot parts coming in to leak tester.
  - Test fixture, chamber or test part materials.
  - Aggressive test times – not enough settle time.
  - Environmental temperature variations.

- **Volume Change**
  - Flexible wall test parts.
  - Aggressive test times – not enough settle time.
  - Improper fixture/chamber design.
  - Room pressure variations for “soft wall” parts.

- **System Leaks**
  - Test fixture/chamber leaks.
  - Seals not robust nor tolerant of part variations and external contamination.
  - Dirty supply air causing valve leakage.

- **Gas Adsorption/Desorption**
  - Test part contamination.
  - Intrinsic part characteristics.

---

www.lacotech.com
© 2016 LACO Technologies. All Rights Reserved.
THANK YOU!

- Stop by our booth (#1238) for a copy of this presentation on a thumb drive.
- Send us your sample part for evaluation in our applications lab.
- LinkedIn Group: Production Leak Testing
- Blog: blog.lacotech.com
- Website: www.lacotech.com