# Succeeding with Production Air Leak Testing Methods

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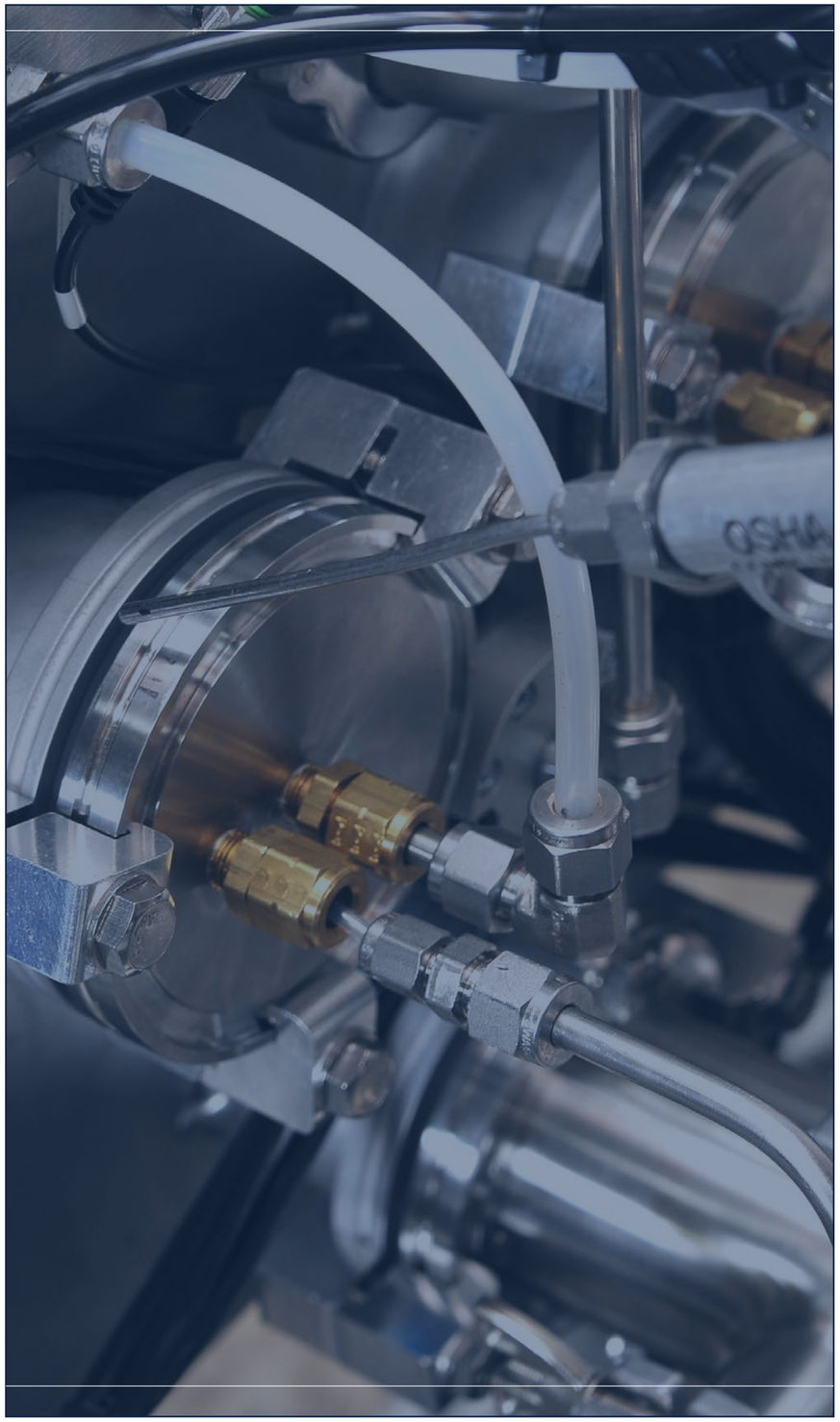


# Overview

- 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)

# Reality…

## 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

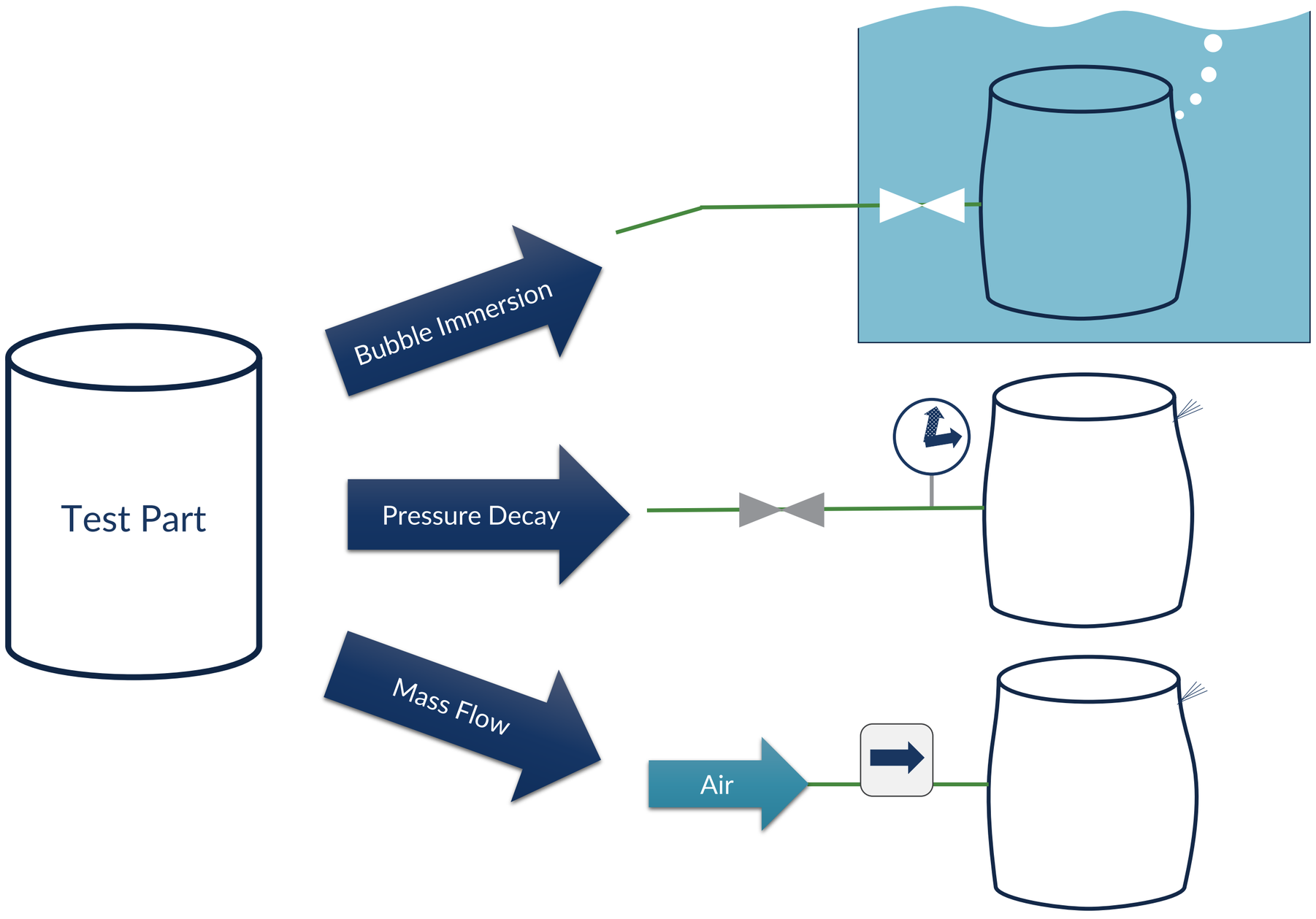
Emission of bubbles from a leak
(Bubble Immersion)

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

## Electronic/Sensor

# Air Leak Testing Methods

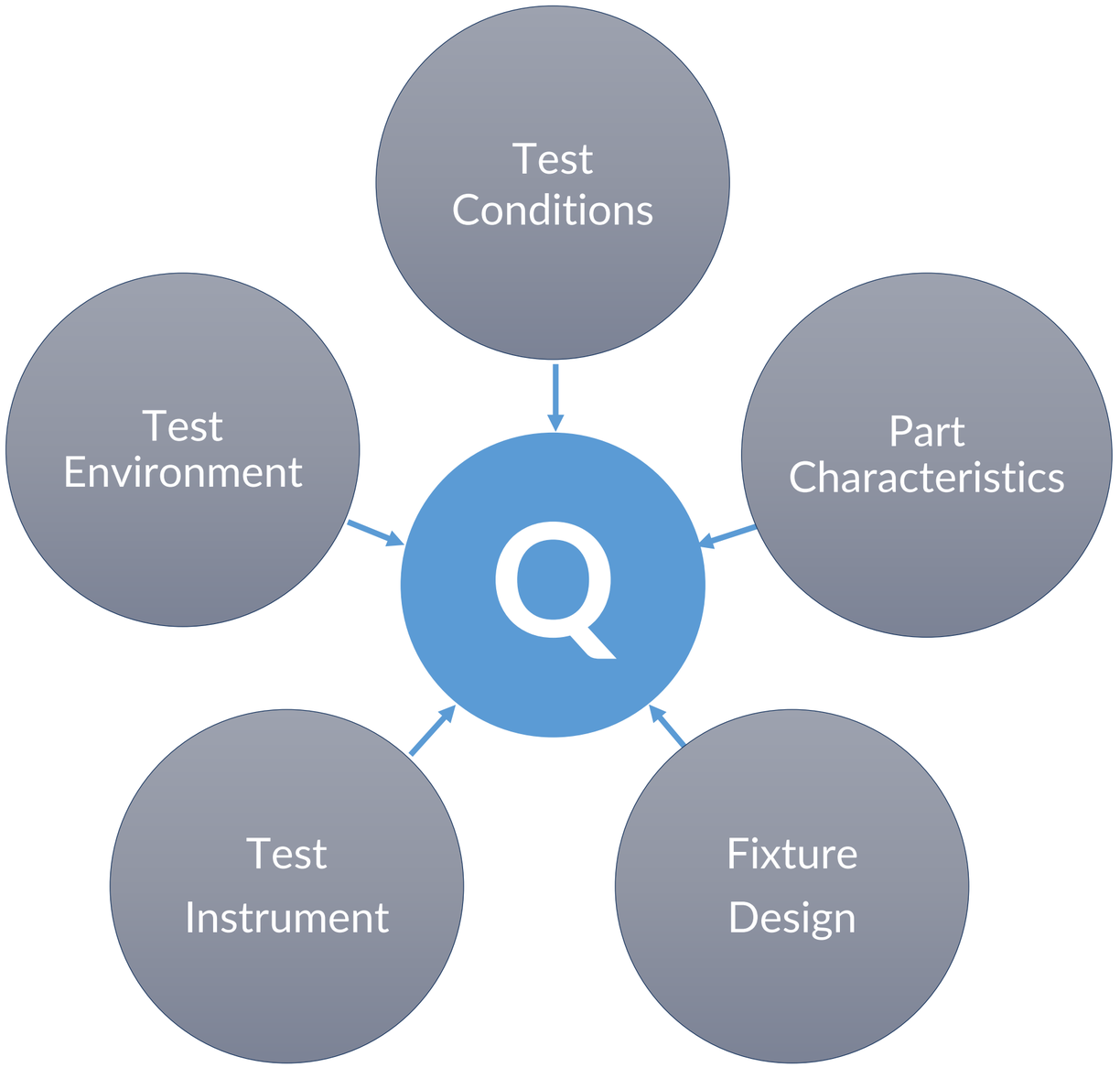
"What is the best method to find leaks?"



# 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

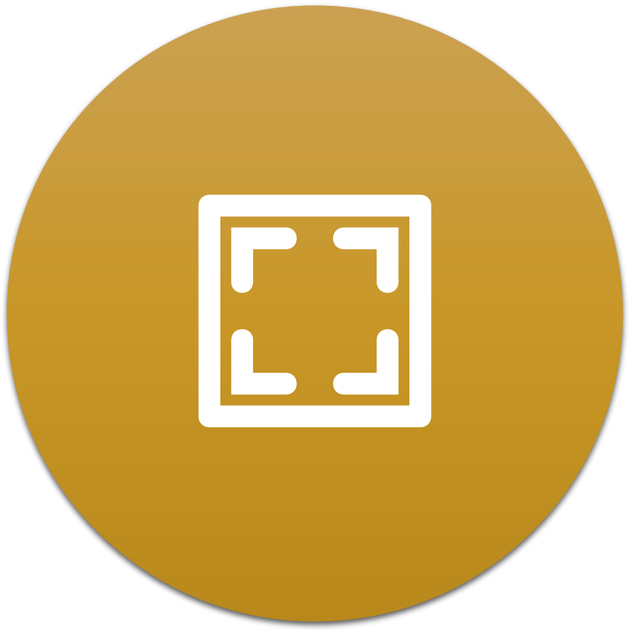
– Requires a test chamber

# OPEN Part Examples





# SEALED Part Examples







# Pressure Change Air Leak Testing

- Pressure Decay
- Vacuum Decay

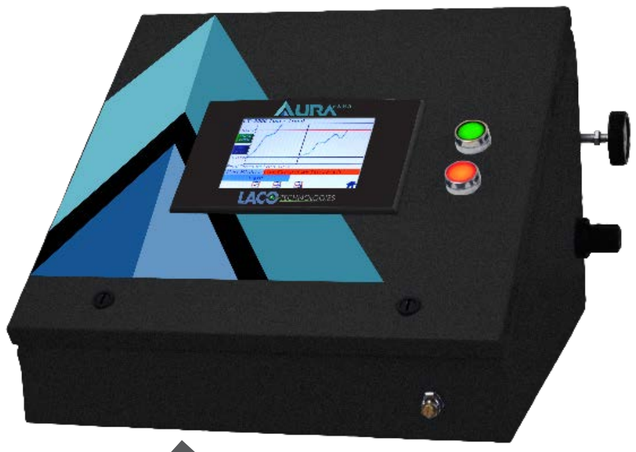
"Open" Parts

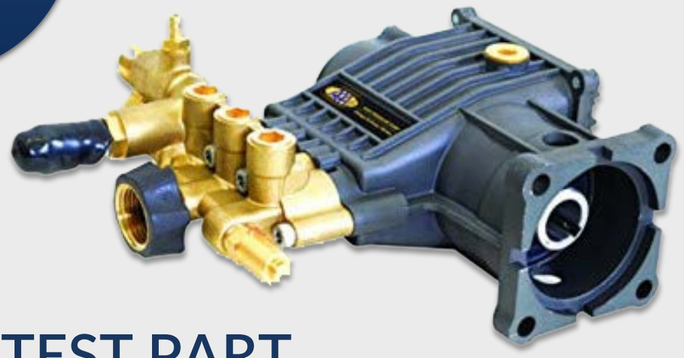
- Chamber Pressure Decay
- Chamber Vacuum Decay

"Sealed" Parts

- Differential Pressure Decay

# Air Pressure Decay Leak Testing – OPEN Part





TEST PART

3-WAY
ISOLATION/VENT
VALVE

REGULATED,
CLEAN AIR
SOURCE

2-WAY
LEAK ISOLATION
VALVE

2-WAY
FILL VALVE

AIR
VENT



CALIBRATED
LEAK STANDARD

PRESSURE
TRANSDUCER

# Air Pressure Decay Leak Test Basic Steps

1
2
3

**Fill**

Achieve test pressure and isolate test volume

**Settle**

All air pressure to stabilize (temperature and volume)

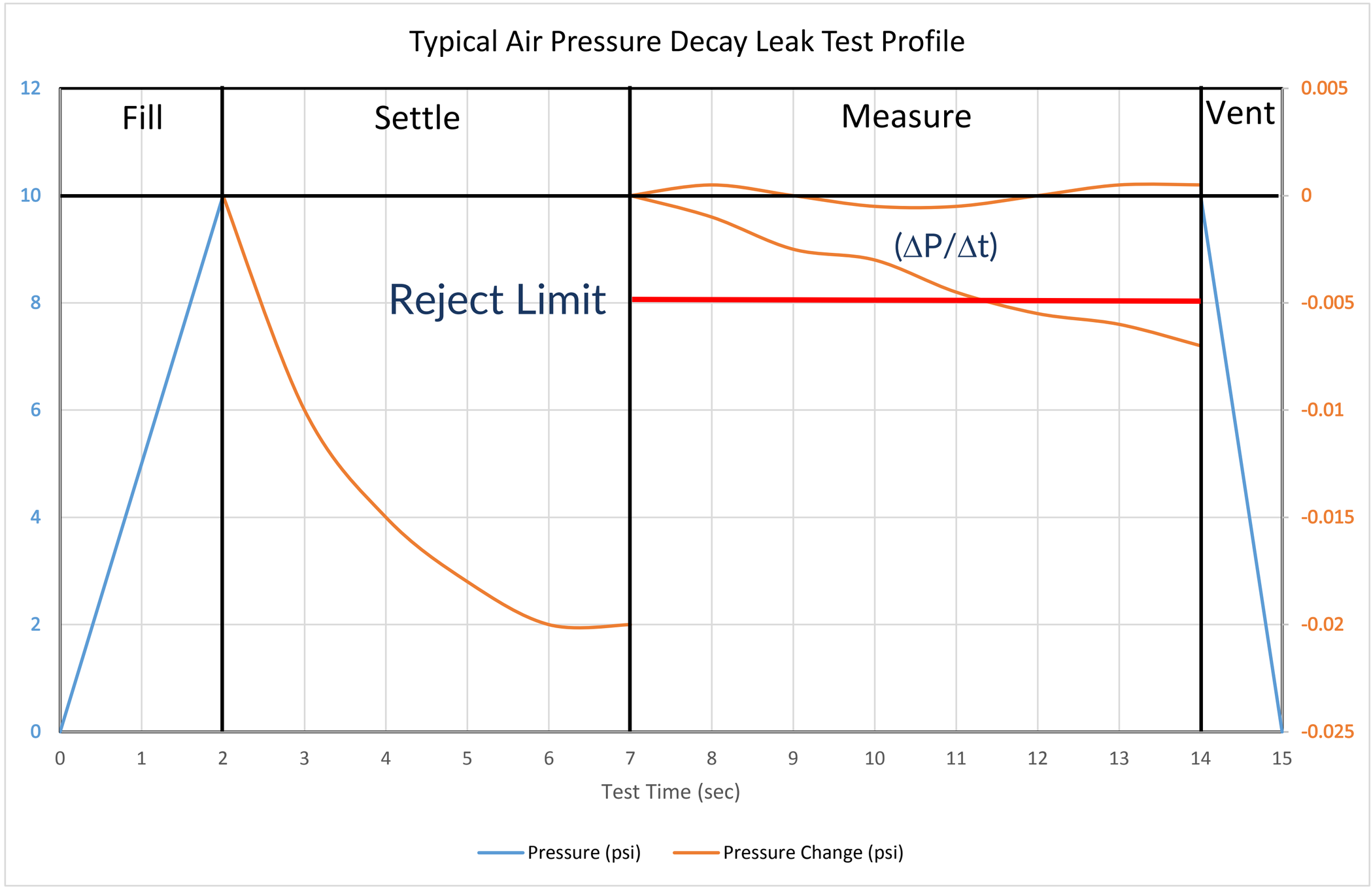
**Measure**

Monitor pressure drop. Determine PASS/FAIL

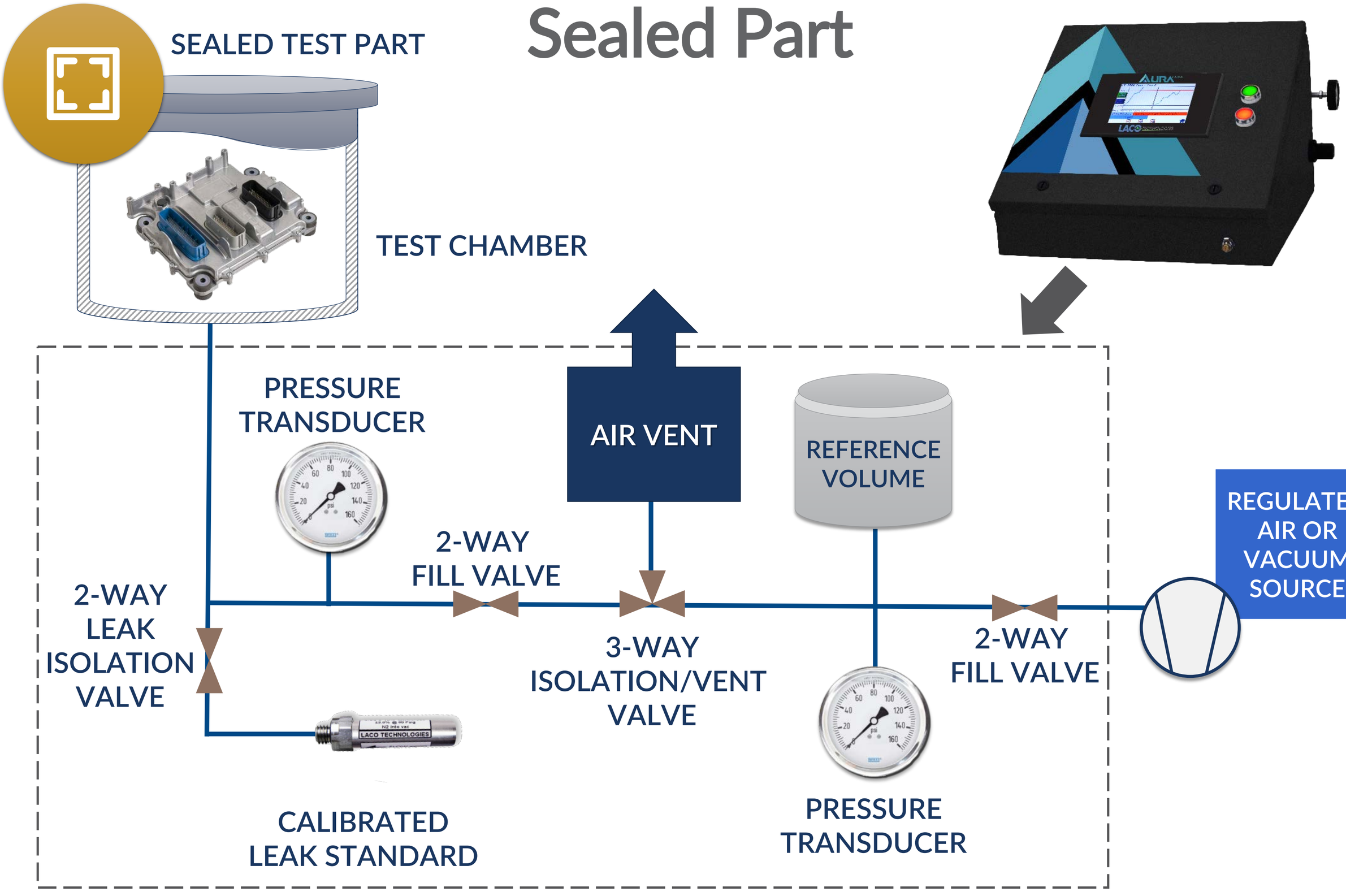
**Vent**

Allow air to vent from test volume

# Basic Principle of Air Pressure Decay Leak Test



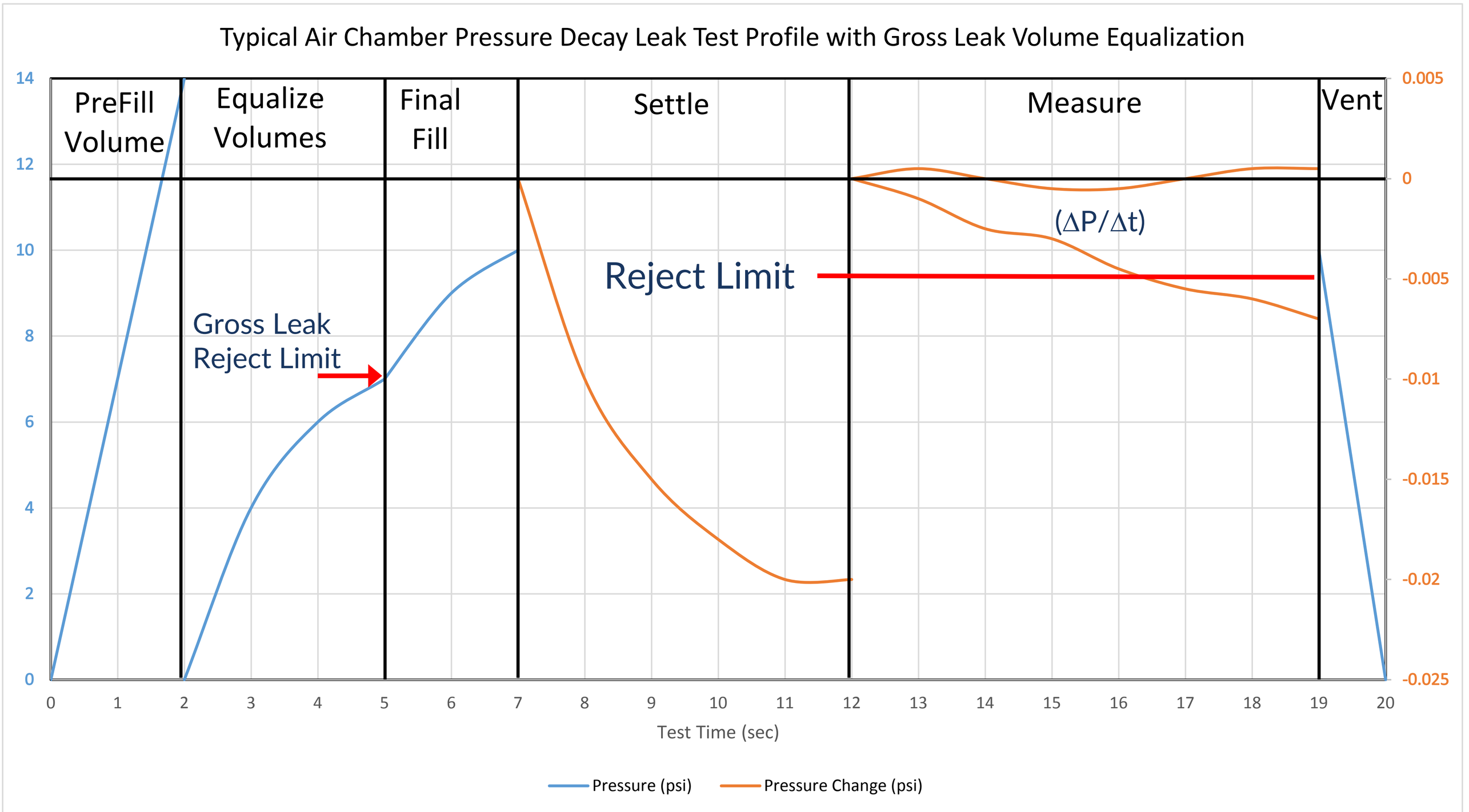
# Air Pressure/Vacuum Decay Chamber Test – Sealed Part



# Chamber Air Pressure Decay Leak Test Basic Steps

| Volume Equalize | Fill | Settle | Measure | Vent |
|---|---|---|---|---|
| Pre-fill test chamber with reference volume and check pressure for gross leak | Continue fill to achieve test pressure and isolate test volume | Allow air pressure to stabilize (temperature and volume) | Monitor pressure drop. Determine PASS/FAIL | Allow air to vent from test volume |

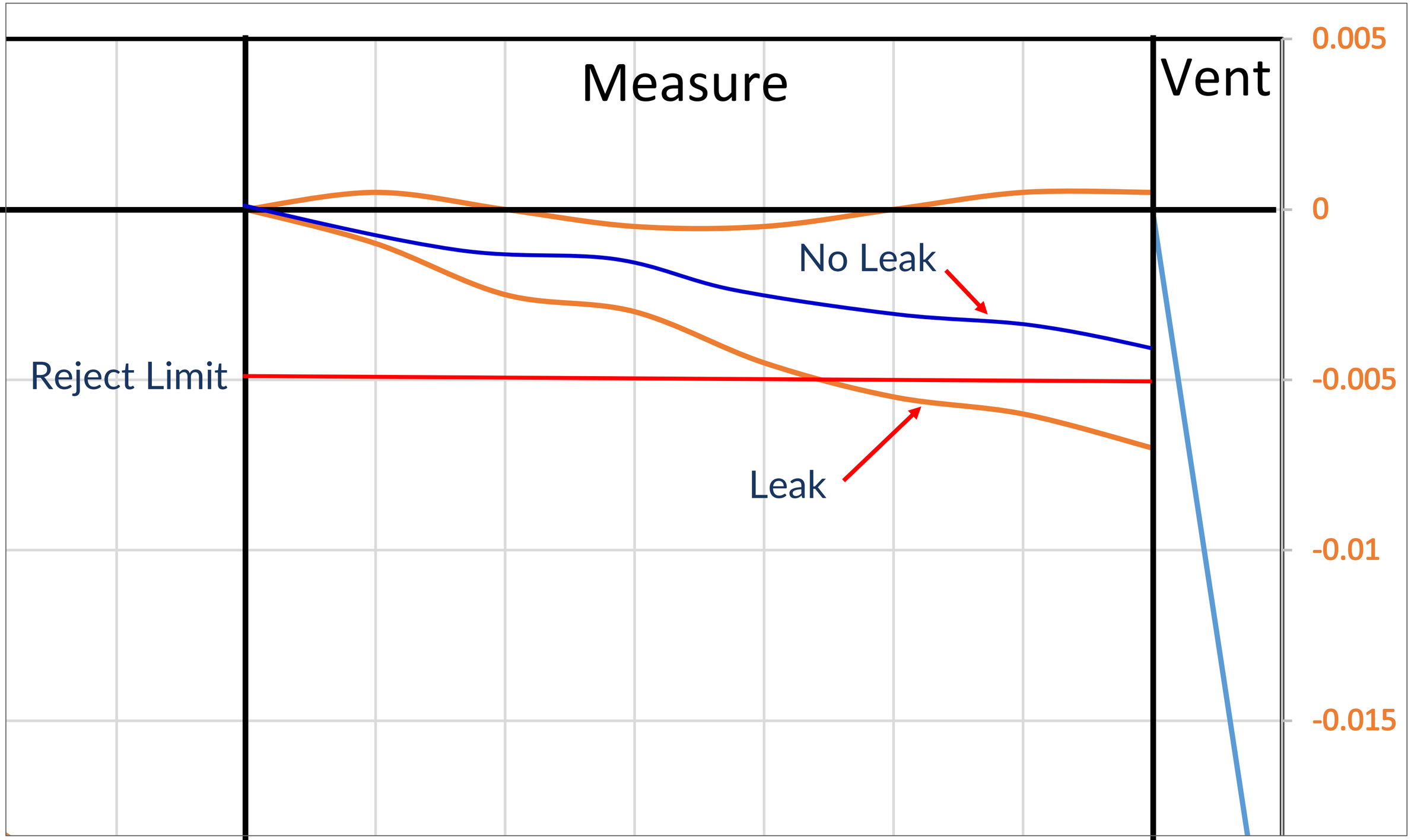
# Basic Principle of CHAMBER Air Pressure Decay Leak Test



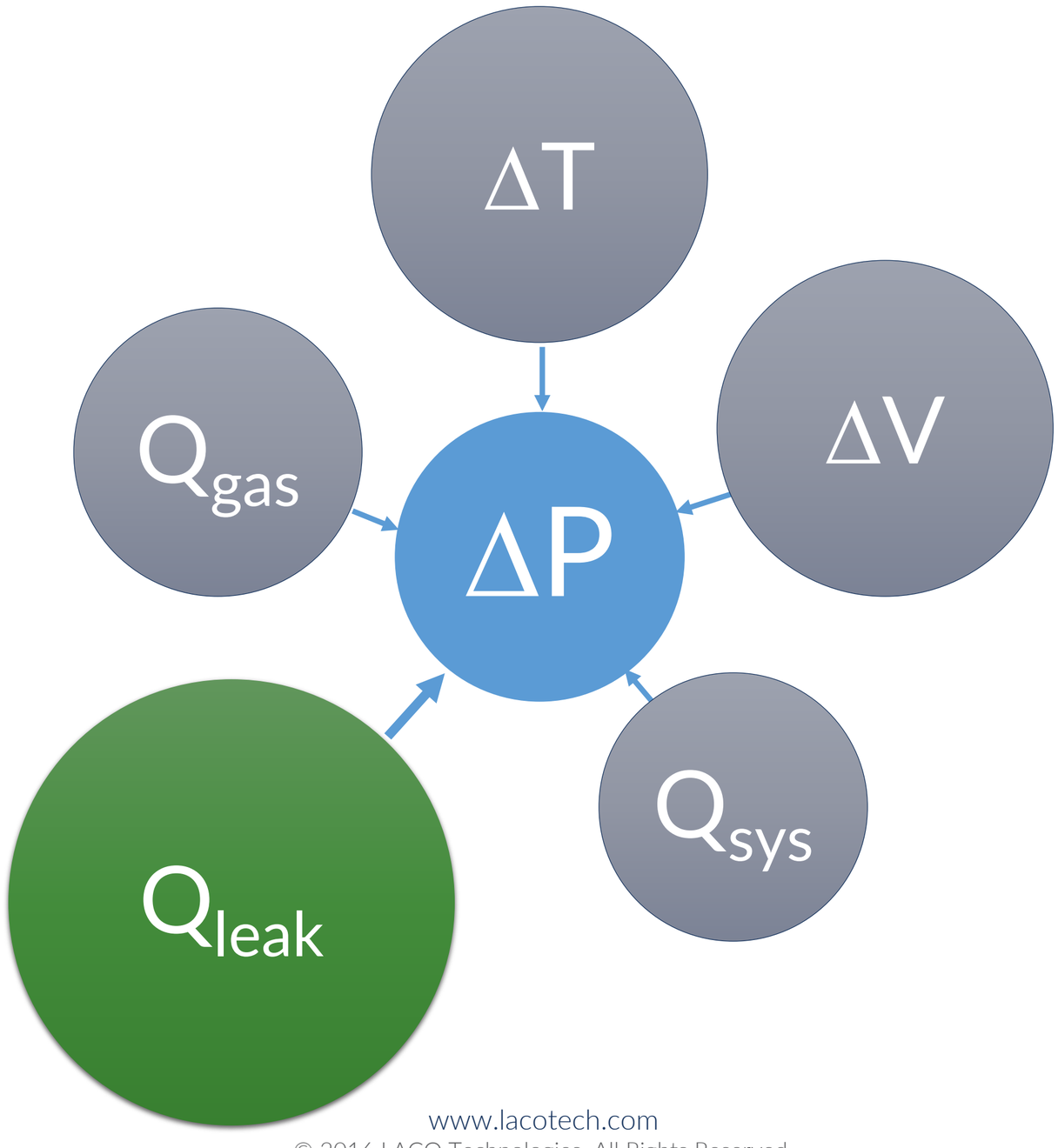
# Keys to Success

- 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



# What Affects Pressure Change Measurement?



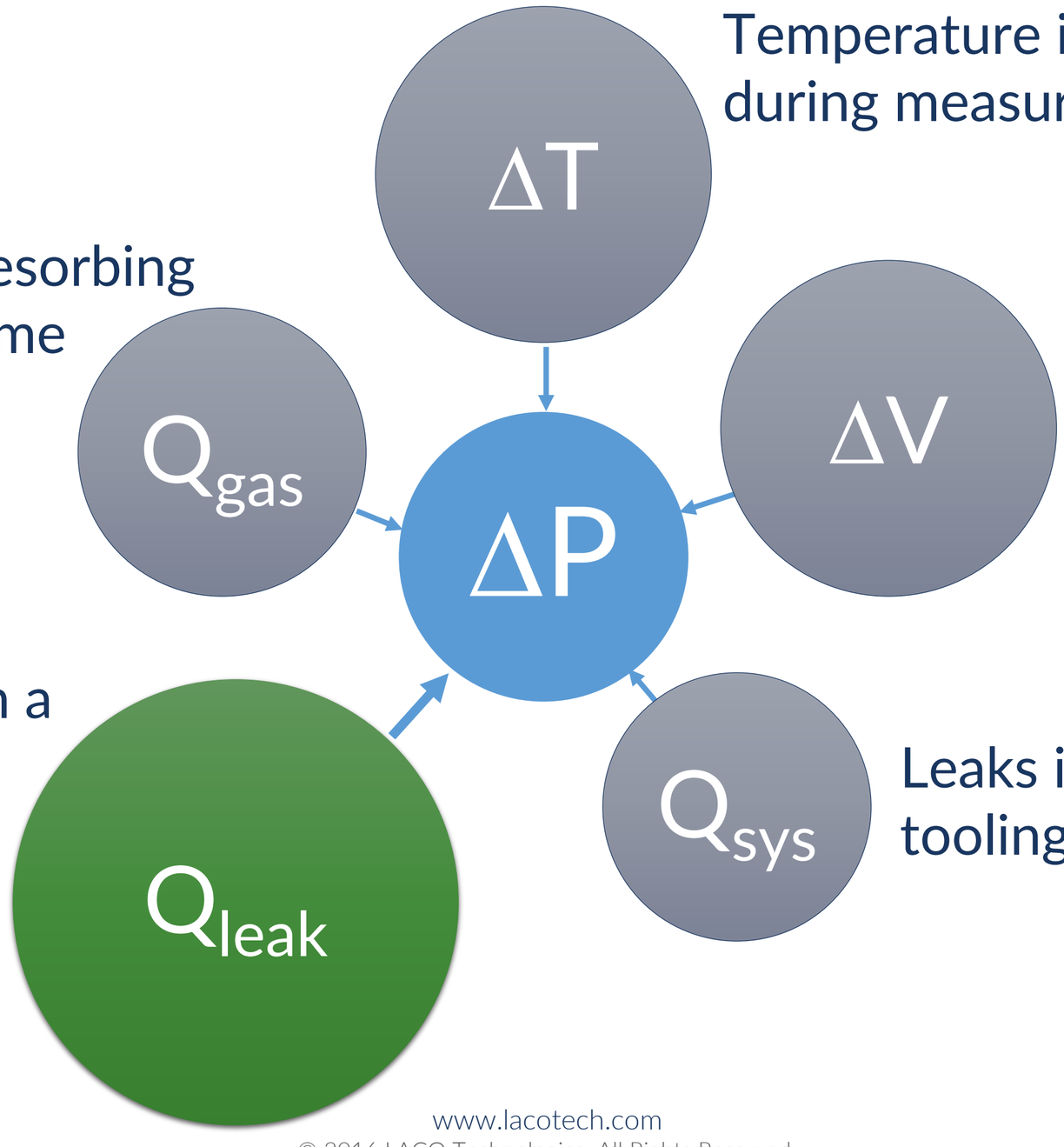
# Pressure Decay Leak Test Theory

$$Q_{leak\ (sccm)} = (\Delta P/\Delta t)*V$$

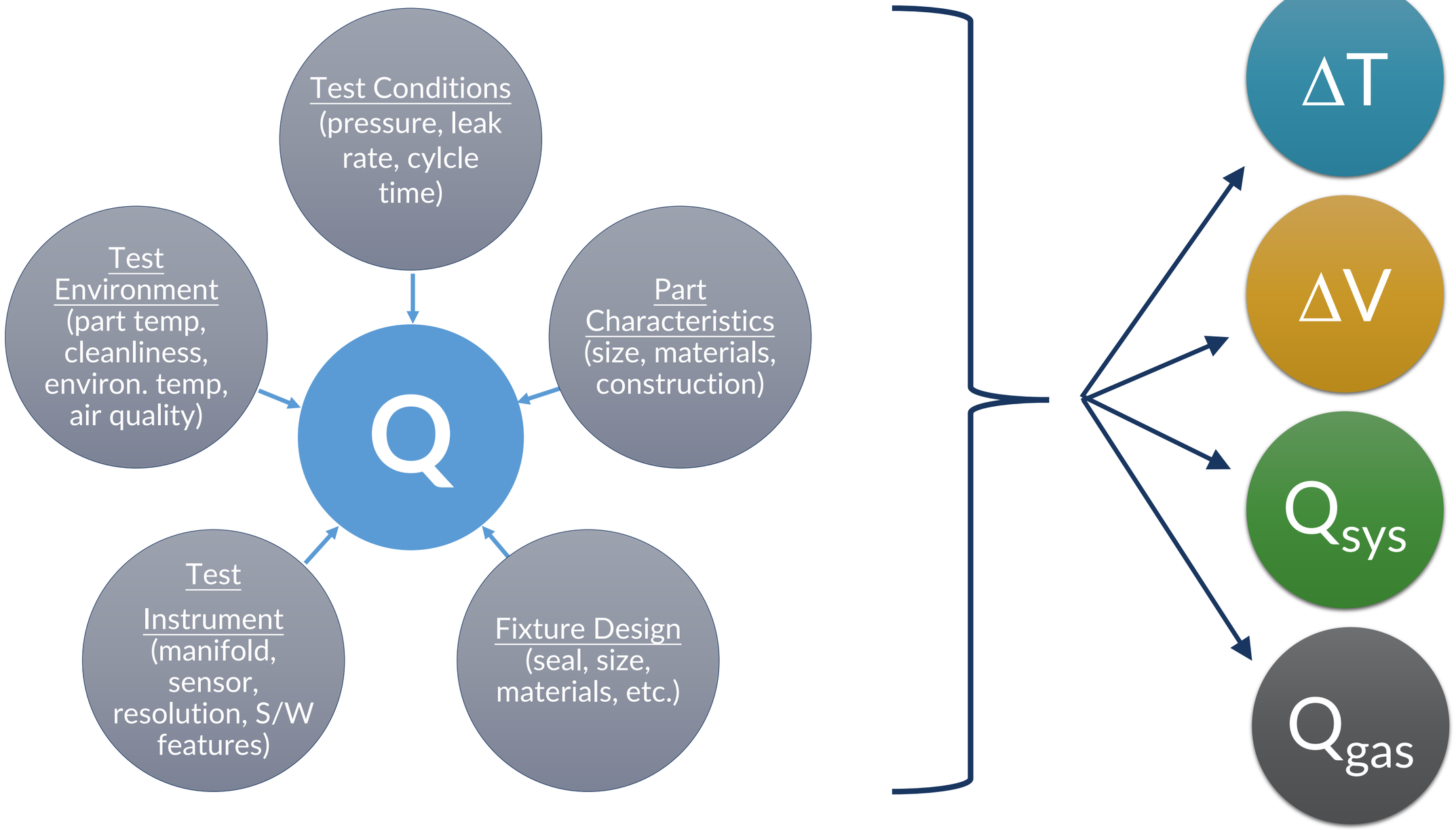
$$\Delta P = Q_{leak} * \Delta t / V$$

$$\Delta P = (Q_{leak} + Q(\Delta V) + Q(\Delta T) + Q_{sys} + Q_{gas}) * \Delta t / V$$

# What Affects Pressure Change Measurement?



# Factors Influencing Leak Rate (Q) Measurement Error



# 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:

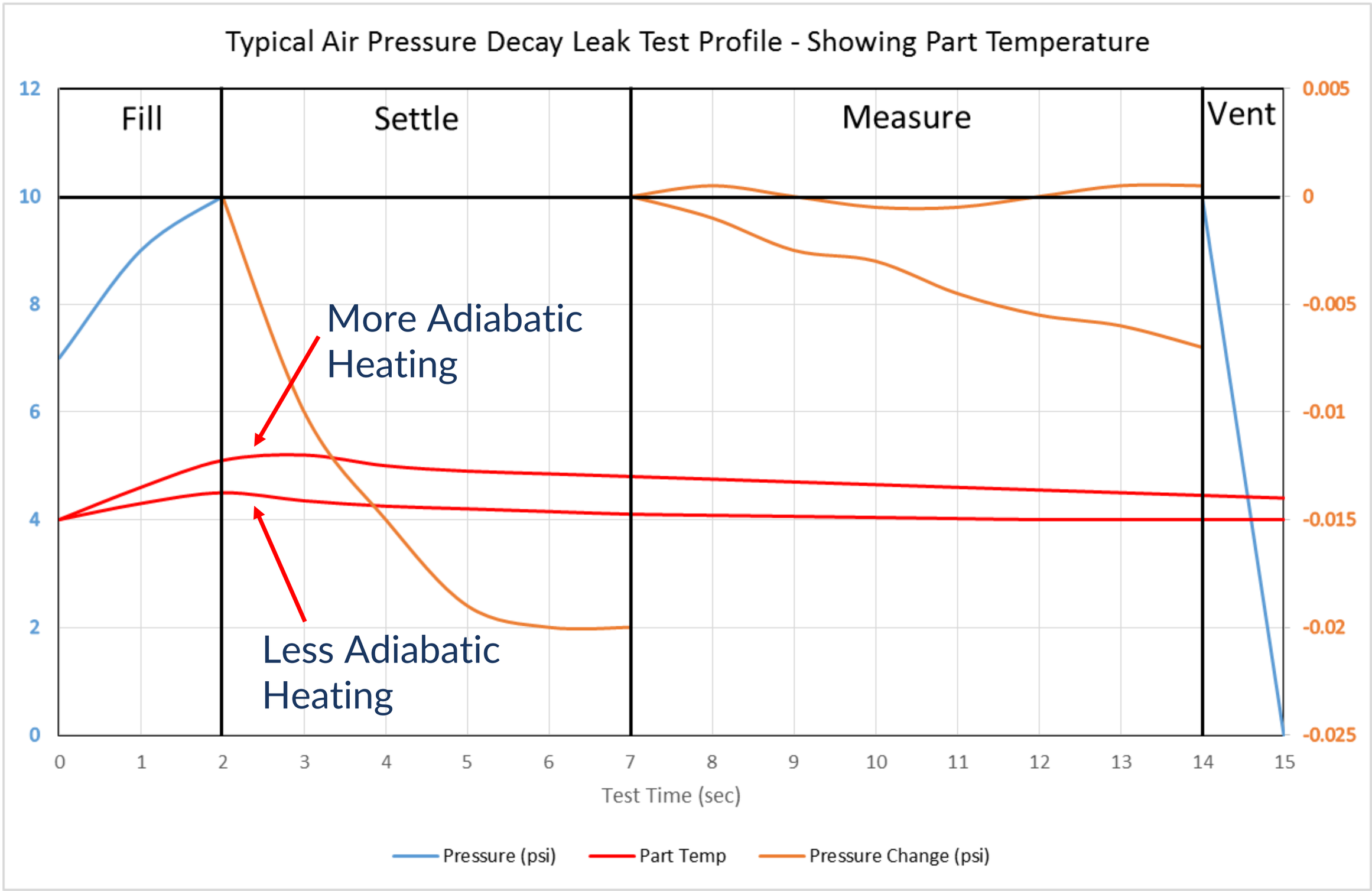
$$P_2 = P_1 * (T_2 / T_1)$$

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



# 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

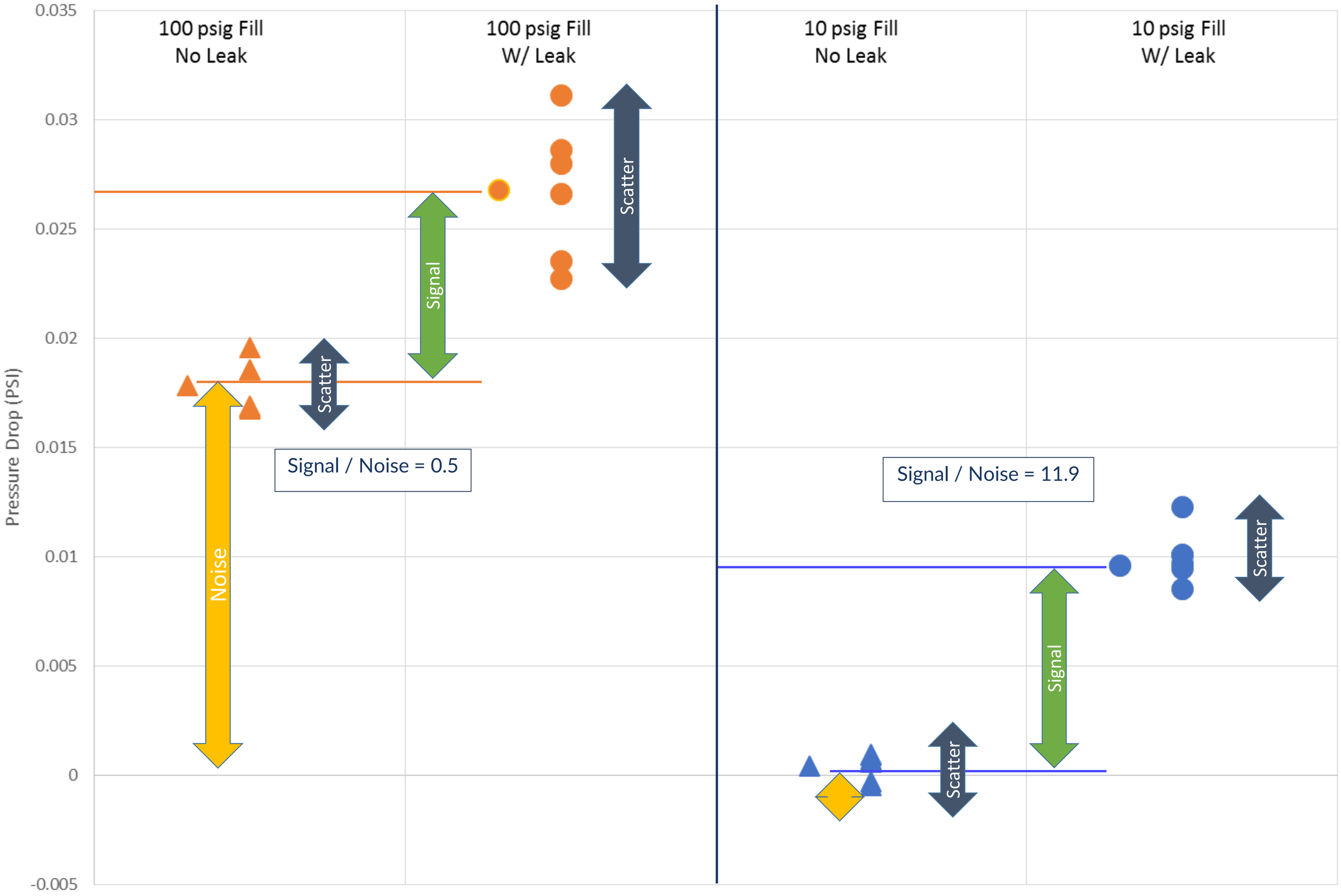
## Test Pressure and Materials Influences

# 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)

# ADIABATIC HEATING DUE TO PART TEST PRESSURE

## 100 versus 10 psig Fill, Alumunum Part, 50 cc Volume, 0.08 sccm Calibrated Leak



# 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.

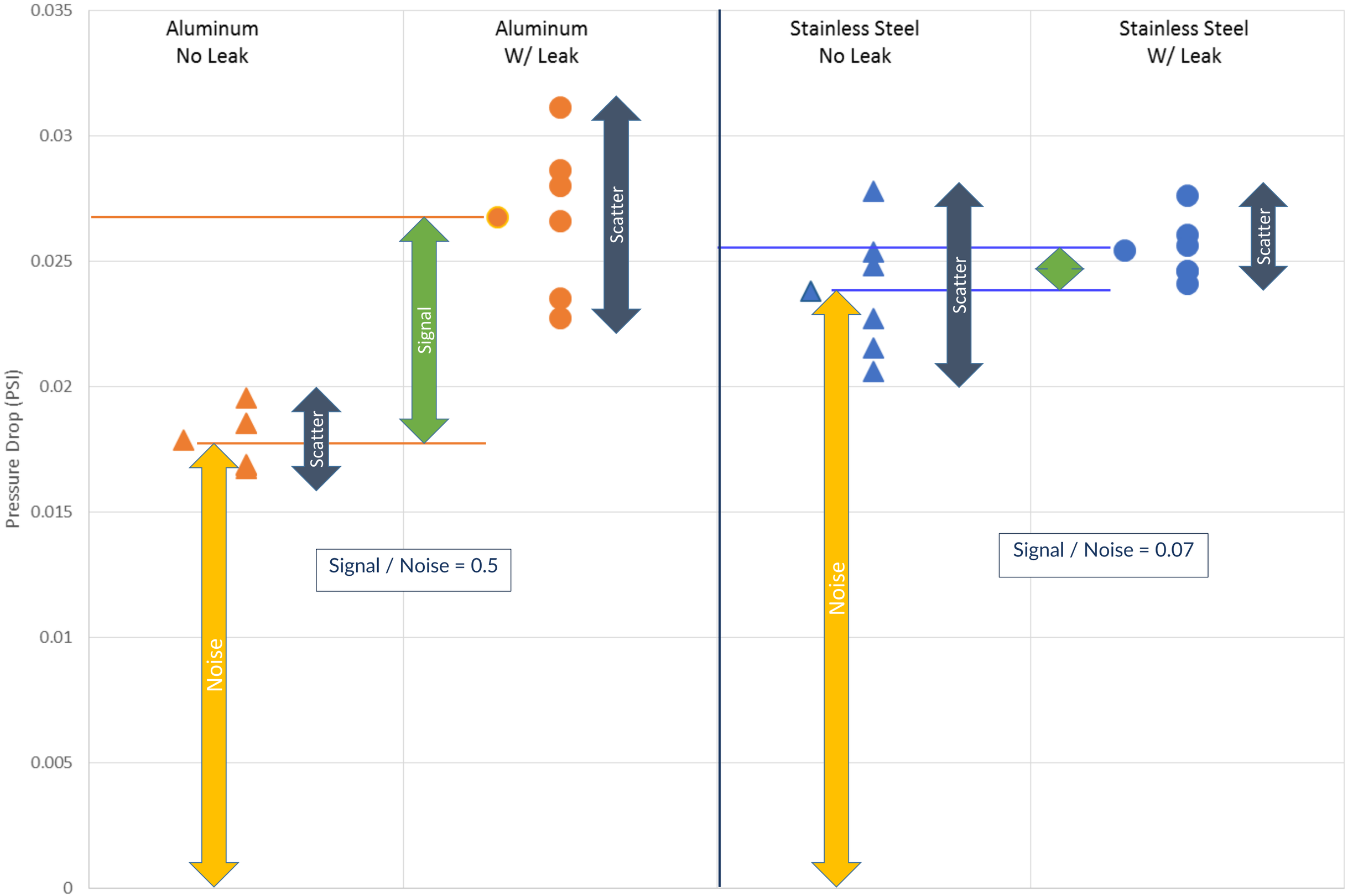
- $S/N = (\Delta P_{leak} - \Delta P_{no\ leak}) / \Delta P_{no\ leak} >= 1$

# 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



# Volume Instabilities During Measurement


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

$$P_2 = P_1 * (V_1 / V_2)$$

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

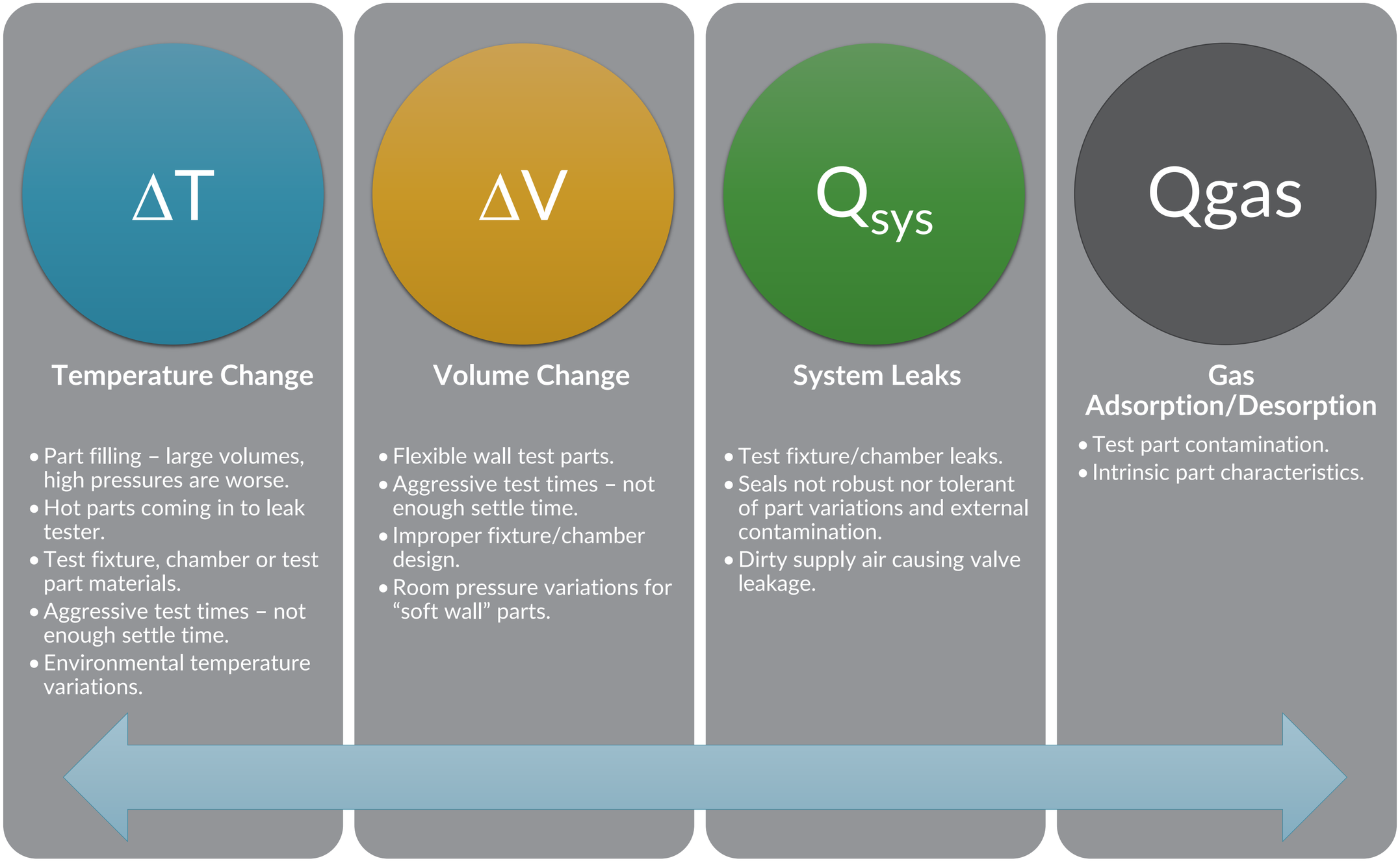

- Environmental Conditions
  - Production Contamination: Particles and other contamination from production processes and environment affect sealing to test part.
  - Poor Air Quality: Dirty air can cause premature valve leakage in the instrument.
- Fixture Design
  - Seal Design: Seals prematurely wear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



# 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.
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- Blog: ***blog.lacotech.com***
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