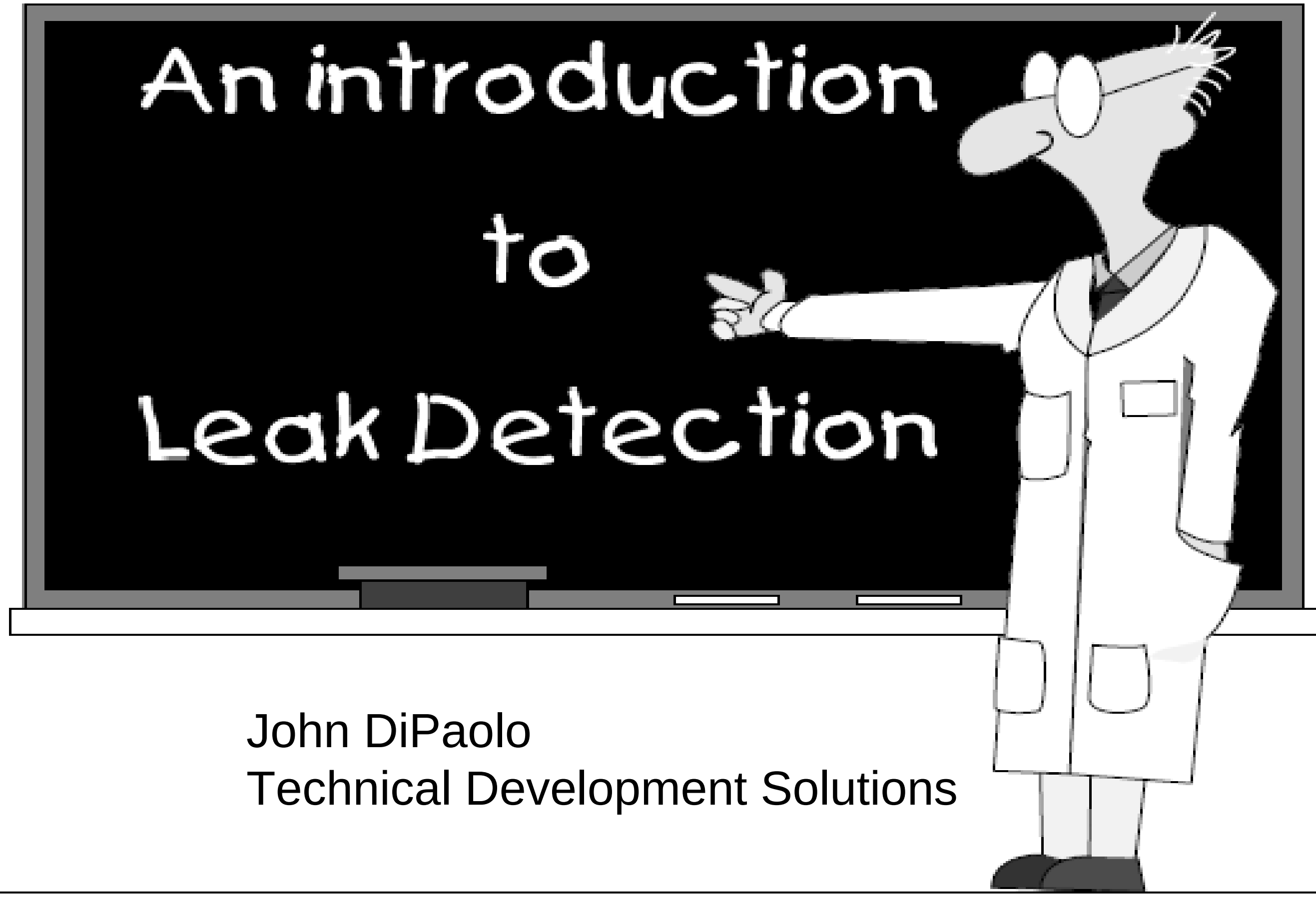


John DiPaolo
Technical Development Solutions

ASGE 2010 Technical Conference

MGM Grand Las Vegas Nevada

Introduction to Leak Detection

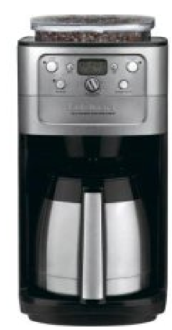
Leak Detection applies to all industries whose products must be “Leak Free” during their lifespan…

A product is considered “Leak Free”:

- Does not release the liquid or gas it contains
- Does not allow liquid or gas to enter

Some examples:

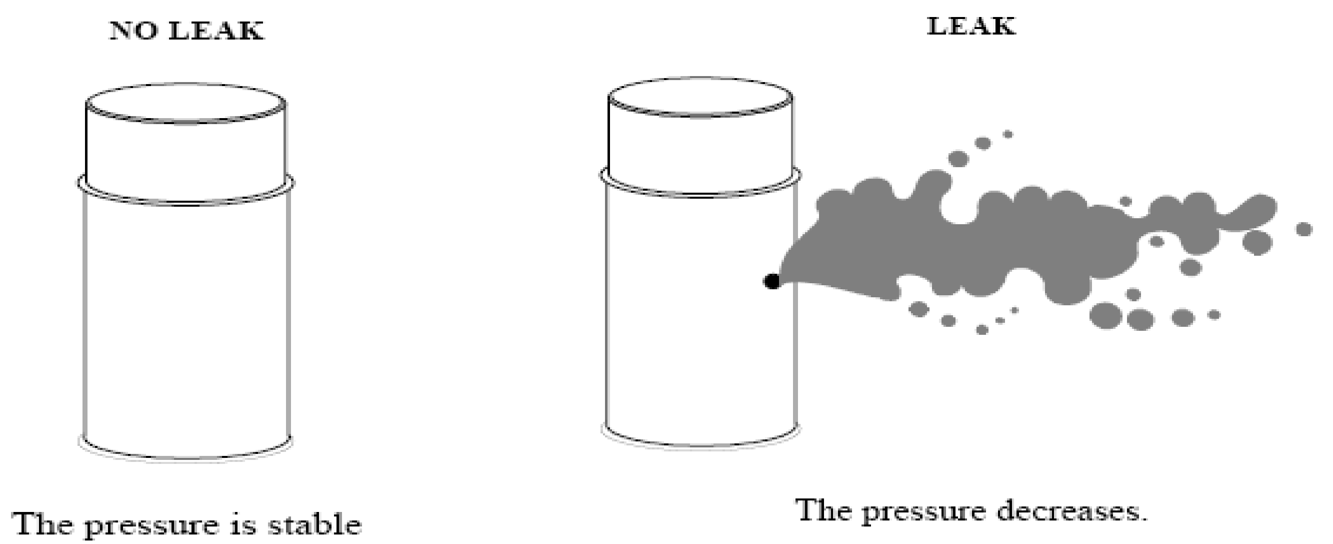
- Mechanical gearbox must not lose its oil
- Water tank on an electric coffee maker
- Gas range with leakage



Introduction to Leak Detection

Fundamental Principle

- Product placed under pressure or vacuum
- Naturally balances back to ambient conditions



Introduction to Leak Detection

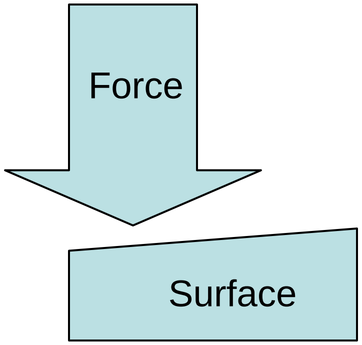
What is Pressure?

- In Physics, pressure is force applied on a surface
- Basic unit is the Pascal…
  - Equal to force of 1 Newton applied to 1 m^2
- Two basic types of pressure are…
  - Static
  - Dynamic

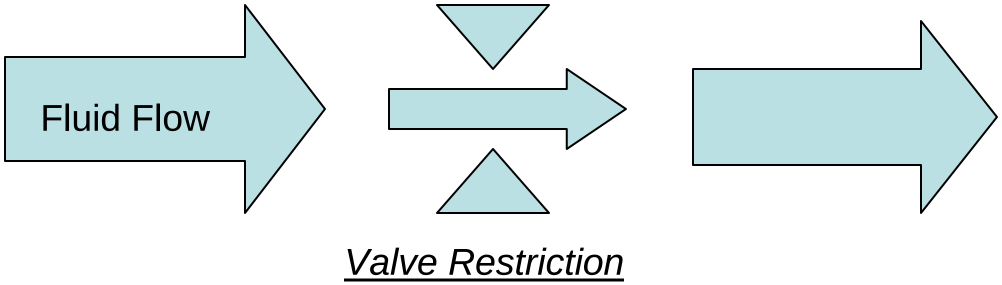
Introduction to Leak Detection

Static and Dynamic Pressure

- Static pressure:
  - Applied under the effect of weight
  - Applied vertically



- Dynamic Pressure:
  - Applicable when fluids are slowed or stopped by pressure



Introduction to Leak Detection

Properties of Substances

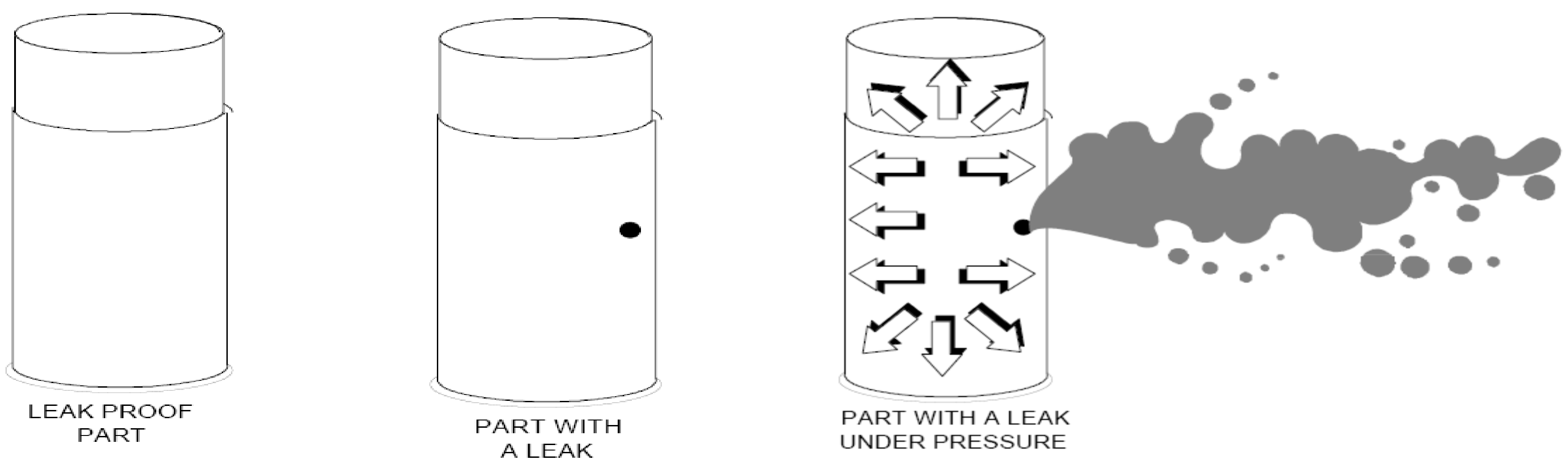
- Solids do not transmit pressure…
  - Solids only transmit forces
- Fluids transmit pressure uniformly according to Pascal's Law…

" An external pressure applied to an enclosed fluid is transmitted equally throughout the volume of the liquid"

Introduction to Leak Detection

Internal Application of Pressure

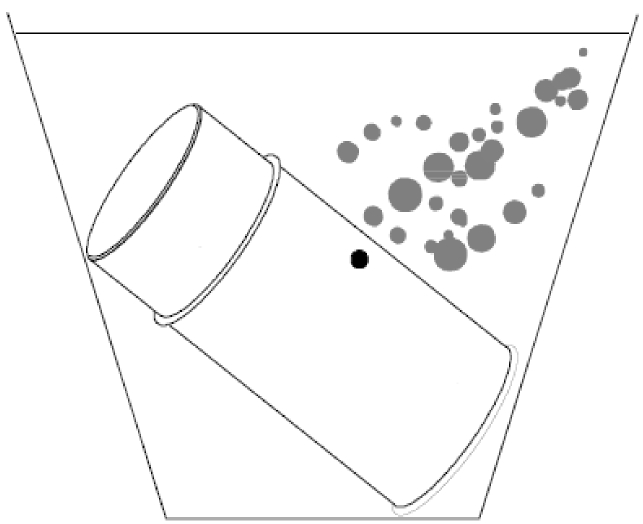
- Atmospheric pressure exerts 100,000 Pa / cm^2
- Pressurizing a part or component
  - Uniformly increase pressure on internal surfaces
  - Relative to external pressure



Different Methods of Leak Detection

Air / Water Method:

- Pressurize product or component
- Immerse in water & observe bubbles

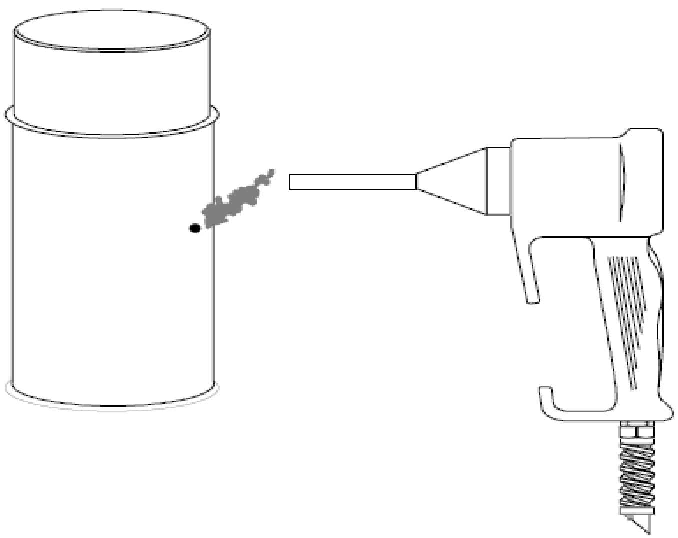


DRAWBACKS	ADVANTAGES
CANNOT BE AUTOMATED	LEAKS ARE PINPOINTED
HUMAN ERRORS	
PRODUCTS GET WET / CONTAMINATED / DIRTY	
NO RECORD OF REJECT LEVEL	

Different Methods of Leak Detection

Tracer Gas Method:

- Inject Helium or Hydrogen / Nitrogen mixture into test part
- Utilize highly sensitive probe to pinpoint leak
- Complement to Pressure Decay system

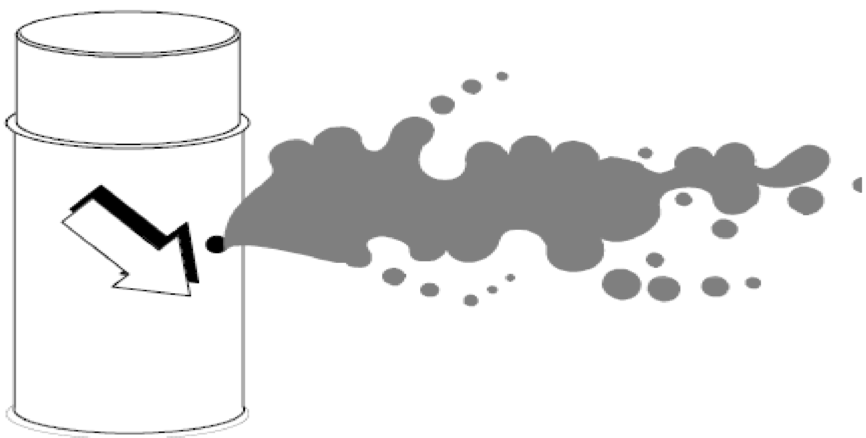


DRAWBACKS	ADVANTAGES
EXPENSIVE	LEAKS ARE PINPOINTED
SPECIALIZED OPERATOR	VERY SENSITIVE
	LARGE VOLUME TESTING

Different Methods of Leak Detection

Air / Air Leak Detection Method:

- Pressurize product & measure pressure drop
- Use pressure drop tolerance level
- Best adapted for industrial products



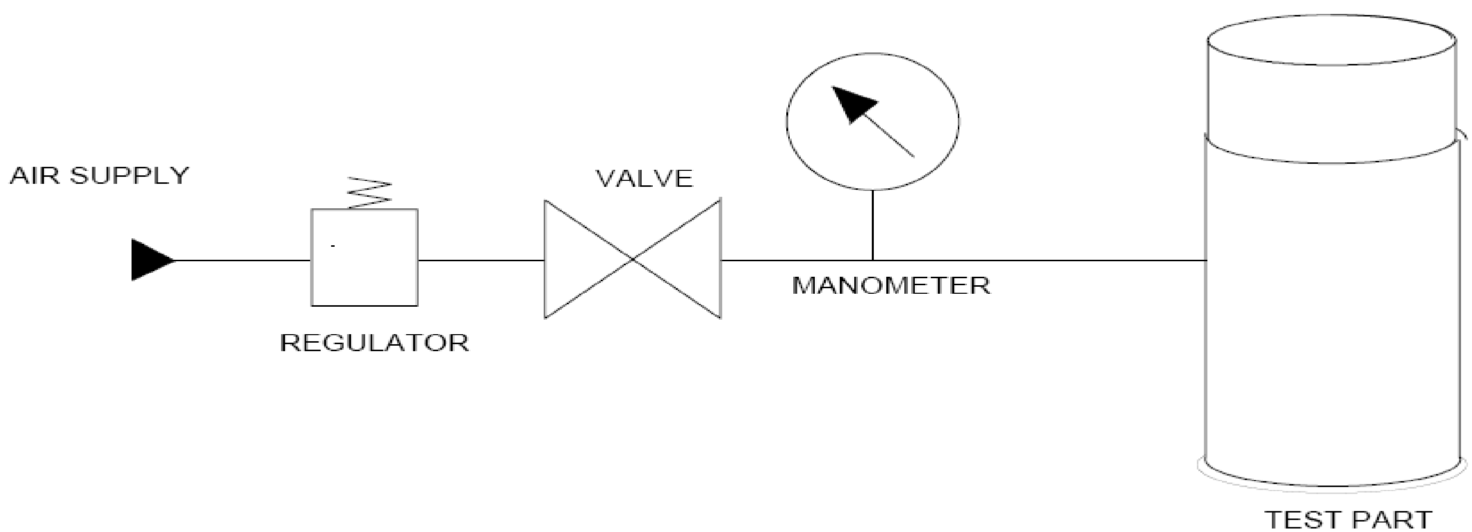
**Which is not a problem in most cases.*

DRAWBACKS	ADVANTAGES
LEAKS ARE NOT PINPOINTED *	CAN BE AUTOMATED
FIXTURING MUST BE PERFECT	NO HUMAN ERRORS
	FAST
	REJECT LEVEL MEASURED
	TRACEABILITY

Different Types of Air to Air Controls

Relative Air to Air Control:

- Hardware to inflate part
- Isolated with valve after pressurization
- Gauge eventually indicates pressure drop if leaking
- Compares pressure inside part to ambient pressure



Different Types of Air to Air Controls

A Customer Example:

- Leak parameters for a gear box manufacturer…

INTERNAL VOLUME TESTED	1,000 cm^3
REJECT LEVEL	3.6 cm^3/mn
TEST PRESSURE	1 bar
TEST MEDIUM	AIR

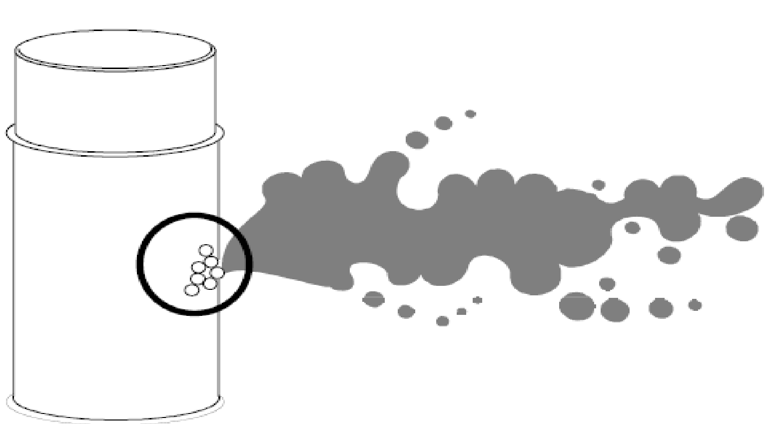
Why would the customer accept a small leak???

Gear box containing 2000 cc of oil would be empty in 10 hours!

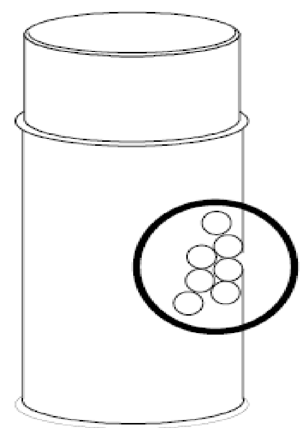
Different Types of Air to Air Controls

A Customer Example (continued):

- ***<u>Leak rates are given in terms of</u>*** ***<u>**Air**…</u>***
  - Ease of measurement
  - Difference of viscosity
  - Same defect may not allow oil through



PART WITH AIR



PART WITH OIL

Different Types of Air to Air Controls

Examples of Allowable Leaks in Gas Appliances Controls

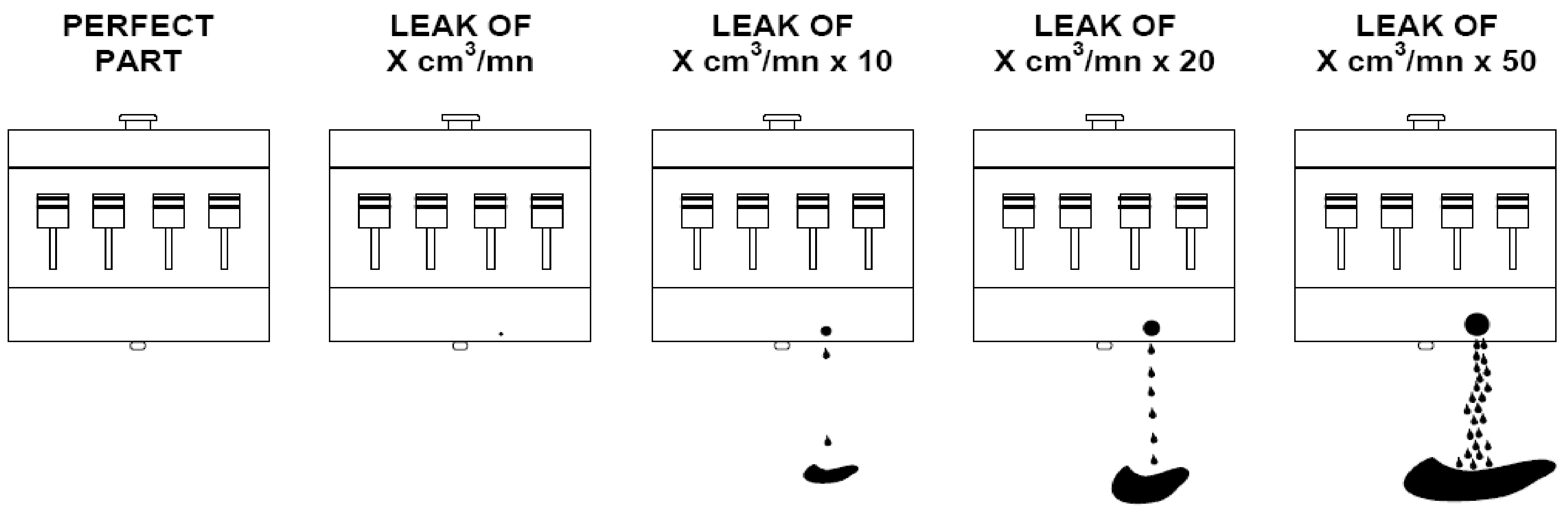
- Automatic Gas Valve: 200 cm^3/hr
- Combination Gas Valve: 200 cm^3/hr
- Manual Gas Valve: 20 cm^3/hr

All tolerances are specified in air corrected to 30 in Hg at 60 degrees F.

Different Types of Air to Air Controls

A Customer Example (continued):

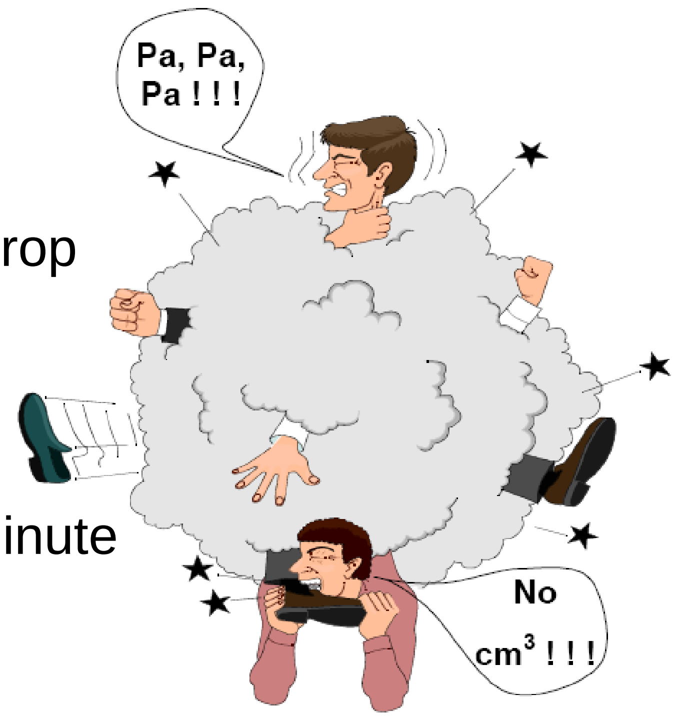
- ***How are leak rate tolerances in* Air *determined?***
  - Longevity tests
    - Identify X cm^3/mn leak in **Air** that allows product to function



Different Types of Air to Air Controls

A Customer Example (continued):

- *<u>Confusion over units of measure…</u>*
  - Leak detectors work in terms of pressure drop
    - Expressed in Pascal's
  - Leak rate tolerances are in terms of flow
    - Expressed in Cubic Centimeters per Minute



It is possible to claim 1 Pascal = 1 cm^3/mn??

Different Types of Air to Air Controls

A Customer Example (continued):

- Short Cut Field Formula for calculating Flow of Leak…

$$F(cm^3/mn) = 0.0006 \times V(cm^3) \times \Delta P\ (Pa/s)$$

$F\ (cm^3/mn)$	**=**	**The Flow of the leak**
0.0006	**=**	**A constant**
$V\ (cm^3)$	**=**	**Volume of the tested part**
$\Delta P\ (Pa/s)$	**=**	**Pressure drop**

Different Types of Air to Air Controls

A Customer Example (continued):

- Origin of the Formula…

- **Theoretical formula**

$$F(m^3/s) = V(m^3) \times \Delta P\ (s)$$

- **Applied formula**

This formula is known more in the leak pressure decay field under the following form :

$$F(cm^3/mn) = 0.0006 \times V(cm^3) \times \Delta P\ (Pa/s)$$

This formula is based on the Boyle Mariotte Ideal gas law

Different Types of Air to Air Controls

A Customer Example (continued):

- To better understand the formula…
  - Gear Box application with “Standard” leak tolerance

INTERNAL VOLUME	1,000 cm^3
ACCEPTABLE LEAK	3.6 cm^3/mn
TEST PRESSURE	1 bar
TEST MEDIUM	AIR

$$F(cm^3/mn) = 0.0006 \times V(cm^3) \times \Delta P\ (Pa/s)$$

$$\Delta P = \frac{F\ (cm^3\ /\ mn)}{0.0006 \times V\ (cm^3)} = \mathbf{6\ Pa/s}$$ *(6 Pa corresponds to 0.06 mBar) = 0.000870 PSI*

Different Types of Air to Air Controls

A Customer Example (continued):

- Water Pump Application…
  - Same leak tolerance as gear box
  - Smaller internal volume

INTERNAL VOLUME	100 cm^3
ACCEPTABLE LEAK	3.6 cm^3/mn
TEST PRESSURE	1 bar
TEST MEDIUM	AIR

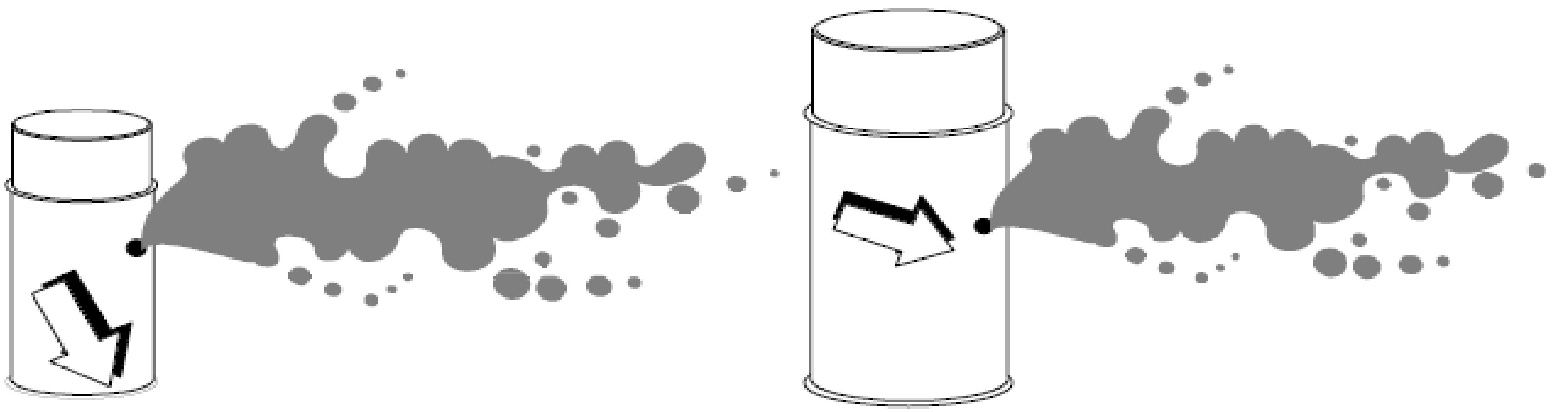
$F(cm^3/mn) = 0.0006 \times V(cm^3) \times \Delta P\ (Pa/s)$

$$\Delta P = \frac{F\ (cm^3\ /\ mn)}{0.0006 \times V\ (cm^3)} = \mathbf{60\ Pa/s}$$

Different Types of Air to Air Controls

A Customer Example (continued):

- Identical leak reject level…
  - Water pump had smaller internal volume
  - Pressure drop in Pascals is different



**THE SMALLER THE VOLUME IS,
THE BIGGER THE ΔP (PRESSURE DECAY) WILL BE FOR AN IDENTICAL LEAK**

Different Types of Air to Air Controls

A Customer Example (continued):

- Same water pump with different specifications…

INTERNAL VOLUME	100 cm^3
ACCEPTABLE LEAK	**7.2 cm^3/mn**
TEST PRESSURE	1 bar
TEST MEDIUM	AIR

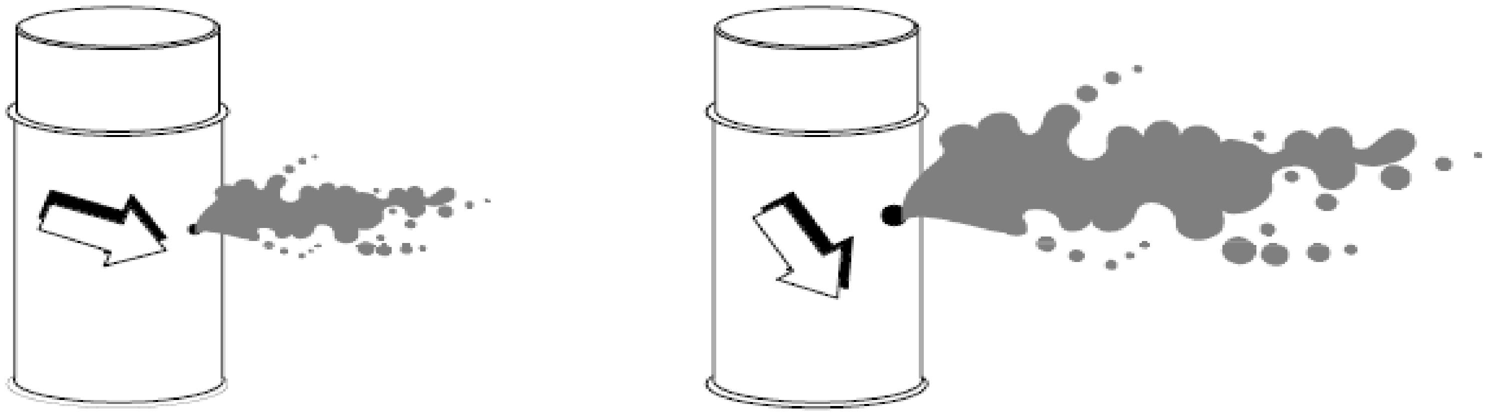
$$\mathbf{F(cm^3/mn) = 0.0006 \times V(cm^3) \times \Delta P\ (Pa/s)}$$

$$\Delta P = \frac{F\ (cm^3\ /\ mn)}{0.0006 \times V\ (cm^3)} = \mathbf{120\ Pa/s}$$

Different Types of Air to Air Controls

A Customer Example (continued):

- Water pump had same internal volume…
  - Larger leak tolerance



THE BIGGER THE LEAK IS, THE BIGGER THE Δ P WILL BE FOR AN IDENTICAL VOLUME

Different Types of Air to Air Controls

A Customer Example (continued):

- Water pump one more time…
  - Larger leak tolerance from last example
  - Increased test pressure

INTERNAL VOLUME	100 cm^3
ACCEPTABLE LEAK	7.2 cm^3/mn
TEST PRESSURE	**2 bar**
TEST MEDIUM	AIR

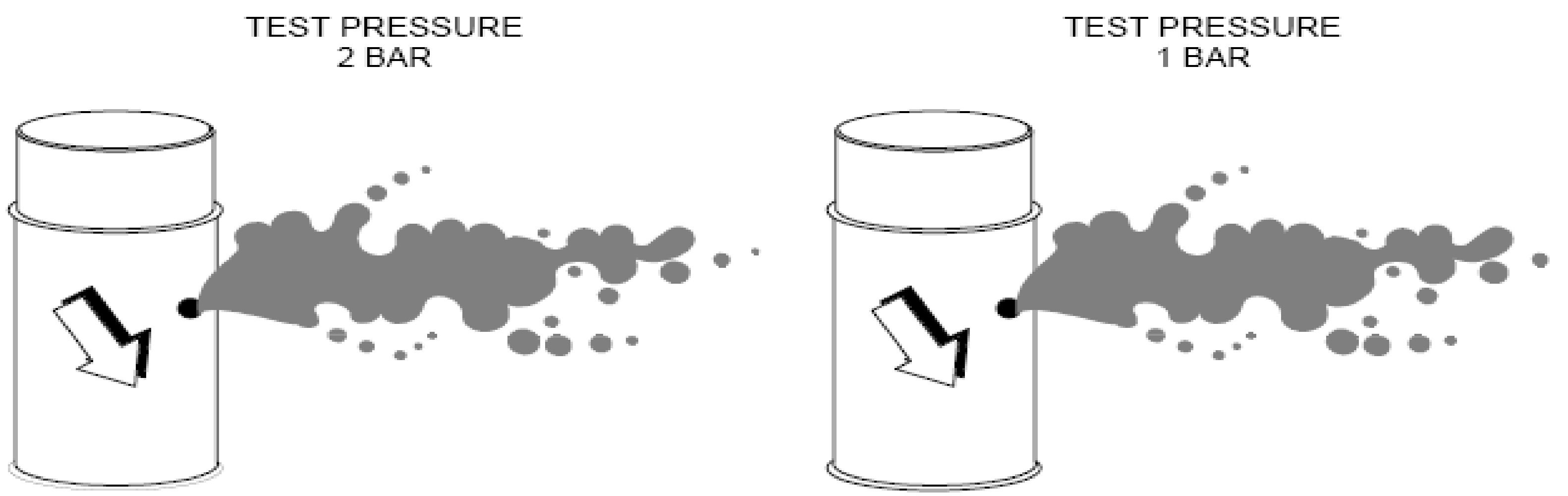
$$\mathbf{F(cm^3/mn) = 0.0006 \times V(cm^3) \times \Delta P\ (Pa/s)}$$

$$\Delta P = \frac{F\ (cm^3/mn)}{0.0006 \times V\ (cm^3)} = \mathbf{120\ Pa/s}$$

Different Types of Air to Air Controls

A Customer Example (continued):

- Water pump had same internal volume…
  - Larger leak tolerance
  - Increased test pressure

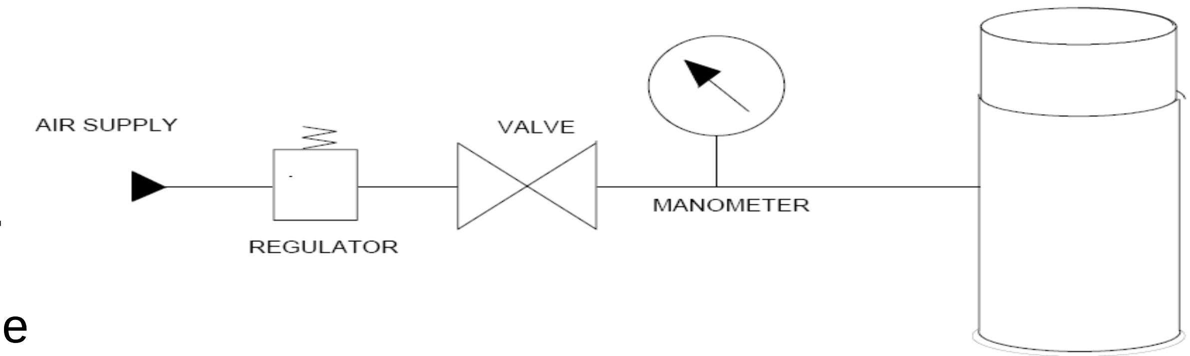


THE PRESSURE DROP (Δ P) DOES NOT DEPEND ON THE TEST PRESSURE

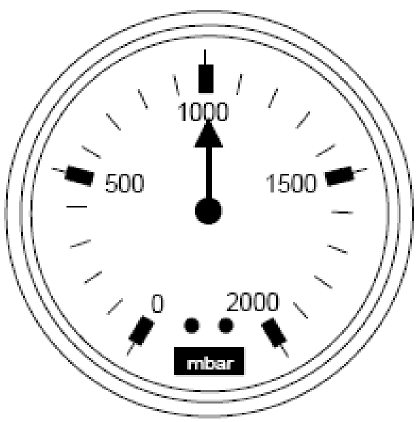
Different Types of Air to Air Controls

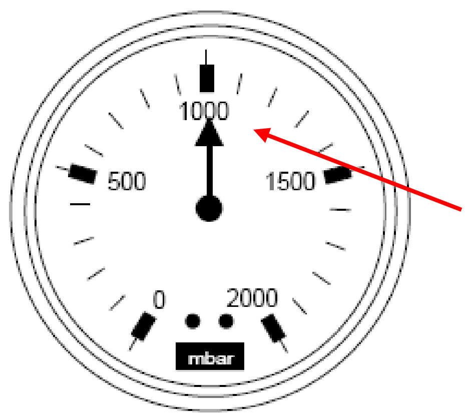
Relative Air to Air Control:

- Closer look at Air to Air capability…



- Gear Box application…
  - 6 Pa pressure drop
  - One second test cycle



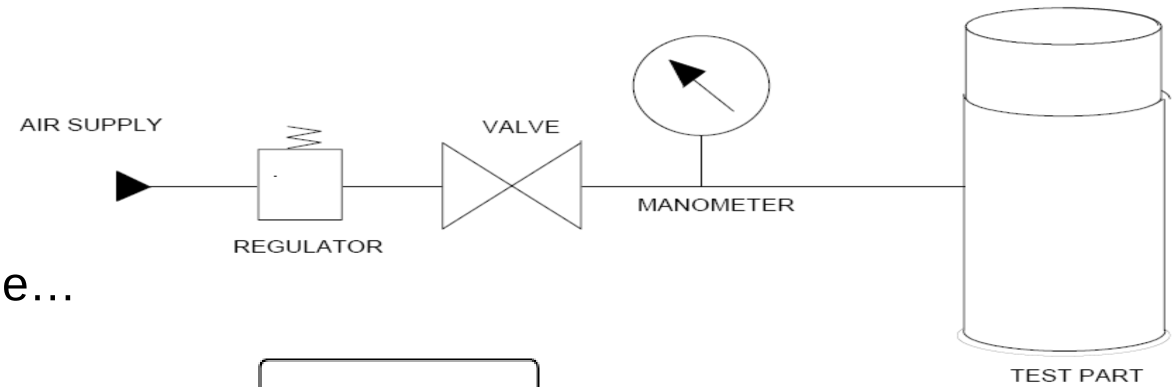


- The needle hasn't moved!
  - Gauge resolution too small

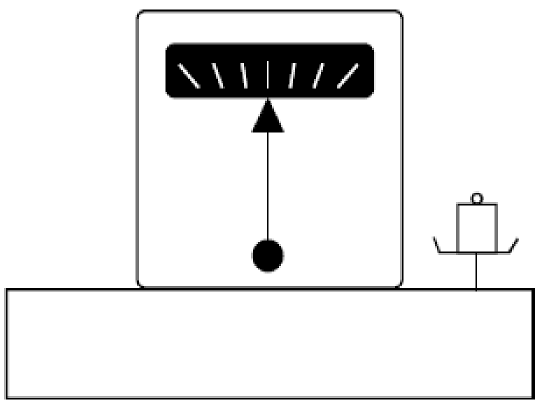
Different Types of Air to Air Controls

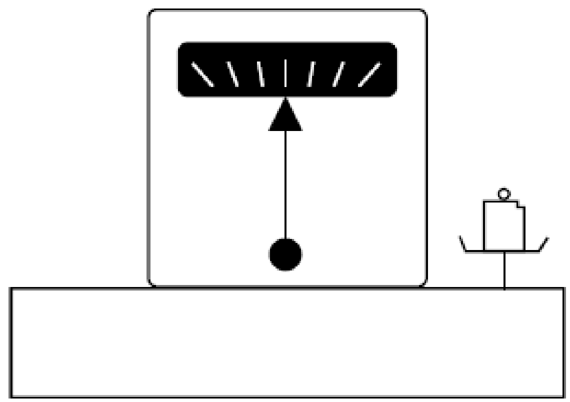
Relative Air to Air Control:

- Closer look at Air to Air capability…



Comparison to a weight scale…



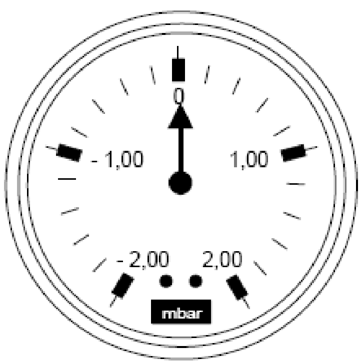


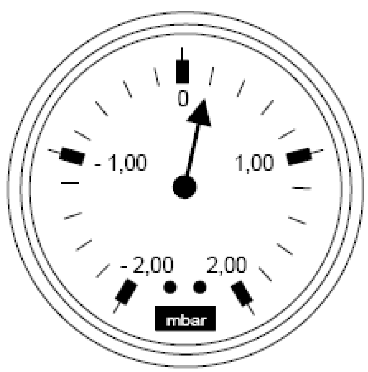
…0.06 Gram removed from a weight of 1,000 Grams; the needle will not move

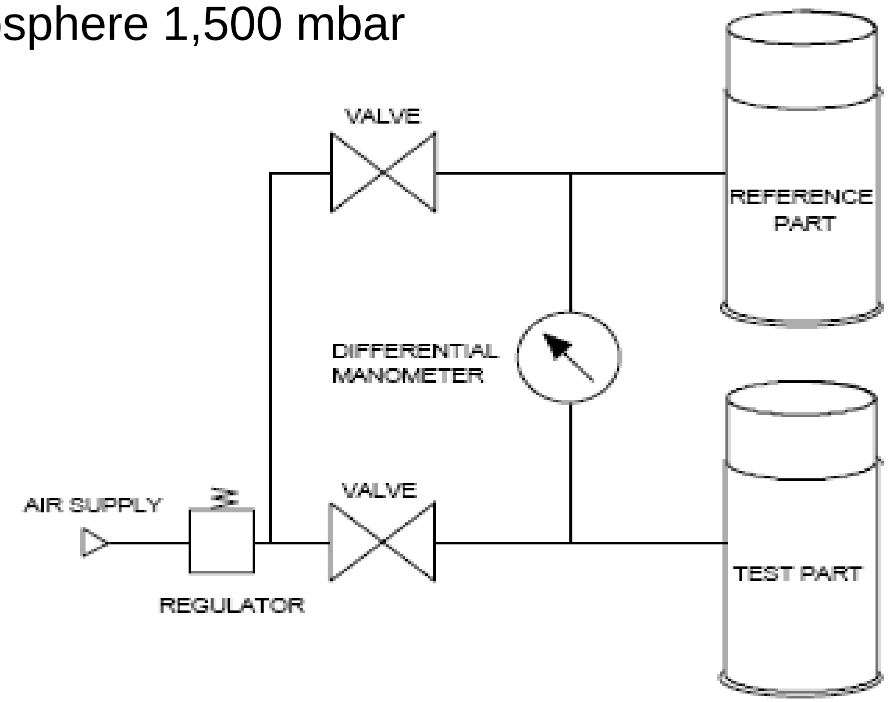
Different Types of Air to Air Controls

Differential Air to Air Control:

- Resolution issues are resolved…
  - Same 6 Pa leak reading from Gear Box
  - Gauge reading differential at +/- 2 mbar
  - Previously reading relative to atmosphere 1,500 mbar







Different Types of Air to Air Controls

Differential Air to Air Control:

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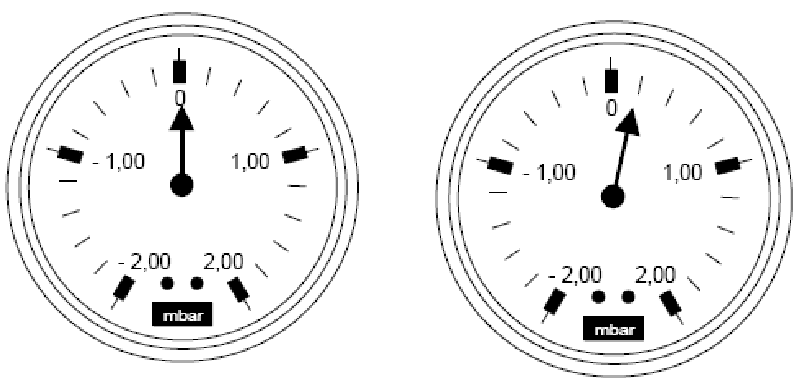
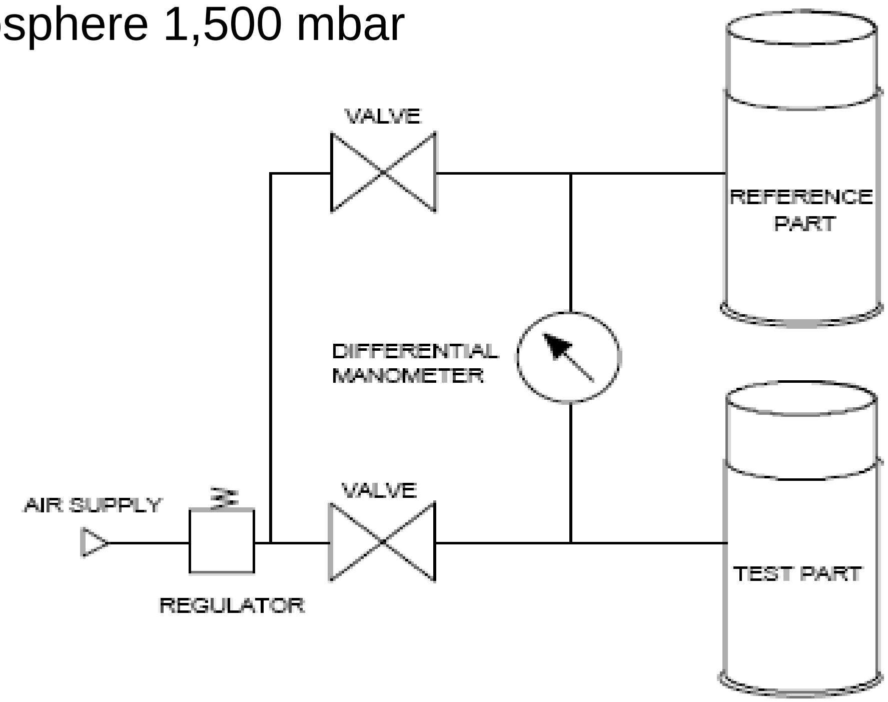
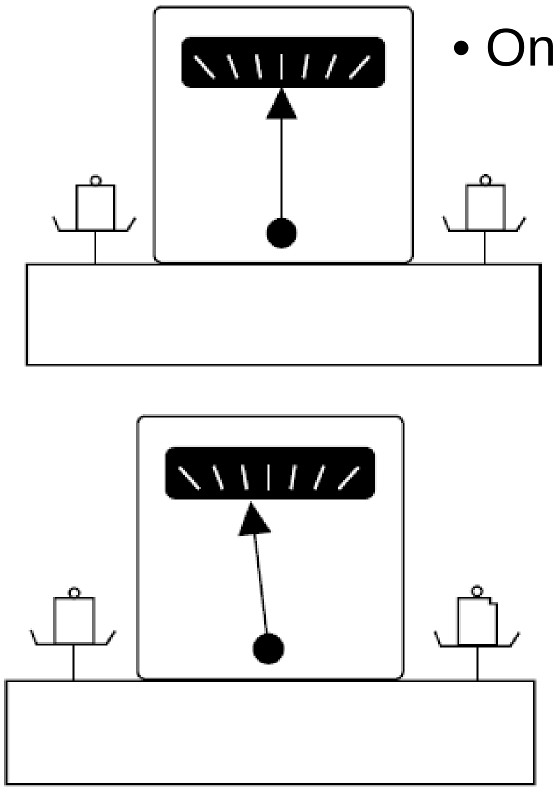


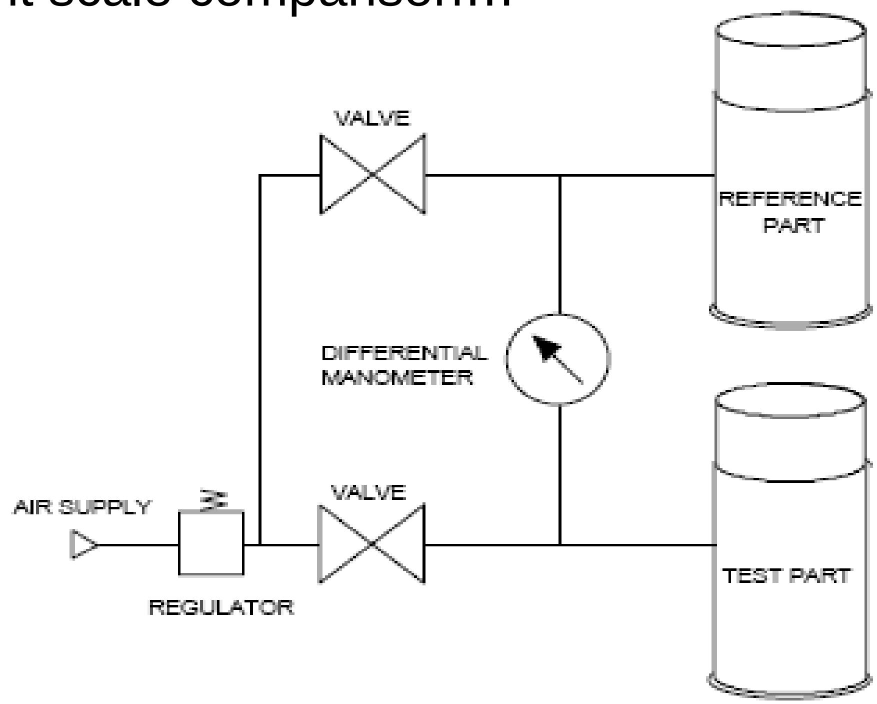


Different Types of Air to Air Controls

Differential Air to Air Control:

• One more weight scale comparison…



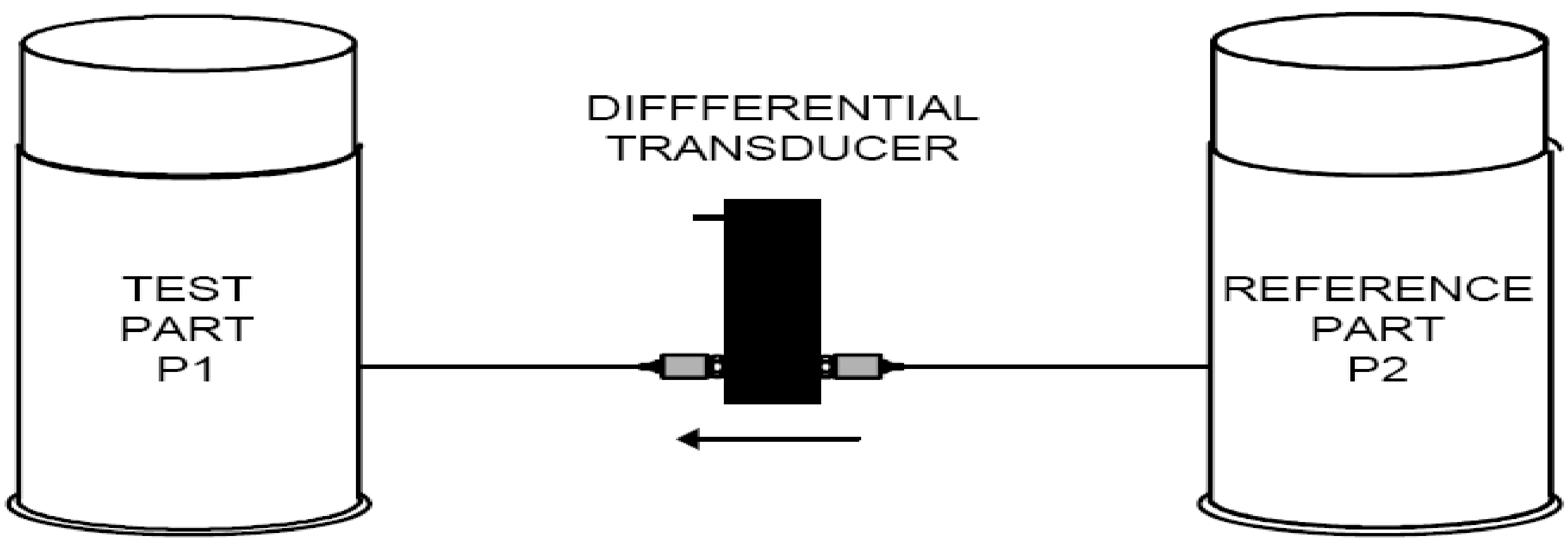


•Because it's a comparison, the weight change becomes visible

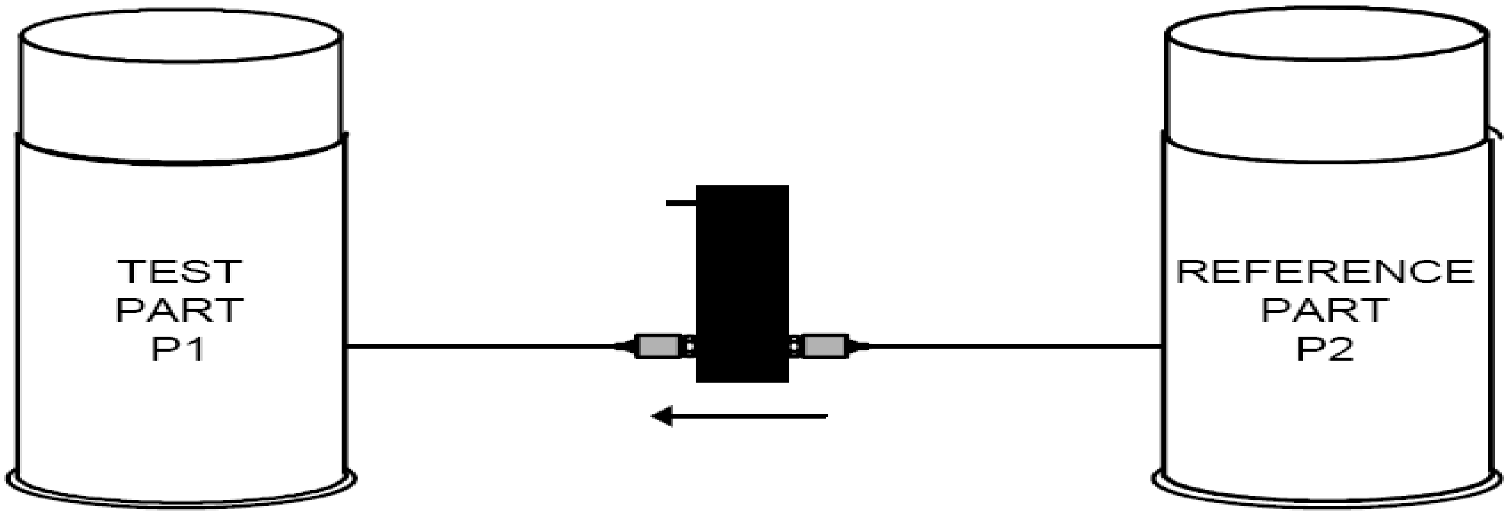
Differential Air to Air Leak Detection

Function of Reference Part

- System to measure small pressure drop between two parts
- Parts are pressurized equally
- Electronic transducer reads variation
- Cancels effects of volumetric and temperature variation



Differential Air to Air Leak Detection

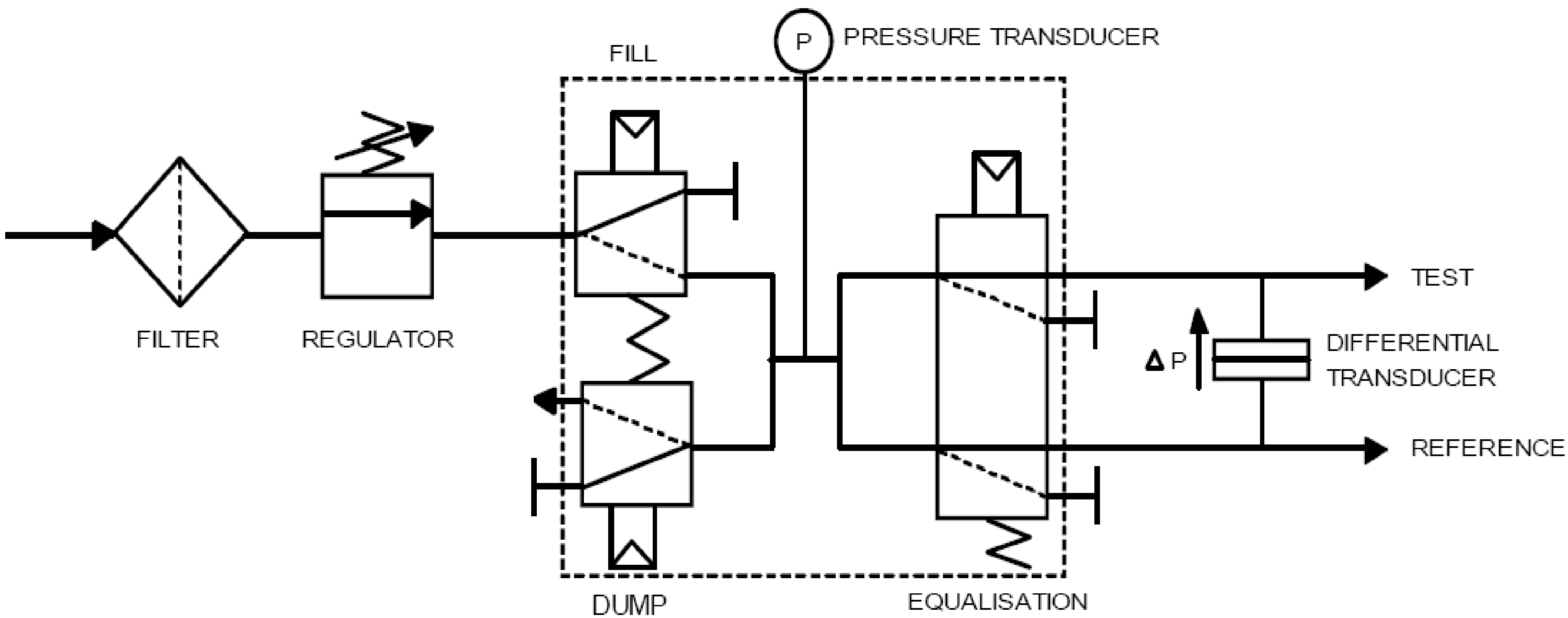


FOR A VOLUME OF 1 LITRE, A VOLUME VARIATION OF 1 CM^3 CORRESPONDS TO A VARIATION OF A PRESSURE OF 200 Pa (under 1 bar absolute pressure) AT CONSTANT TEMPERATURE

FOR A RELATIVE PRESSURE OF 1 BAR, A TEMPERATURE VARIATION OF 1°C CORRESPONDS TO A PRESSURE VARIATION OF 680 Pa

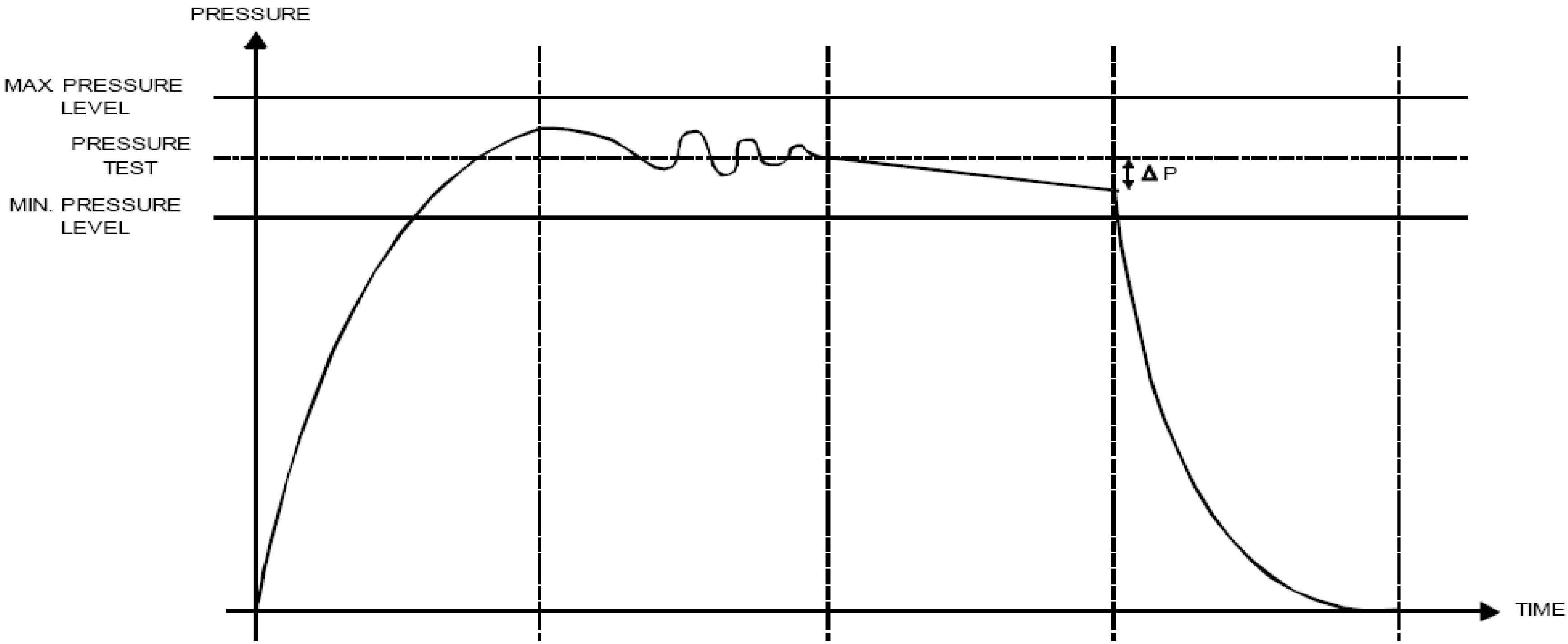
Differential Air to Air Leak Detection

Basic Diagram



Differential Air to Air Leak Detection

Cycle Function

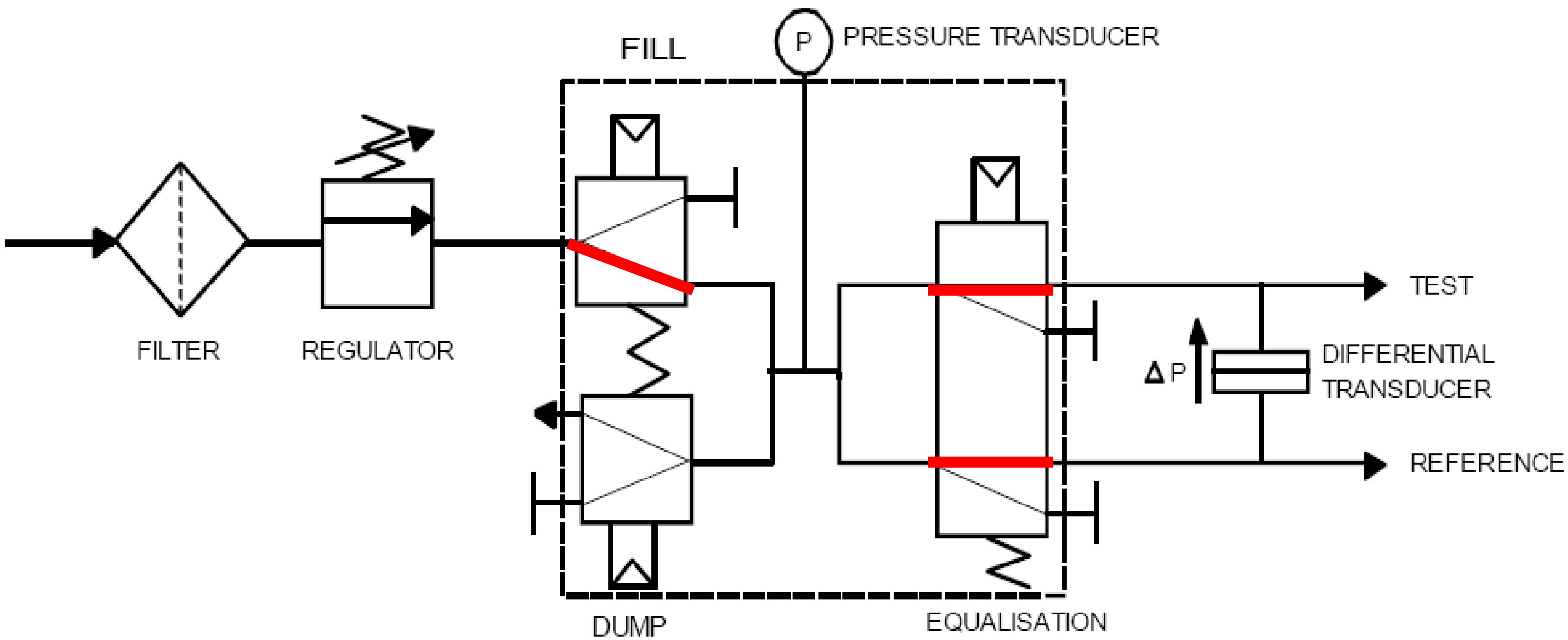


STAGE	**FILL**	**STABILIZATION**	**TEST**	**DUMP**
OBJECTIVE	P = P TEST	P TEST = P REFERENCE MIN level < P < MAX level	ΔP = P TEST - P REF	P = P ATM

Differential Air to Air Leak Detection

Fill Time

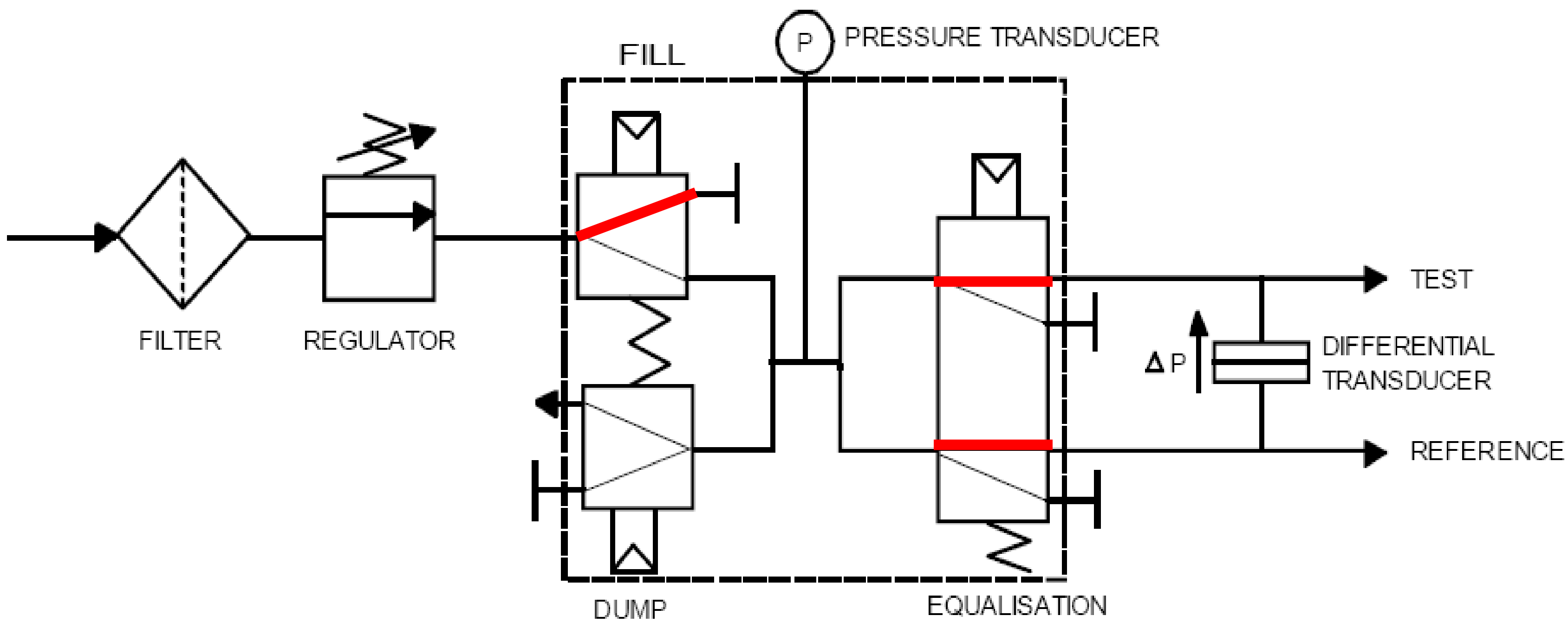
- Fill valve opens
- Pressurizes Test and Reference parts
- End of Fill cycle; test pressure is measured



Differential Air to Air Leak Detection

Stabilization Time

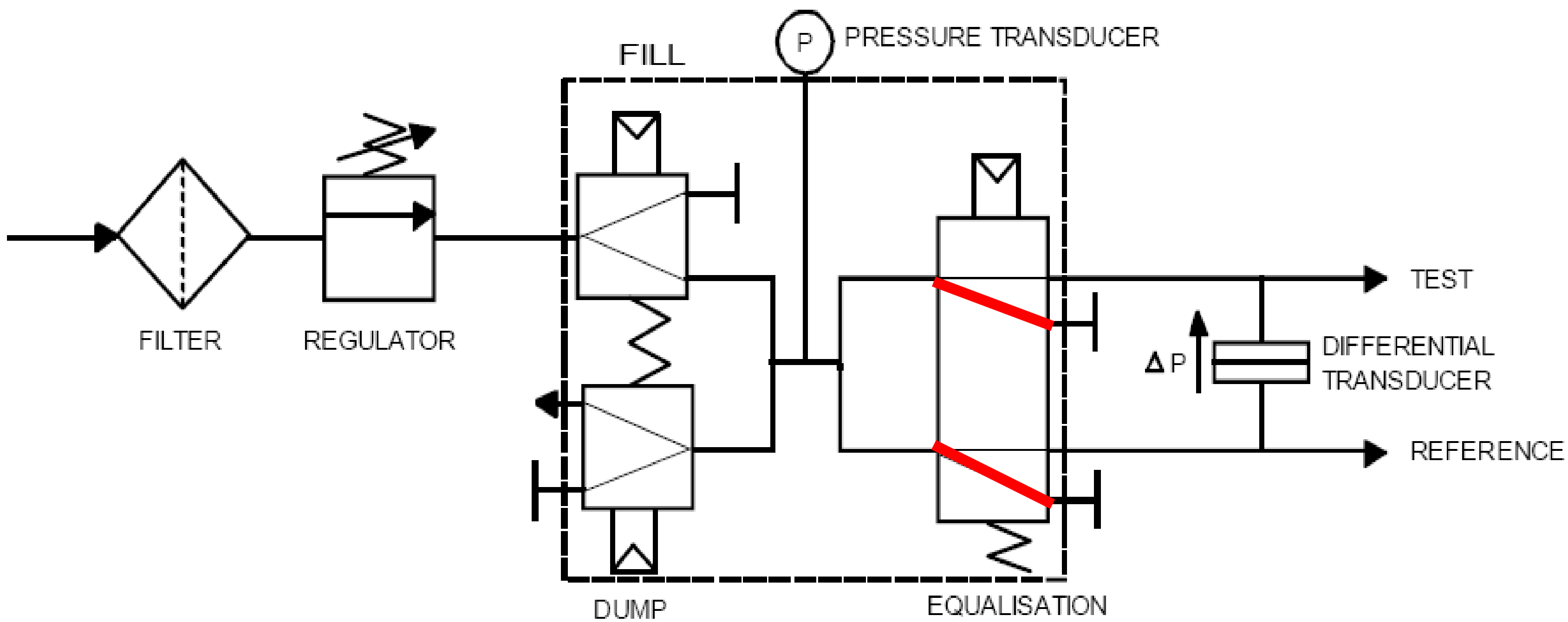
- Fill valve closes
- Test & Reference parts isolated from incoming pressure
- Pressure & Temperature effects stabilize gradually between parts



Differential Air to Air Leak Detection

Test Time

- Stabilization valve closes
- Test & Reference parts isolated from each other
- Differential Transducer measures difference of pressure between parts

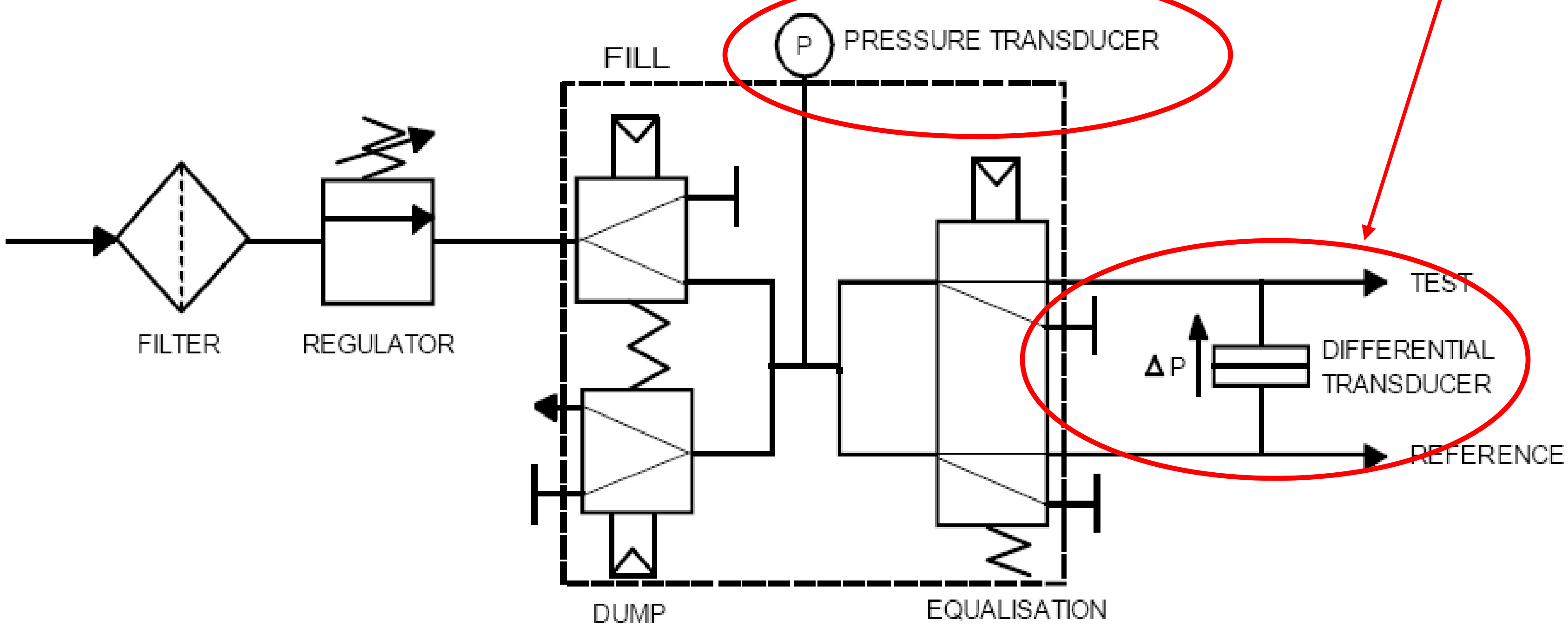


Differential Air to Air Leak Detection

Transducer Facts:

- Differential Transducer located after valve
- Closer to test part
- Same pressure variations as test part
- Isolates equalization valve
- Susceptible to contamination

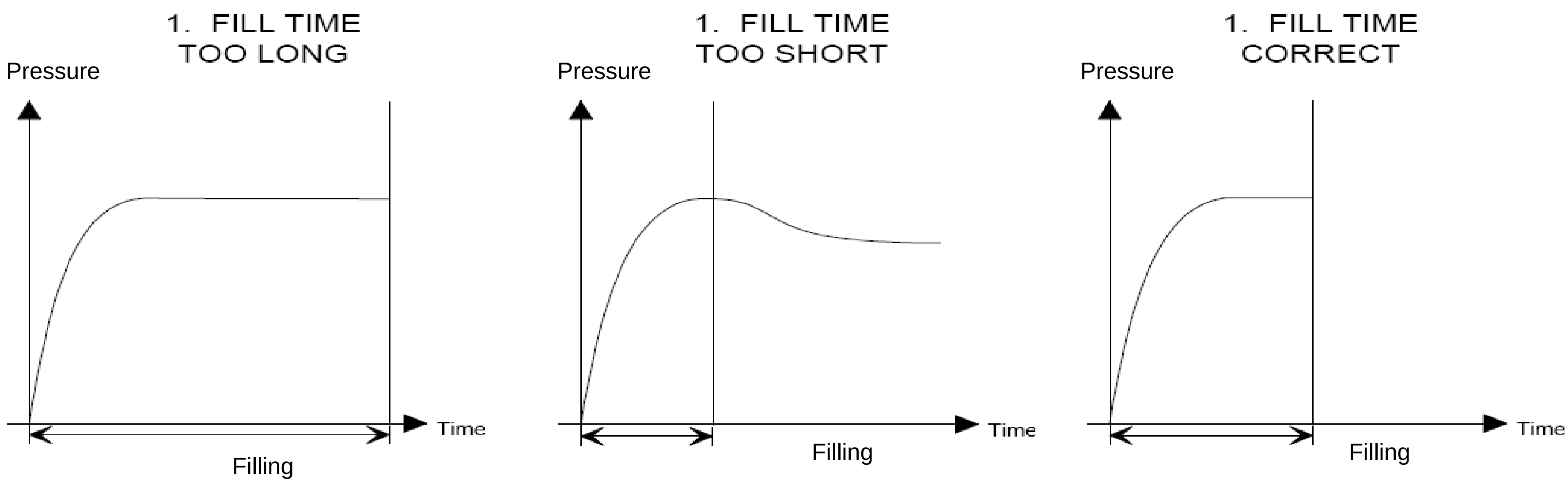
- Pressure Transducer ahead of valve
- Monitors test pressure
- Protects Differential transducer (Gross leak)



Differential Air to Air Leak Detection

Steps of the Leak Test Cycle…

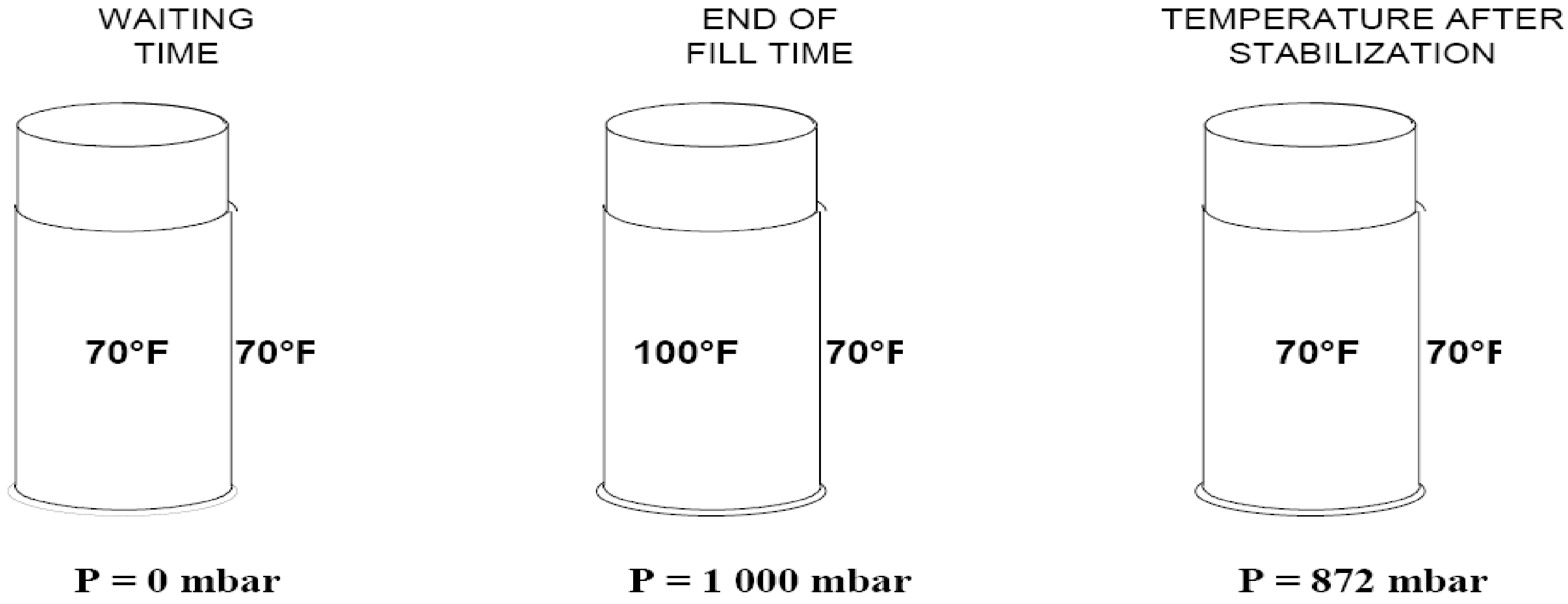
- Fill Time (Two main parameters)
- Test Pressure:
    - Expressed in bar, PSI or Kpa
    - Not always related to actual performance of product
- Fill Time:
    - Time to pressurize test & reference parts
    - Timing must be correct



Differential Air to Air Leak Detection

Steps of the Leak Test Cycle…

- Fill Time (Continued)
  - Short Fill Time inaccurate
  - Air heated from compression
  - Cools after stabilization inside test part



Differential Air to Air Leak Detection

Steps of the Leak Test Cycle…

- Setting Fill Time
    - Start with long Fill Time (FTTL)
    - Test pressure must be stable
    - Shorten until pressure drop from heating observed

- *Adjust Fill Time using following formula…*

$$\text{FTTL} = \sqrt[4]{\text{volume in cc x test pressure in mbar}}$$

- *Example, volume = 1,000 cc and pressure = 2,000 mbar…*

volume in cc x test pressure in mbar = FTTL

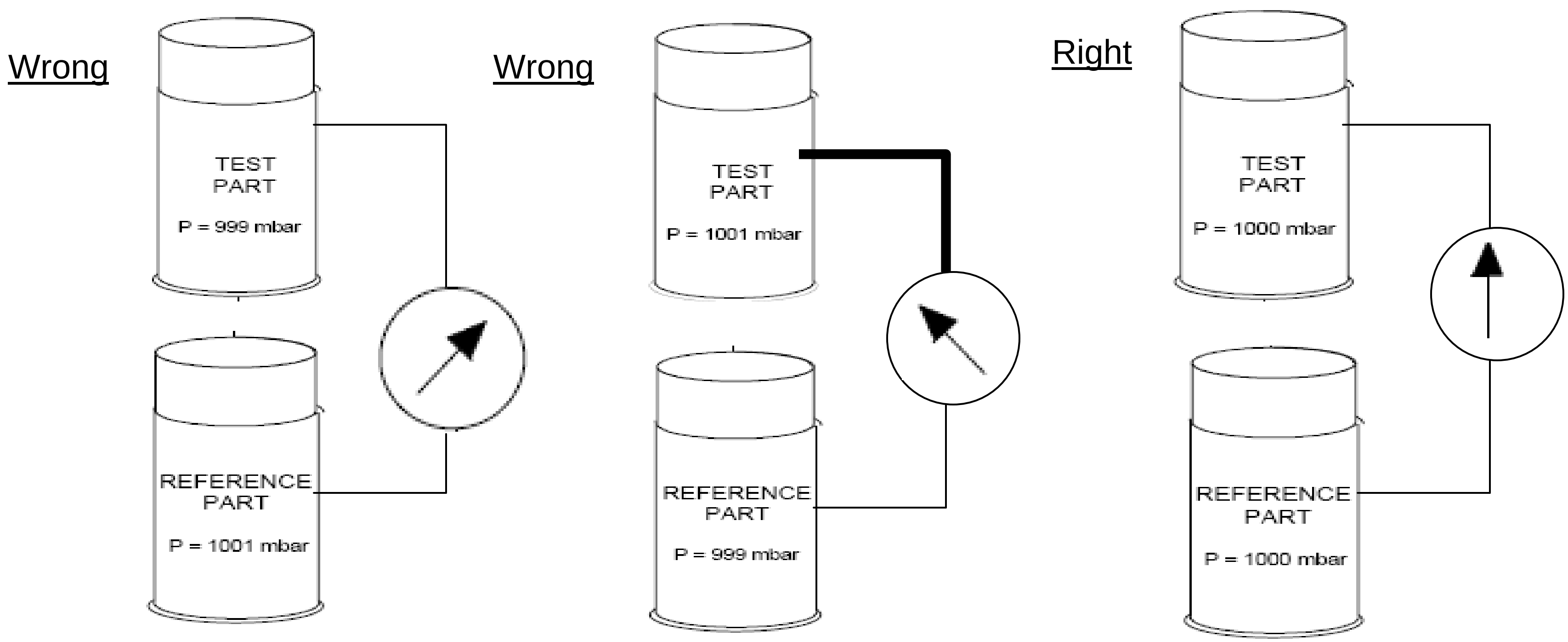
1,000 x 2,000 = 2,000,000

$$\sqrt[4]{2{,}000{,}000} = 38 \text{ (seconds)}$$

Differential Air to Air Leak Detection

Steps of the Leak Test Cycle…

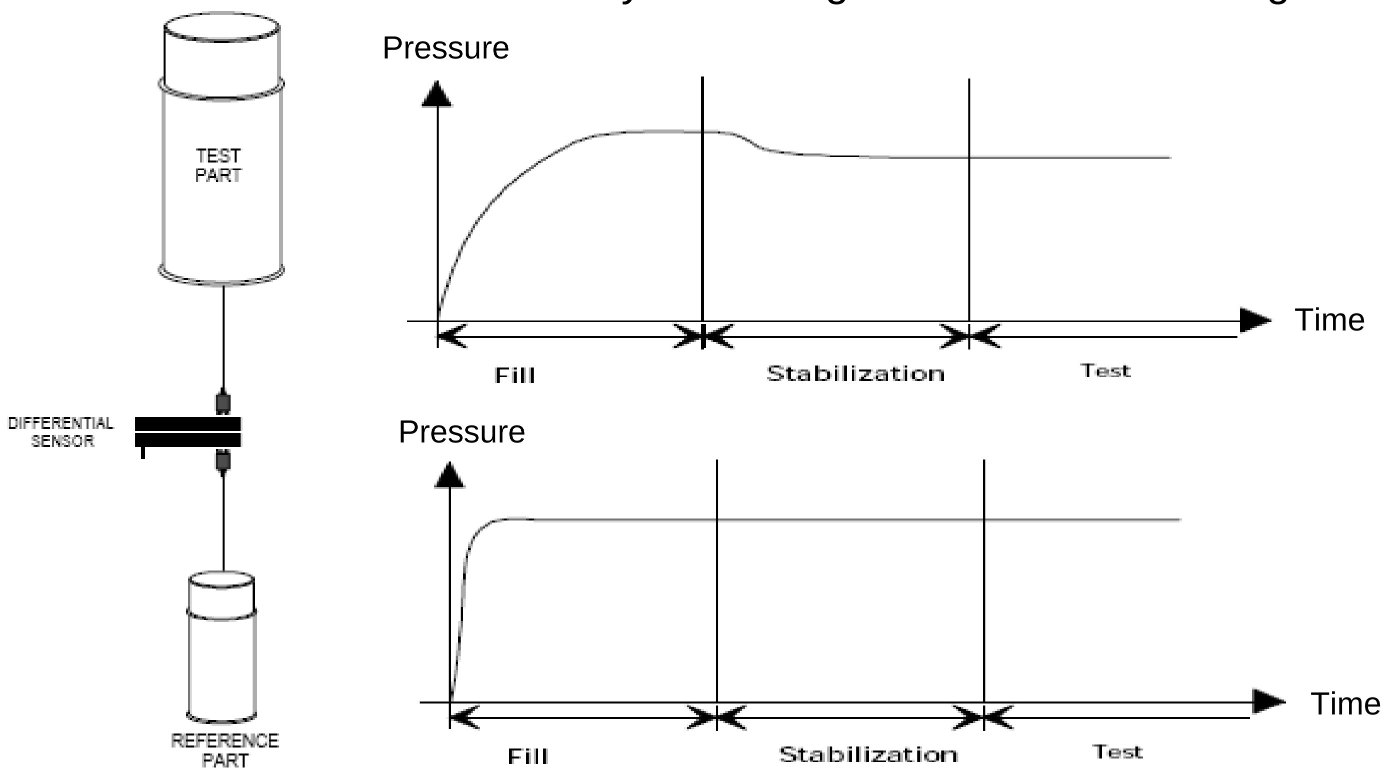
- Stabilization Time (Two main parameters)
  - Difference in tubing
    - Difference in length and/or diameter
    - Pressure higher in part with favorable connection
    - Test cycle starting too soon will indicate gross leak



Differential Air to Air Leak Detection

Steps of the Leak Test Cycle…

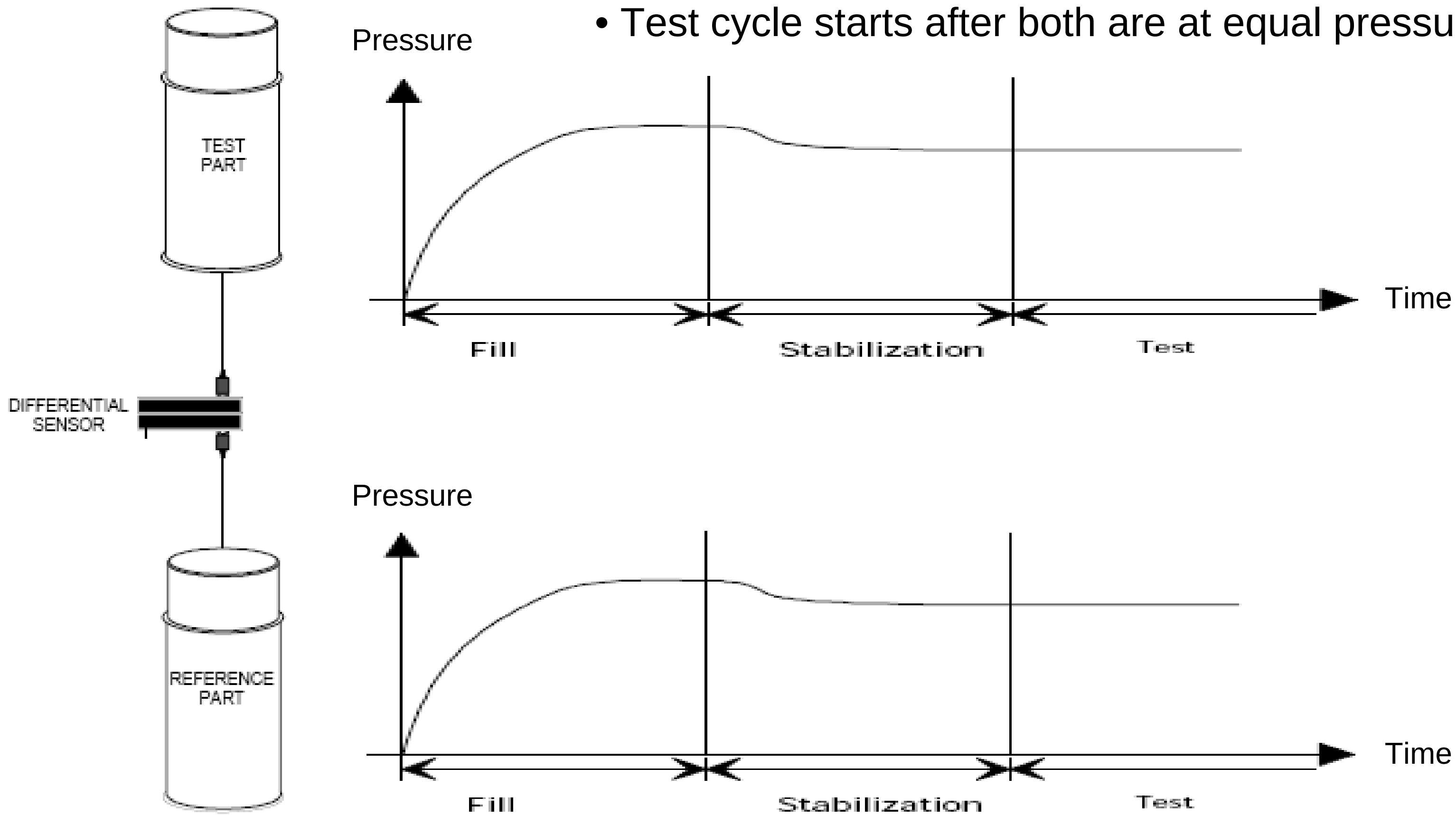
- Stabilization Time (Two main parameters)
  - Difference in volume
    - Smaller part will stabilize faster
    - Test cycle starting too soon will indicate gross leak



Differential Air to Air Leak Detection

Steps of the Leak Test Cycle…

- Stabilization Time (Two main parameters)
  - Equal volumes
    - Parts see same heating effects
    - Test cycle starts after both are at equal pressure



Differential Air to Air Leak Detection

Steps of the Leak Test Cycle…

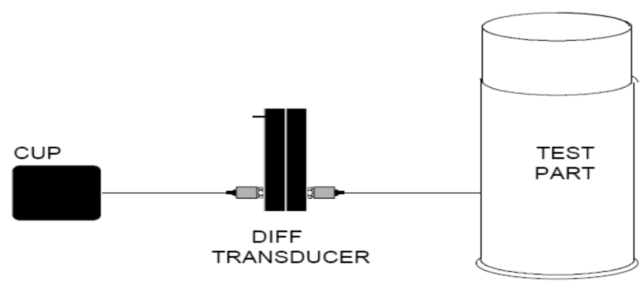
- Setting Stabilization Time
  - Start with long Stabilization time
  - Should get good “Zero” with non-leaking part
  - Reduce in steps until test result goes over “Zero”

- *Is it necessary to use a reference part?*
  - Shortens overall cycle time temperature stabilizes at the same time
  - Allows faster start of Test cycle
  - Generates offset results…

INTERNAL TEST VOLUME	1,000 cm^3
INTERNAL REFERENCE VOLUME	10 cm^3
REJECT LEVEL	3.6 cm^3/mn
TEST PRESSURE	1 bar

Part with 5 cm^3/mn leak and reference cap with 0.1 cm^3/mn leak
Using our formula from earlier we get the following results…

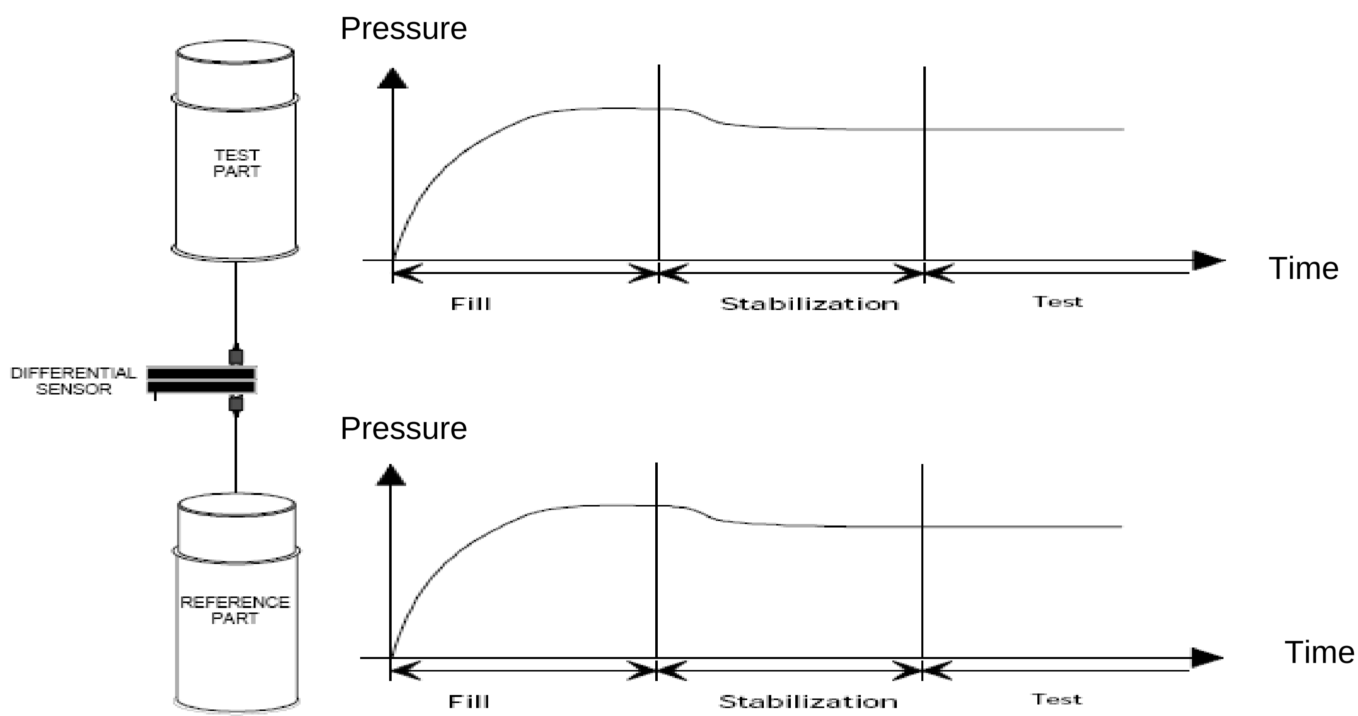
Reference = 16.6 Pa
Test = 8.3 Pa
Reading = - 8.3 Pa



Differential Air to Air Leak Detection

Steps of the Leak Test Cycle…

- Test Time
  - After Fill & Stabilizations have been optimized
  - Set to fit desired machine cycle
  - Results must be repeatable



Leak Detection Tooling Considerations

Fixture Seals...

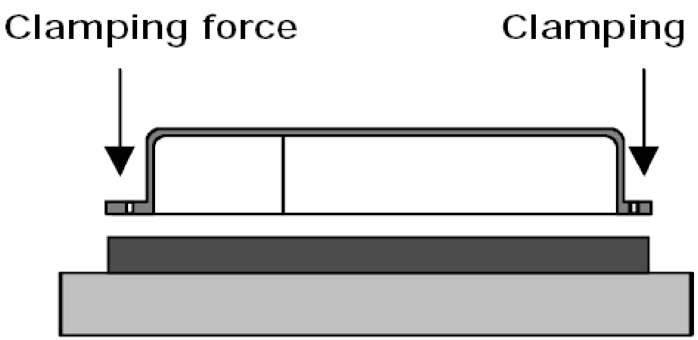


Fig 1

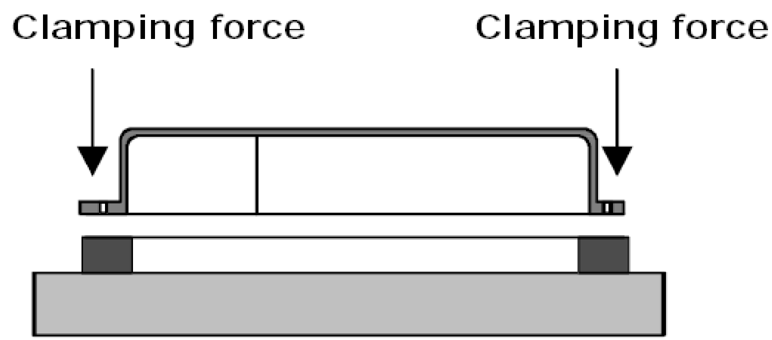


Fig 2

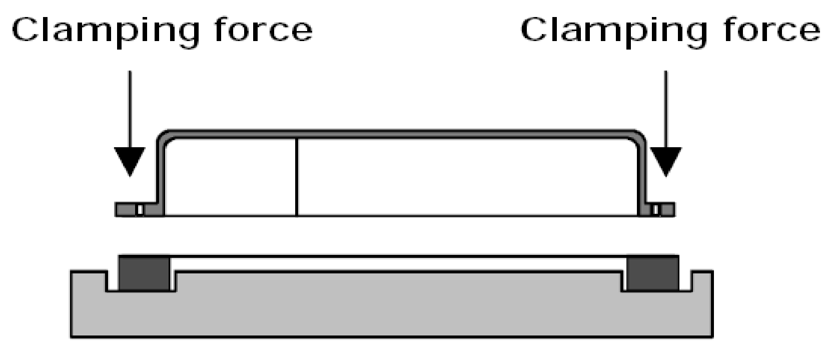


Fig 3

Poor Designs

Figure 1: Flat pad seal
Figure 2: Thick gasket not retained
Figure 3: Thick gasket in retaining groove

Leak Detection Tooling Considerations

Fixture Seals...

- Use as much seal surface as possible
- Use heat conductive material for fixture
- Minimize seal material in contact with test air (does not conduct heat well)

Good Design

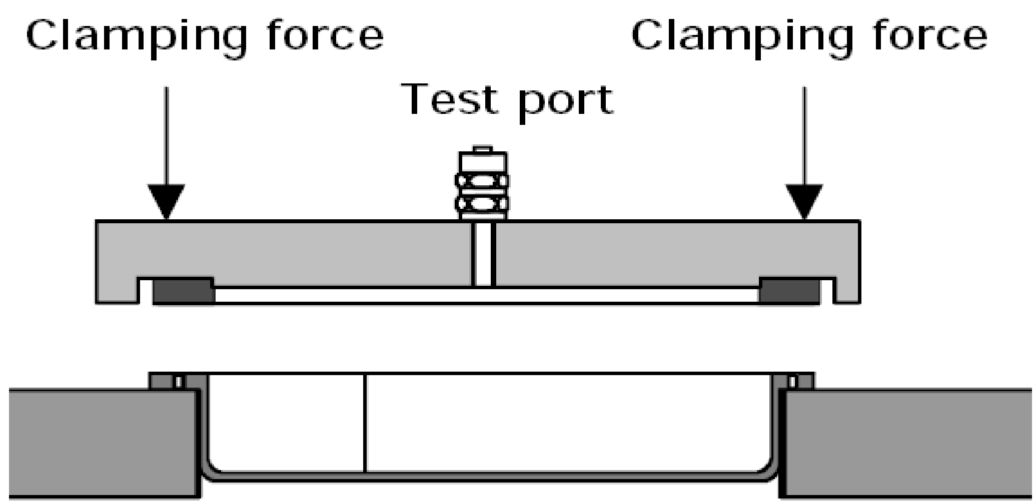


Fig 4

Leak Detection Tooling Considerations

Other Seal Considerations...

- Seals should be captured
- Minimize seal movement during test
- Should have metal-to-metal contact for repeatability
- Prolongs seal life

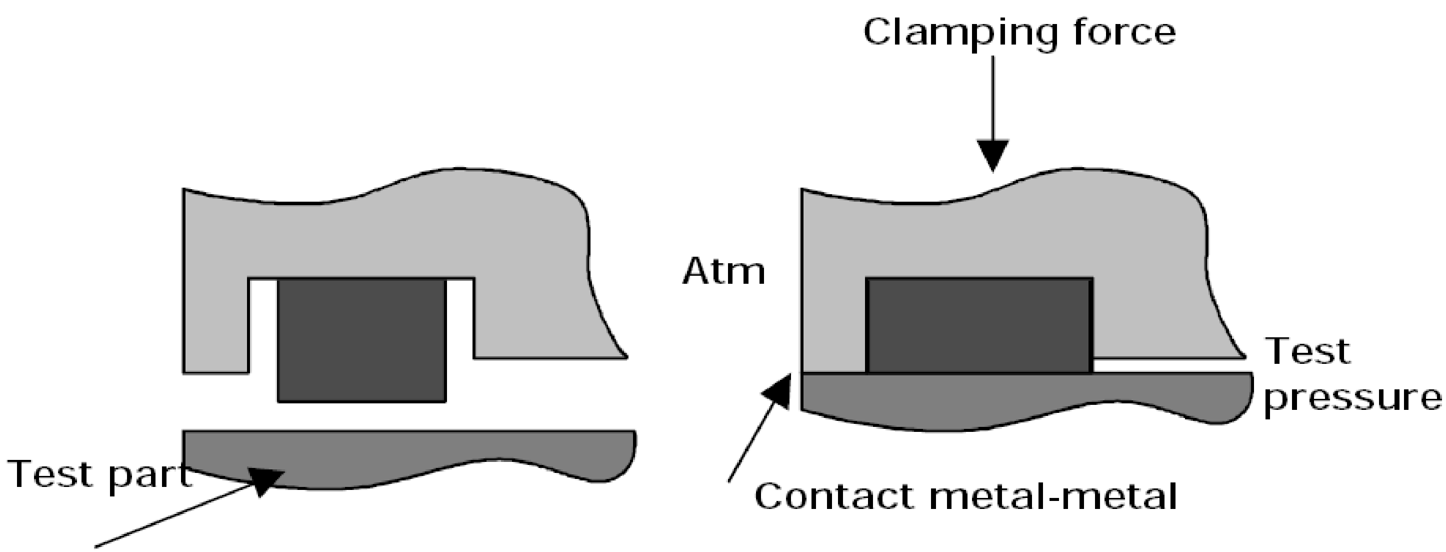


Fig 5

Leak Detection Tooling Considerations

Other Seal Considerations...

- Do not seal on threads or sharp surfaces
- Preferable to seal on machined surface
- Should be visible and accessible to operator
- Should be easy to troubleshoot and replace

Other seal groove methods :

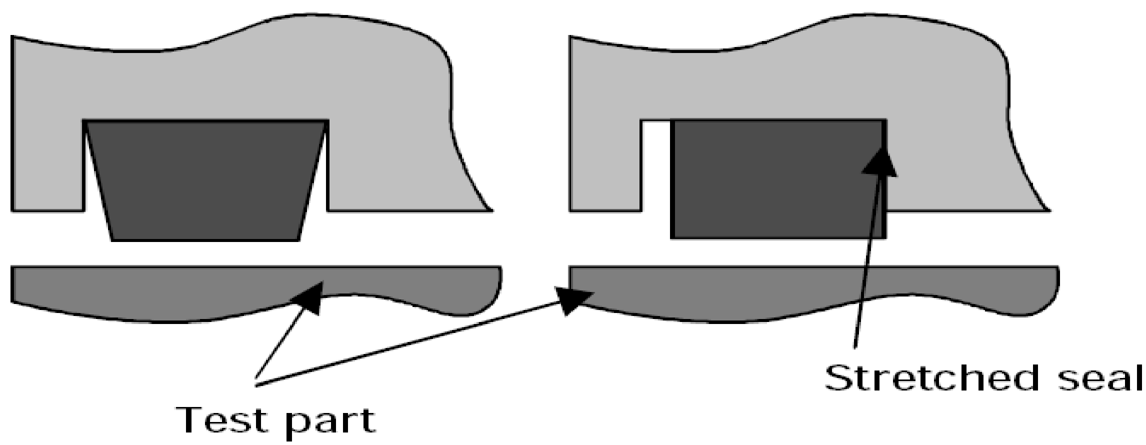


Fig 6

Leak Detection Tooling Considerations

Seal Materials...

Gum Rubber

- Tensile Strength: from 2800 to 3000 psi
- Hardness: Soft
- Strong and resilient
- Stretches but has memory
- Non-marking and non-toxic

- Weakness: deteriorates rapidly

Polyurethane

- Tensile Strength:
- Soft: 6000 psi, Medium: 4500 psi, Hard: 5500 psi, Extra hard: 7500 psi
- Can be used in oily environment
- Resists tearing and abrasion

Leak Detection Tooling Considerations

Other Seal Considerations...

- Clamping Forces

The total clamping force should be approximately three times the forces required to hold the air pressure applied by open areas of the test part to the seals.

In our example : 8 in by 11 in : Area =88 sq.in.   Test pressure : 40 psi (2.7 bar)

$F = P \times A = 88 \times 40 \Rightarrow F = 3{,}520\text{lbs}$ (Minimum force to overcome the air pressure)

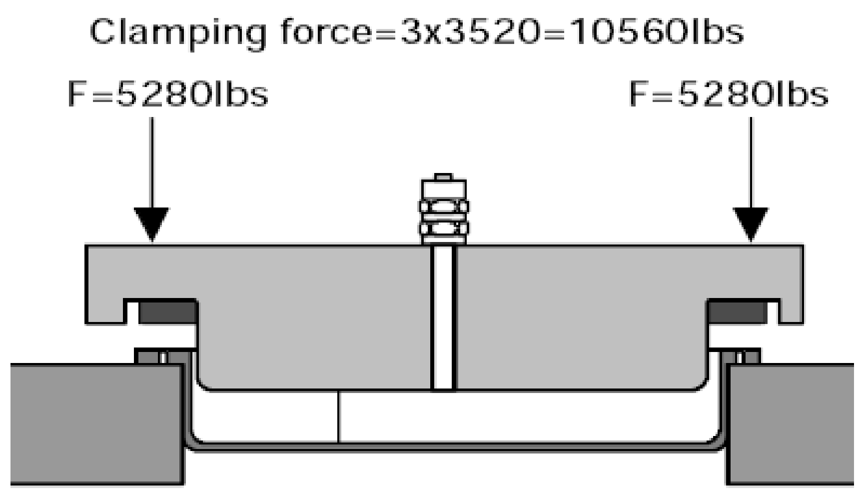


Fig 7

Leak Detection Tooling Considerations

Other Seal Considerations...

- Use Thermal Insulation to stabilize test results by…
  - avoiding heat exchange between test part & fixture
  - avoiding heat exchange between fixture and ambient air

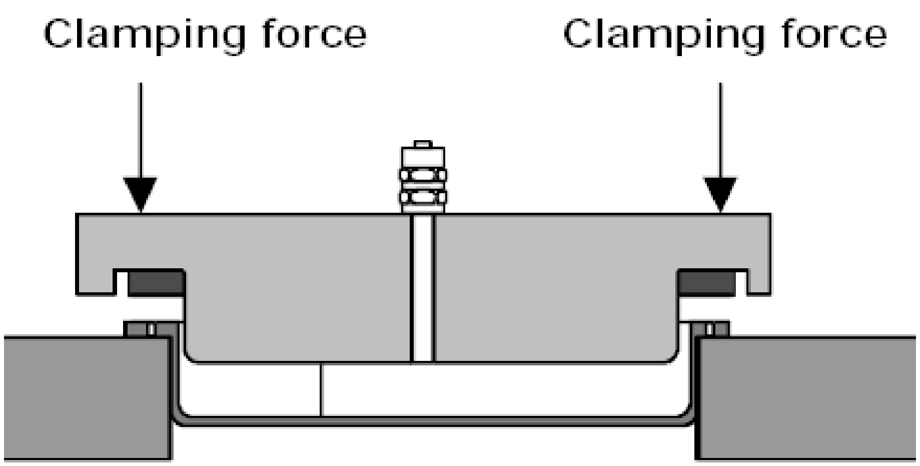
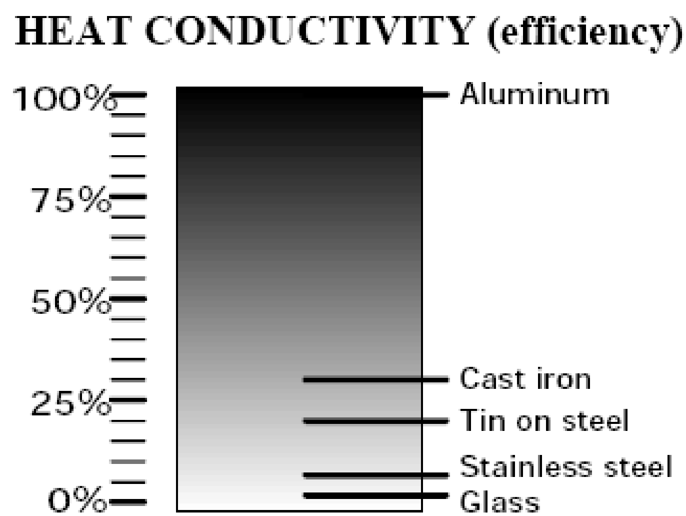
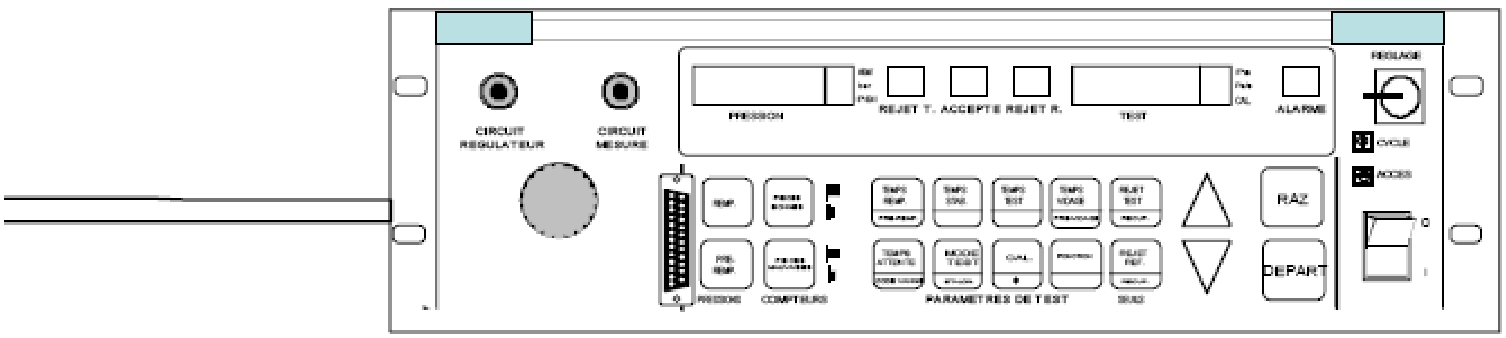


Fig 8



Leak Detection Tooling Considerations

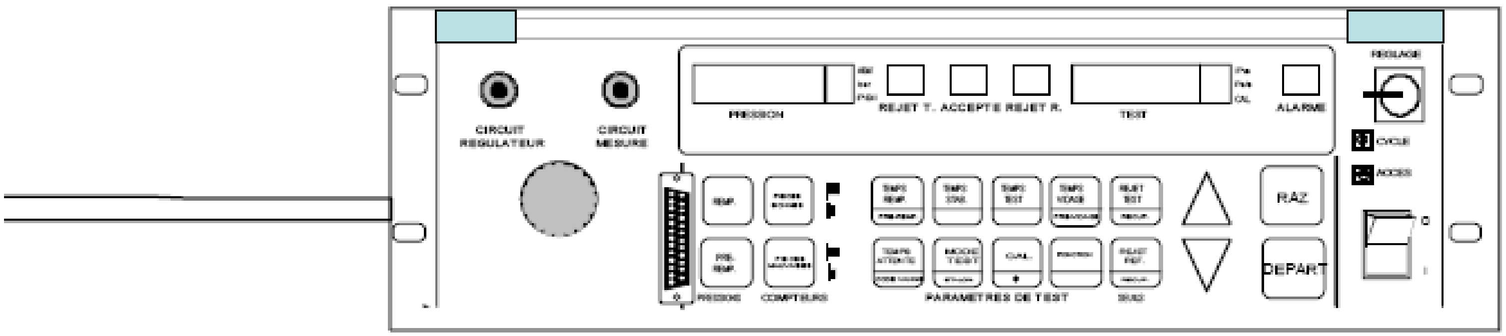
Test Unit & Supply Tubing...



- Mount tester close to fixture
- Keep tubing runs short & should be semi-rigid
- Do not use “quick” connections in test circuit
- Tie test & reference tubing together & insulate to “standardize” thermal effects
- Threaded connections should use sealant not sealing tapes

Leak Detection Tooling Considerations

Final Considerations...



- Test air should be clean & dry
- Protect test area against drafts to avoid temperature flucuations
- Protect test area from vibration
- Mount fixture seals & test inlet high in machine to avoid contamination
- If parts are contaminated evacuate to atmosphere from fixture
- Operator should avoid touching part during test

References

1. “Leak Pressure Decay Training Part 1 & Part 2”, Version 13, by Pascal Keller, Ateq Corporation, 42000 Koppernick Road #A4, Canton MI 48187

2. “Design Considerations for Air Leak Test Fixture”, Version 1.0, Ateq Corporation, 42000 Koppernick Road #A4, Canton MI 48187

3. “Improve Pressure Decay Leak testing”, Quality Magazine Online, Quality Test & Inspection, March 2005, by Charles Nylander, President; Sensister Technologies, Inc

4. “Automatic Valves for Gas Appliances”, ANSI Z21.21b 1999

5. Combination Gas Controls for Gas Appliances, ANSI Z21.78 1997

6. Manually Operated Gas Valves for Appliances, Appliance Connector Valves and Hose End Valves, ANSI Z21.15 1997