HKA Technologies Inc.

Leak Testing in Manufacturing

HKA Technologies Inc.

Introduction and Background

- Engineering and consulting for the last 17 years
- Focus on leak testing in the last five years
- 19 leak test systems installed at Dana plants
- 11 systems installed at Walker Exhausts, Camb.
- Work closely with system integrators, but still do turnkey automation as required

Leak Testing in Manufacturing

Leak Test Comparison						Source: InterTech Development	
	Pressure Decay	Differential Pressure	Mass Flow	Differential Mass Flow	Mass Flow Bell Jar	Helium Sniffer	Helium Vacuum
Initial Cost	Low	Moderate	Moderate	Moderate	Moderate	Moderate	High
Fixture Cost	Low	Low	Low	Low	High	Moderate	High
Test Time	Longest	Shorter	Shortest	Shorest	Shortest	Shorter	Shortest
Accuracy	Poorest	Better	Best	Best	Best	Better	Best
Small Leaks	Unsatis.	Satis.	Best	Best	Best	Better	Best
Ideal Pressure	Low-Medium	Medium	Up to 150 psi	Up to 150 psi	High	Medium	High
Temp. Compensation	Difficult	Difficult	Available	Available	Available	N/A	Available

Leak Testing in Manufacturing

<table>
<tr><td></td><td colspan="4">Leak Flow Rates in Standard cc/second</td><td></td><td></td><td colspan="2">Source: Cincinnati Test</td><td></td></tr>
<tr><td></td><td>10^{+1}</td><td>10^{0}</td><td>10^{-1}</td><td>10^{-2}</td><td>10^{-3}</td><td>10^{-4}</td><td>10^{-5}</td><td>10^{-6}</td><td></td></tr>
<tr><td></td><td colspan="2">Gross Leak</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="4">Air Leak Testing</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="5">Dunk/Bubble Testing</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="6">Helium Sniffer Probe</td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="7">Helium Accumulation System</td><td></td><td></td></tr>
<tr><td></td><td colspan="8">Helium Vacuum System</td><td></td></tr>
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Types of Leak Testing

- Air Under Water
- Sniffers/Snoop
- Air Leak Testing
- Helium Mass Spectrography

Air Under Water Testing

- Part is pressurized with air, placed under water, operator looks for bubbles

- **Advantages:** Inexpensive for most parts; can locate the source of leak; seals not critical, not affected by part temperature.
- **Disadvantages:** Hard to quantify leak rate - bubbles per minute, size of bubbles can vary; relies on operator diligence; some parts may trap bubbles; part gets wet; often requires part drying.
- **Implementation:** Good lighting very important; use of air bladder for rapid raising/lowering of water; need quick method to filter/drain tank to facilitate clear water

Sniffers/Snoop Testing

- Sniffers are manual probes that the operator uses to scan the part to be tested. Can sniff for helium, refrigerants and other gases. A small flame can be used for combustible gases.
- Snoop is a soapy liquid that is applied to the surface of pressurized parts.

- **Advantages:** Can locate the source of the leak.
- **Disadvantages:** Cannot quantify the leak rate; both methods rely on operator diligence; not normally used for volume production.

Helium Mass Spectrography Testing

- Air is evacuated from the part, the part is pressurized with helium (or a mixture of helium); a bell jar is placed over the part; any escaping helium is captured; by measuring the concentration of helium a leak can be established.

- **Advantages:** Capable of testing for very small leaks 10^{-7} sccm; capable of short cycle times on large volume parts; minimal effects due to temperature or temperature changes.
- **Disadvantages:** High initial cost system; complex test fixtures requiring bell jar and seals, high operating costs including helium and pumps; gross helium leaks may contaminate all tests for significant durations.

- Air Leak Testing

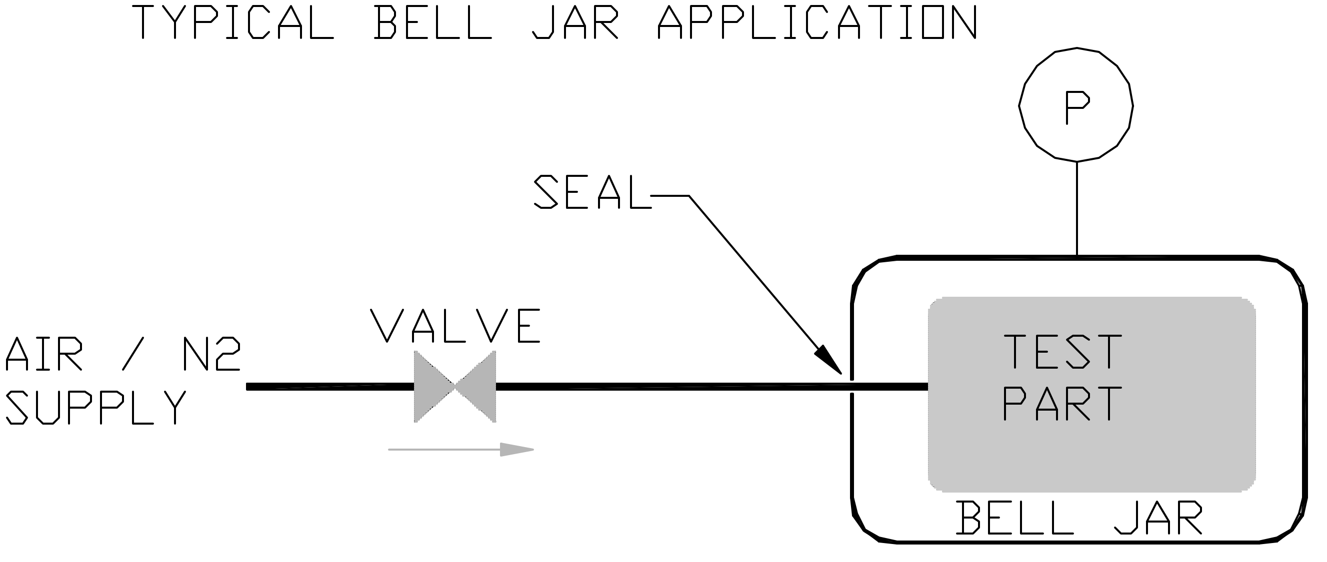
- Conventional vs Bell Jar
- Pressure Decay and Differential Pressure
- Mass Flow and Differential Mass Flow
- Testing of Two Parts – One reference, one test

Conventional vs Bell Jar

- Conventional methods pressure the test part with air (or N_2) and use some means to measure the pressure drop within that part.
- Bell jar methods use a bell jar to surround the part under test and measure the increase in pressure in the bell jar if any gas escapes from the part under test.

- **Advantages of Bell Jar:** Can yield superior results to pressure drop methods; very good for high pressure testing; accurate transducers can be used since working pressures are just above atmospheric; temperature effects are minimized.
- **Disadvantages of Bell Jar:** Medium to high initial cost; complexity of fixtures and seals; sealing around the pressure connection to the part; volume of the bell jar must be kept to a minimum (one for each part) or leak rate resolution is lost.

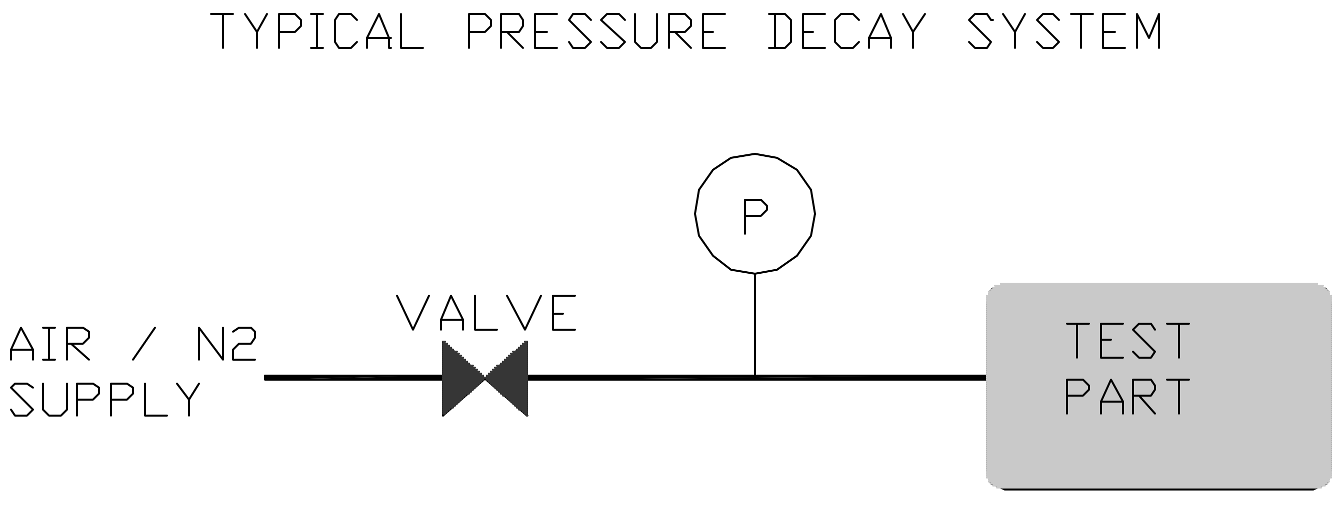
Conventional vs Bell Jar



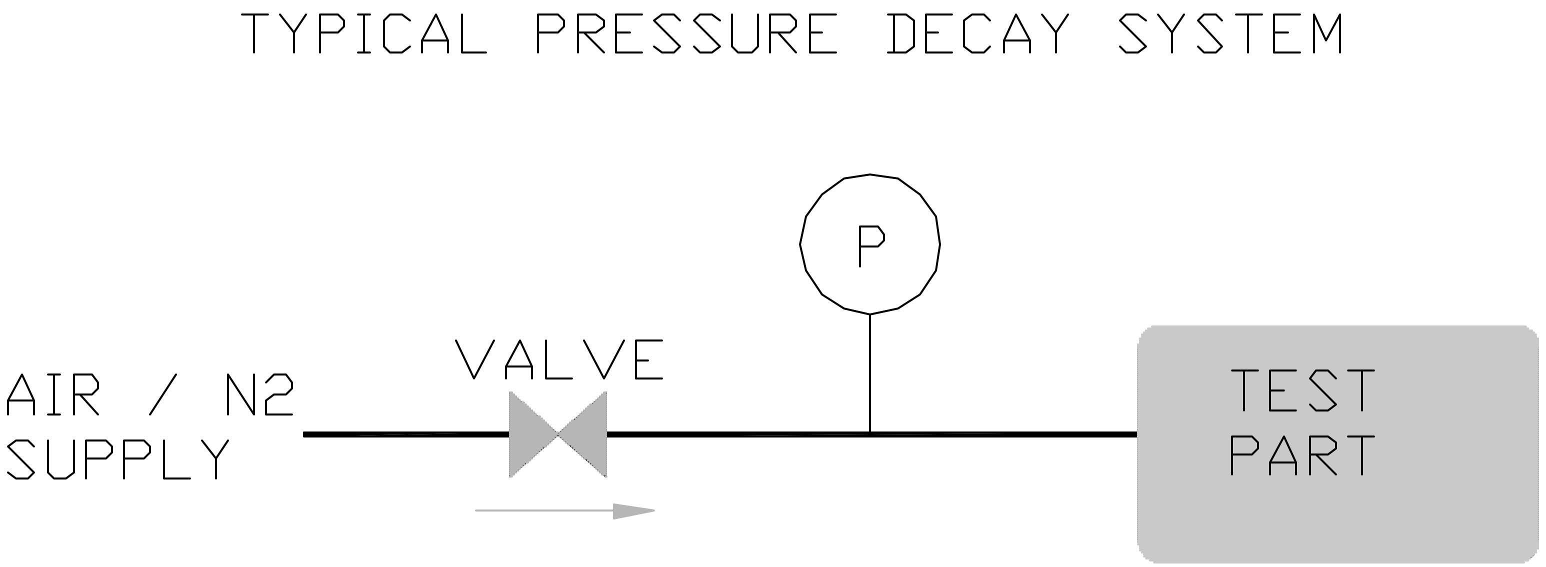
Pressure Decay

- Pressure decay is the oldest and simplest method of detecting leaks using air. The part with a pressure sensing device is filled at the test pressure though a valve; the valve is closed and the drop in pressure over time is measured. Knowing the part volume, test pressure, and time, a leak rate can be calculated.
- **Advantages:** The simplest and least expensive form of leak testing. Given long times it can be very accurate.
- **Disadvantages:** The slowest of the leak testing systems.

Pressure Decay



Pressure Decay

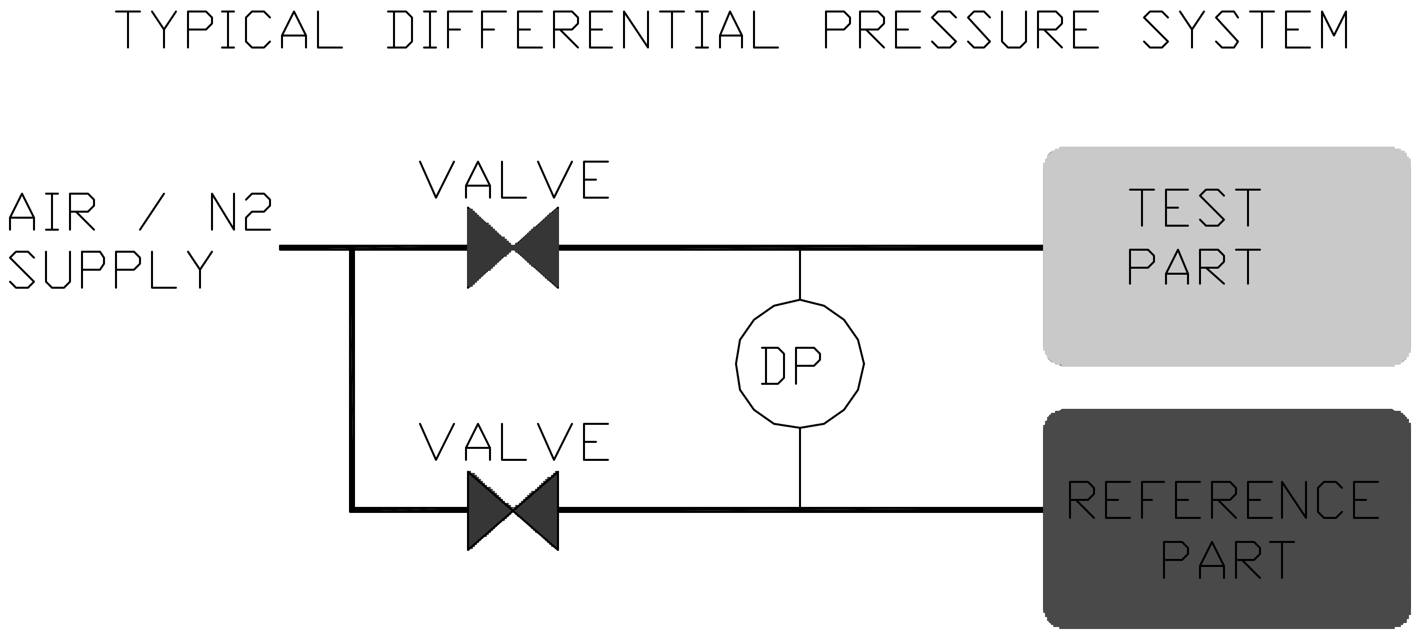


Differential Pressure

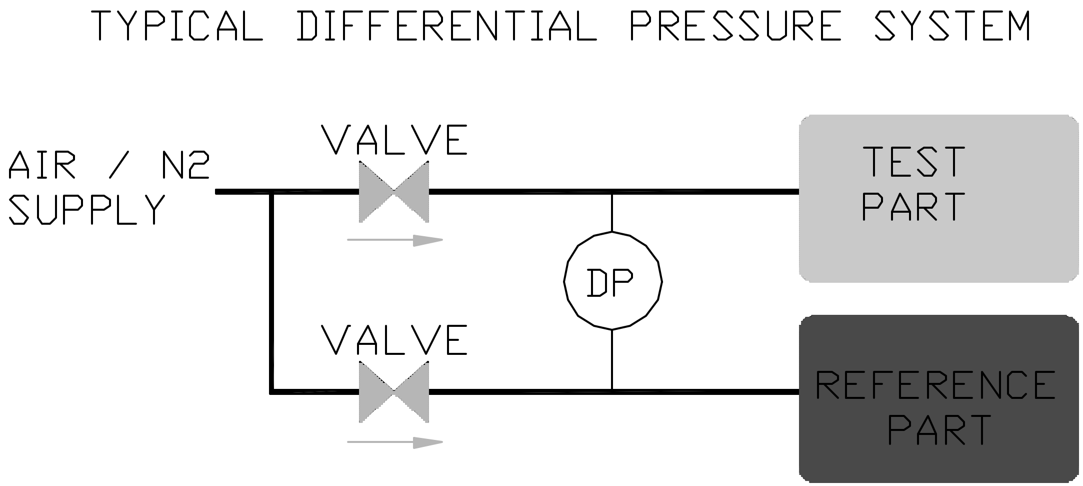
- Differential pressure uses a reference part along with the part under test. Under ideal conditions, the reference part is identical to the test part. A differential pressure transducer is connected to the reference and test parts and both parts are pressurized through valves to the test pressure. Once the test pressure is reached and stabilized, the valves feeding the parts are closed and the differential pressure is monitored over time. Knowing the part volumes, test pressure, and time, a leak rate can be calculated. In most real systems, there is an additional valve which bypasses the differential pressure transducer for a period of time called the stabilization period.

- **Advantages:** Superior to pressure decay in that adiabatic cooling and heating effects due to gas expansion and pressurization are cancelled. The differential pressure transducer can have a smaller range and be more accurate than pressure decay
- **Disadvantages:** Slow method of leak testing; very time dependent.

Differential Pressure



Differential Pressure

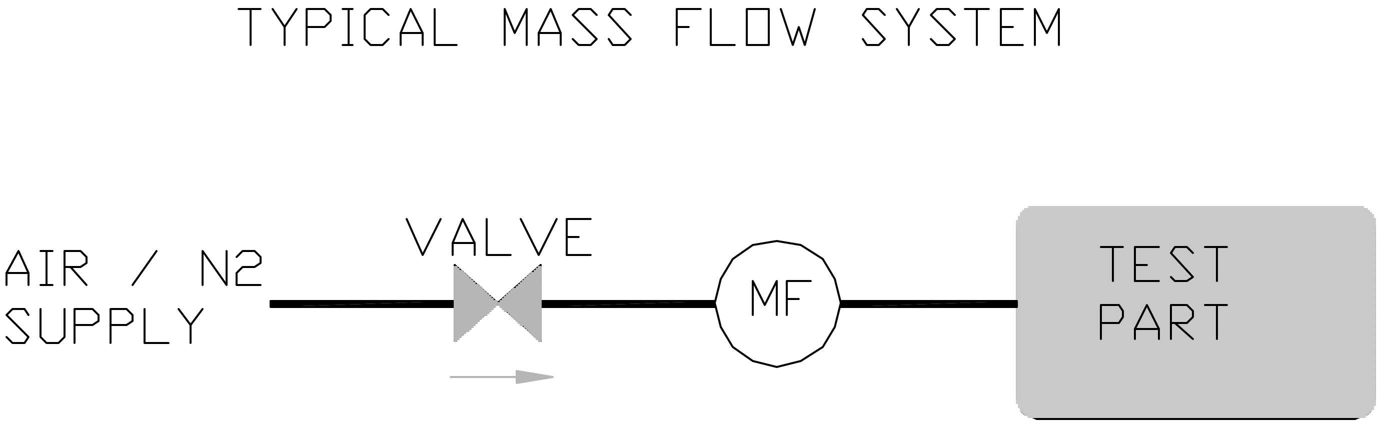


Mass Flow

- Mass Flow in its simplest implementation has the test part connected to the pressure source through a mass flow transducer. Once the valve is opened, air will flow through the mass flow transducer to fill the part. If there are no leaks, the flow will reach "0". If there is a leak, the value can be read directly from the measured flow without any calculations for pressure, volume or time. In most real systems, the flow transducer is initially bypassed by an additional valve to allow for rapid filling of the part under test.

- **Advantages:** Simple calibration procedures; fastest air leak system.

Mass Flow

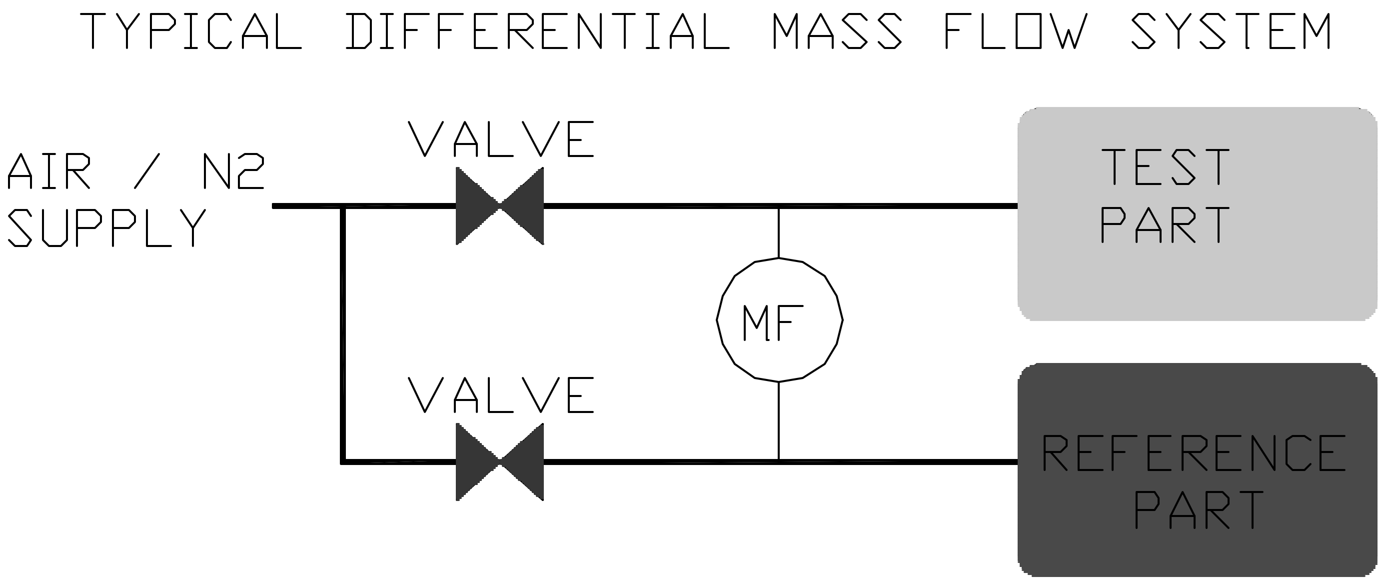


Differential Mass Flow

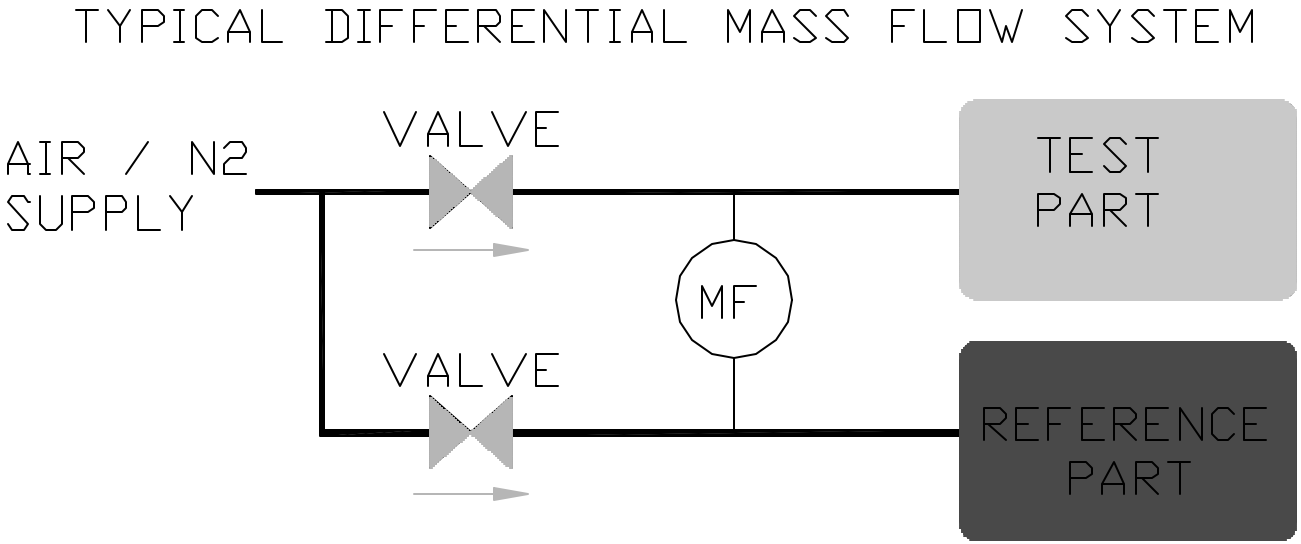
- Differential Mass Flow is similar to differential pressure except the differential pressure transducer is replaced by a mass flow transducer. This system has additional benefits from using mass flow.

- **Advantages:** Mass flow will give faster leak values than differential pressure; leak readings are not time dependent provided sufficient time is given for stabilization; simple calibration procedures; can add temperature compensation.

Differential Mass Flow



Differential Mass Flow



Testing Two Parts

- Using either differential pressure or differential mass flow, the reference part can be replaced by a second test part – allowing two parts to be tested at the same time – thus doubling throughput. Whether this is practical depends on the reject rate and the type of rejects.
- The danger of this method is that if both parts have nearly identical leaks, the test would pass the even though the leaks rates of each part may exceed the limit.
- In many real applications, the chances of two parts with the same leak rates being tested together is so remote that there is no danger of accepting “bad” parts.

Ideal Gas Law PV = nRT

- All air leak test systems are subject to the ideal gas law, where **P** = absolute pressure, **V** = contained volume, **n** = number of moles of gas (mass measurement), **R** = a constant and **T**= absolute temperature in degrees Kelvin
- For a gas contained in a closed volume, V, n, and R are all fixed which means P varies directly with T. In air leak testing, we are measuring **P**ressure (or more correctly the change in pressure), so therefore a change in Temperature will directly change our reading of **P**ressure and therefore our reading of leak rate.
- Leak rates are always given in standard units, most often **sccm** – standard cubic centimeters per minute at room temperature and atmospheric temperature.
- If we test a part at atmospheric pressure (14.7 psia), and that part undergoes a 1% change in temperature, we would expect a corresponding 1% change in pressure. Since we are measuring pressure change to determine leak rate, we would read a leak rate of 1% of the volume even though there was no actual leak.

Ideal Gas Law PV = nRT

- If we are testing at 150 psig, the 1% of volume would correspond to 1% X 150/14.7 or approximately 10.2 sccm. - **NB. - TEMPERATURE EFFECTS INCREASE AS THE TEST PRESSURE INCREASES**.

- Whenever a gas is compressed or expands, adiabatic heating or cooling takes place. When parts are air leak tested, the gas first expands and is the compressed as the part is filled to the test pressure. These adiabatic effects do not totally cancel but are minimized using differential measurement techniques.

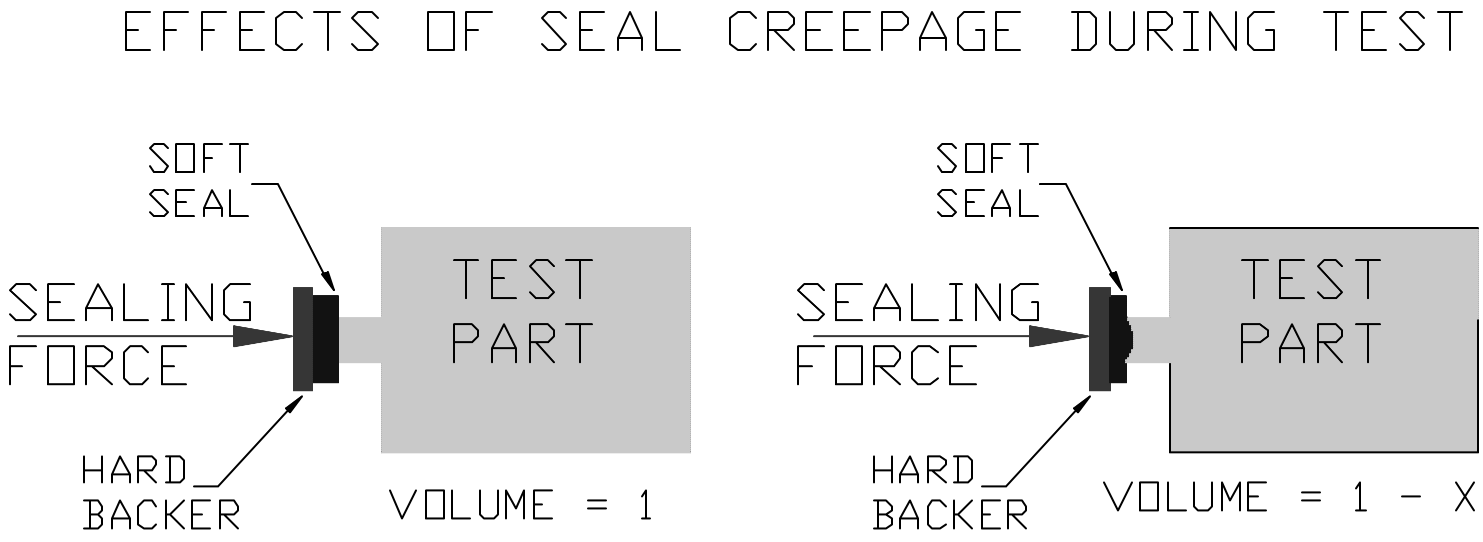
Seals and Fittings

- In air leak testing, there is always the problem of reliable sealing to one or more ports to the part under test. Every part presents its own unique problems.
- The higher the test pressure, the more demanding the seals become.
- The choice of materials and configuration depend on the part geometry and test pressures. The finish of the part in the seal area is also critical.
- Do not use push fittings for leak test applications even though they may be rated for the test pressures. Push fittings rely on air pressure to seal. Every time pressure is applied and released, these fittings “move” and find new seating surfaces. They may seal reiably 90% of the time but there is no guarantee they will seal every time.

Seals and Fittings

- We strongly recommend Swage Lok or A Lok fittings – stainless steel, if they are going to be re-used several times.
- Thick wall ¼” poly tubing works well with these fittings at pressures up to 150 psig.
- Many seals are actuated with either air cylinders or toggle clamps. If seal components are soft they can creep continuously under pressure during the test cycle. This creepage can result in the effective volume of the part being reduced during the test cycle, and from the ideal gas law, this will appear as an increase in pressure in the test part, thus possibly masking a real leak.

Seals and Fittings



Properties of Heat Exchangers vs Other Parts

- Heat exchangers present unique challenges to leak testing. It is not the actual temperature of the parts being tested that effects the measured leak rate, but the change of temperature of the part (and therefore the gas contained) during the test cycle.
- Valves, for example, tend to have a massive body with minimal surface area and are readily leak tested since their change in temperature to ambient is minimal during test.
- Heat exchangers tend to have low mass and high surface area and they will change temperature quickly if there is even a slight difference from ambient. Even small changes in temperature during testing can cause errors in leak readings greater than the specified leak rate.

Properties of Heat Exchangers vs Other Parts

- There are two solutions to overcoming these temperature effects with heat exchangers:
- The first involves setting up climate controlled areas for all leak testing and ensuring parts have stabilized to this environment before being tested.
- The second involves some form of temperature compensation in the leak test system.

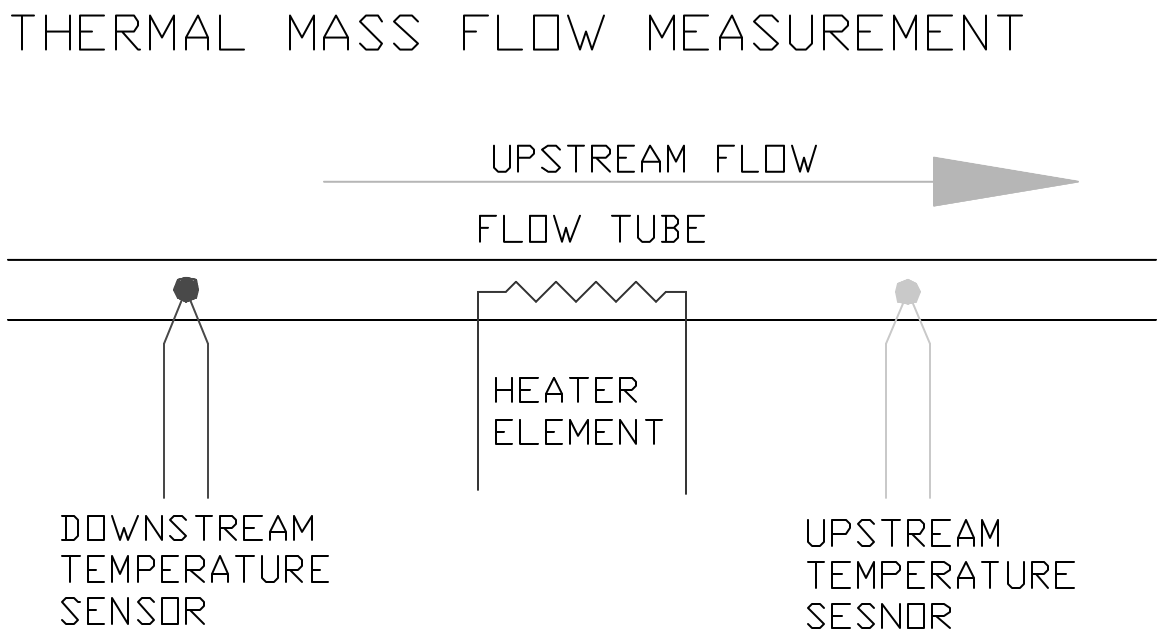
Mass Flow Technology – Correalis to Thermal (Automotive)

- Cost effective mass flow transducers have only become available in the last five years.
- Prior to this, measurements of gas flows were based on the Correalis Effect. These transducers worked on the principle that if a gas flowed through a tube with a 180 degree curve, the mass of the gas would exert a force to twist this tube and that this force could be accurately measured. As can be imagined, very small flows would exert very small forces, making measurement extremely difficult. These expensive systems needed to be isolated from all external disturbances by means of sophisticated shock mounts.

Mass Flow Technology – Correalis to Thermal (Automotive)

- The automotive industry's need for inexpensive, reliable, gas flow measurement has lead to the development of thermal mass flow measurement transducers for gases.
- These transducers have temperature sensors located before and after a central heating element. The temperature sensors are arranged in a bridge configuration to allow small differences in temperature to be readily measured. Any gas flowing through the transducer will pick up heat from the heating element and the resultant difference between downstream and upstream temperature is measured. Since it is the mass of the gas which is heated and its temperature sensed, this method is independent of gas pressure.
- In converting mass flow to volume flow, the specific heat of the gas is a factor.

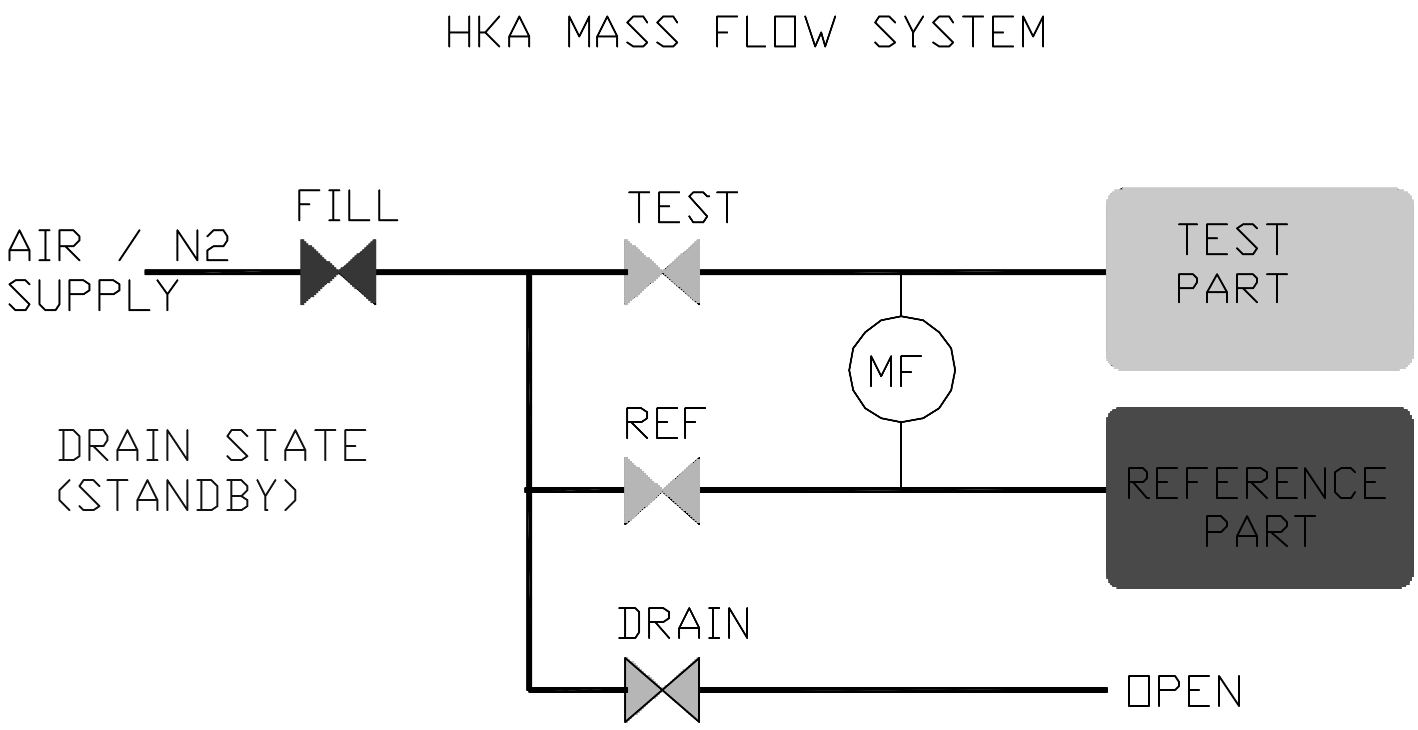
Mass Flow Technology – Correalis to Thermal (Automotive)



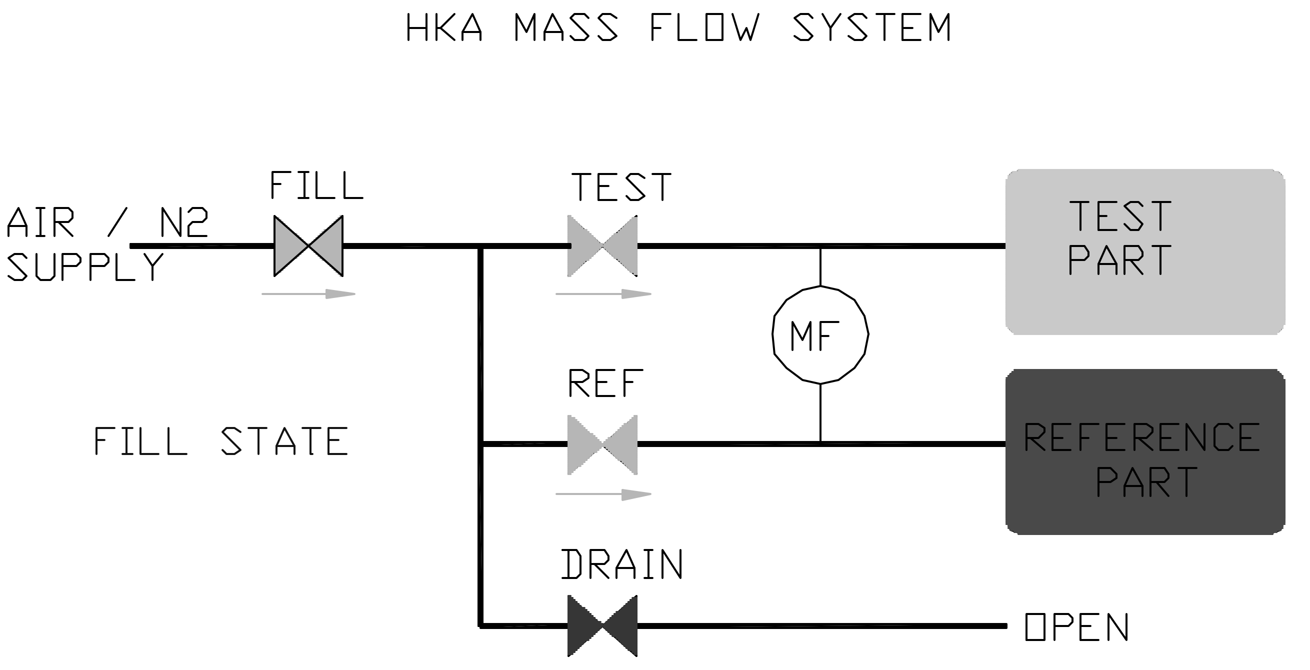
HKA Mass Flow Technology

- HKA has based its CT-1000 Leak Test Line on the latest mass flow technology.
- Our mass flow transducers are produced by Honeywell for the automotive industry in large quantities and provides us with excellent specifications and high quality at a low cost.
- The CT-1000 is configured for either mass flow or differential mass flow.
- The mass flow configuration is used for high leak rate products like mufflers at Tenneco Walker Exhausts with leak rates of 1.5 lpm or higher.
- A differential mass flow configuration is used for most Long Manufacturing applications.

HKA Mass Flow Technology



HKA Mass Flow Technology



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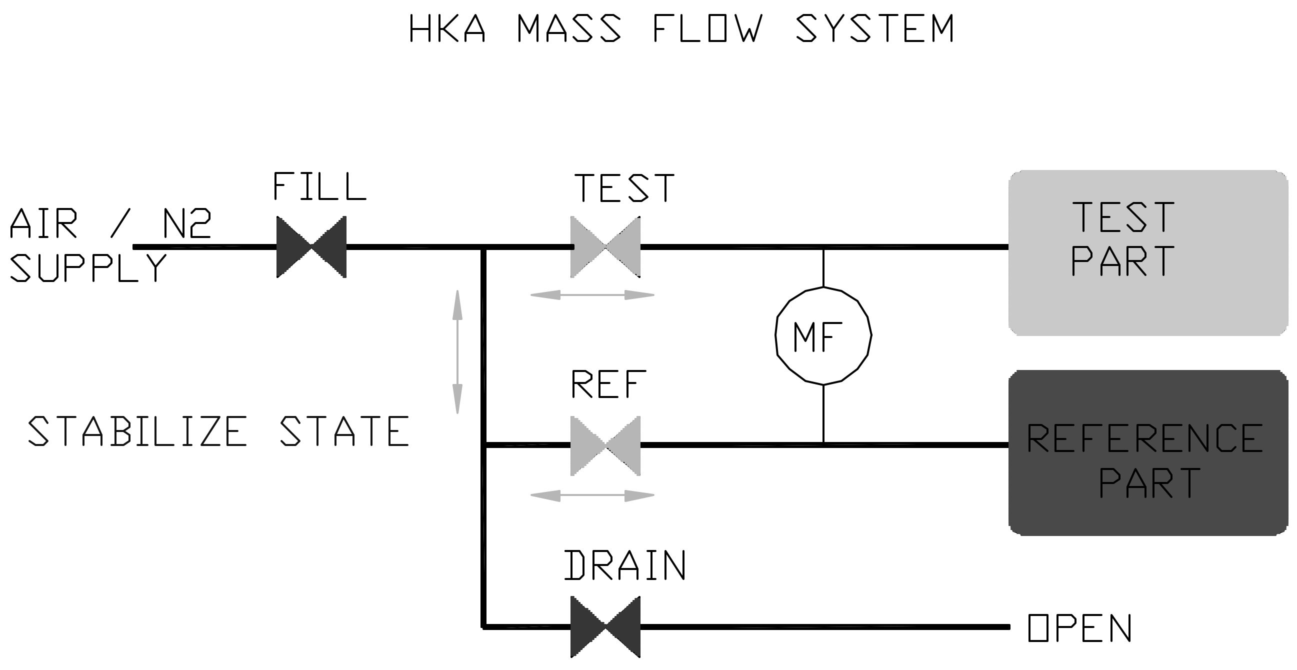

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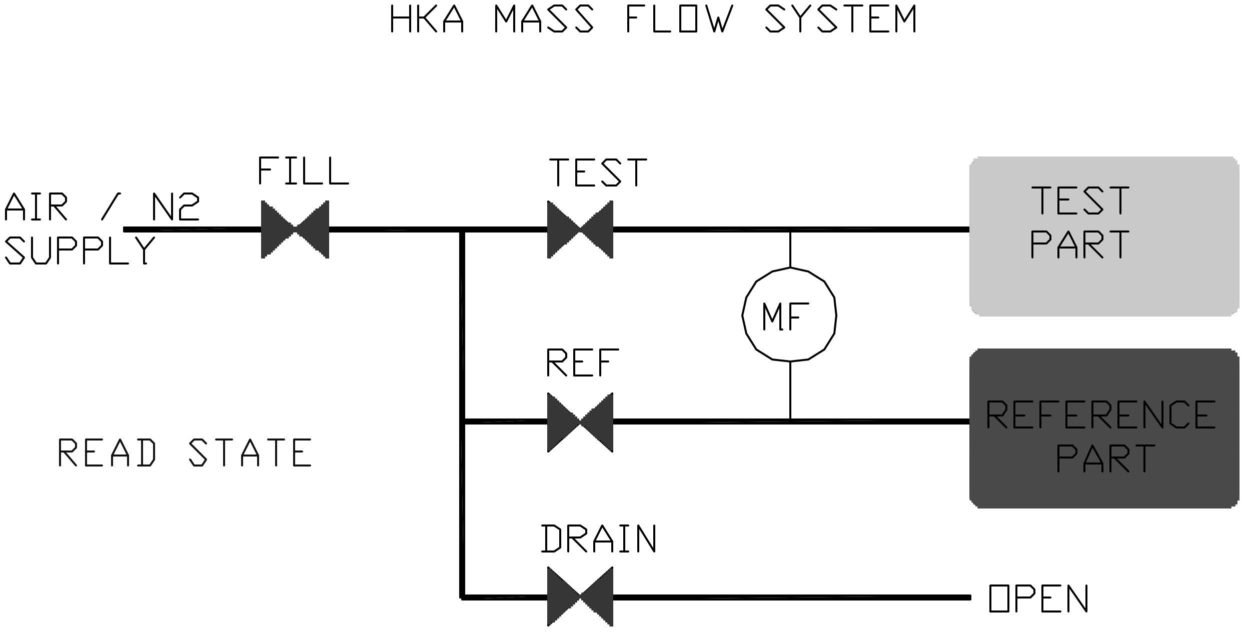


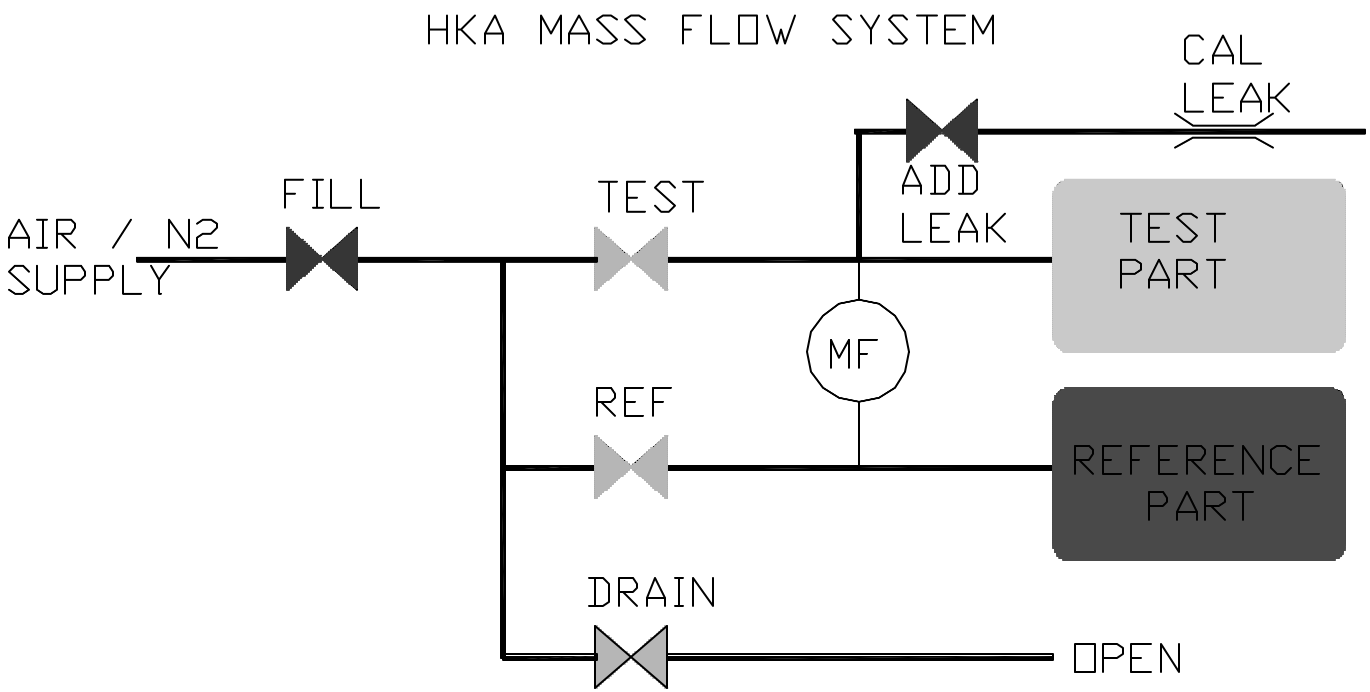
HKA Mass Flow Technology

- All CT-1000s are supplied with a calibrated leak. This allows for easy calibration for any application and provides for verification of system performance at any time. The calibrated leak must be at least 0.5 sccm at the specified pressure.
- Calibration should be done with two no leak parts.
- During calibration, the system performs two test cycles without the calibrated leak enabled and two cycles with the calibrated leak enabled. The first two readings and the last two readings are compared and if within 5% of the programmed leak limit, the calibration will be successful.
- By incorporating the calibrated leak and its control into our leak test system we have achieved the simplest calibration method of any leak test system available.

HKA Mass Flow Technology

- Every system is provided with a calibrated leak to meet the requirement of the particular application. The leaks are made for a given sccm leak rate at a given test pressure.
- We recommend that the calibrated leak be slightly higher than the leak limit.
- Using this method, a known no leak master part will always pass without the calibrated leak added and will always fail with the calibrated leak added.
- Operator verification of system performance becomes a daily (or more frequent) procedure.
- All of our stainless steel calibrated leaks are manufactured using NIST traceable instruments for pressure and flow.

HKA Mass Flow Technology



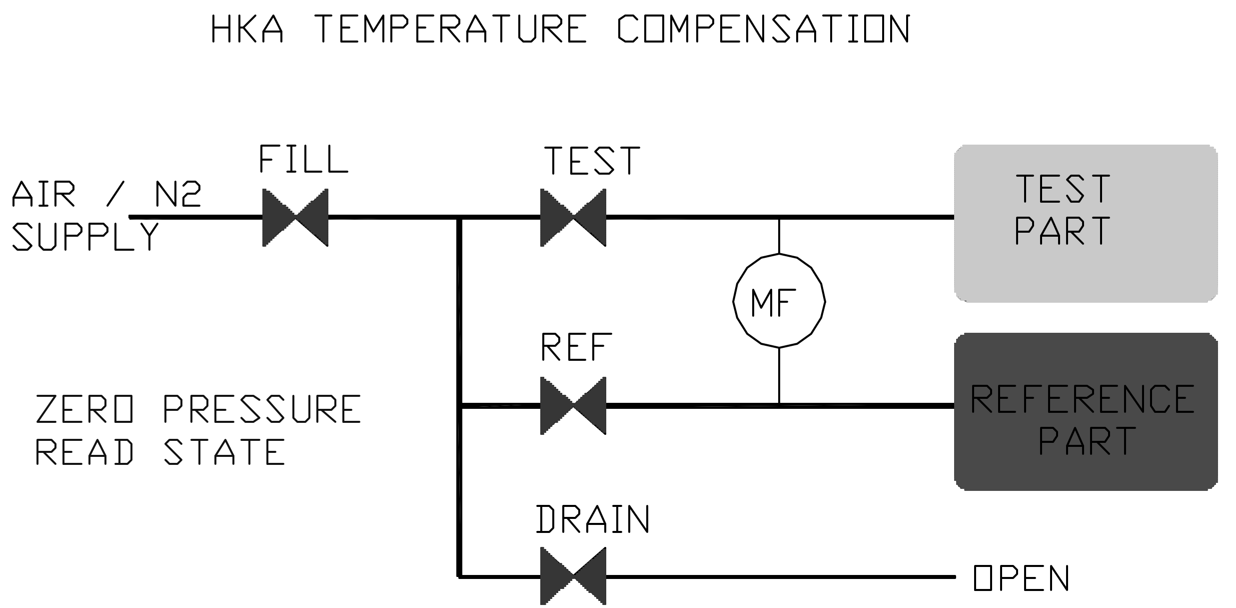
HKA Mass Flow Technology

- See Dwg 10 - Missing

HKA Temperature Compensation

- Our latest method of temperature compensation is based on measuring flow between the reference part and the test part prior to either part being pressurized.
- Any flow at this time is due entirely to pressure changes caused by temperature changes in the test part relative to the reference part during this measurement period.
- This measured initial flow is then multiplied by a flow factor (pressure dependent) and the result added or subtracted from the final flow reading.

HKA Temperature Compensation



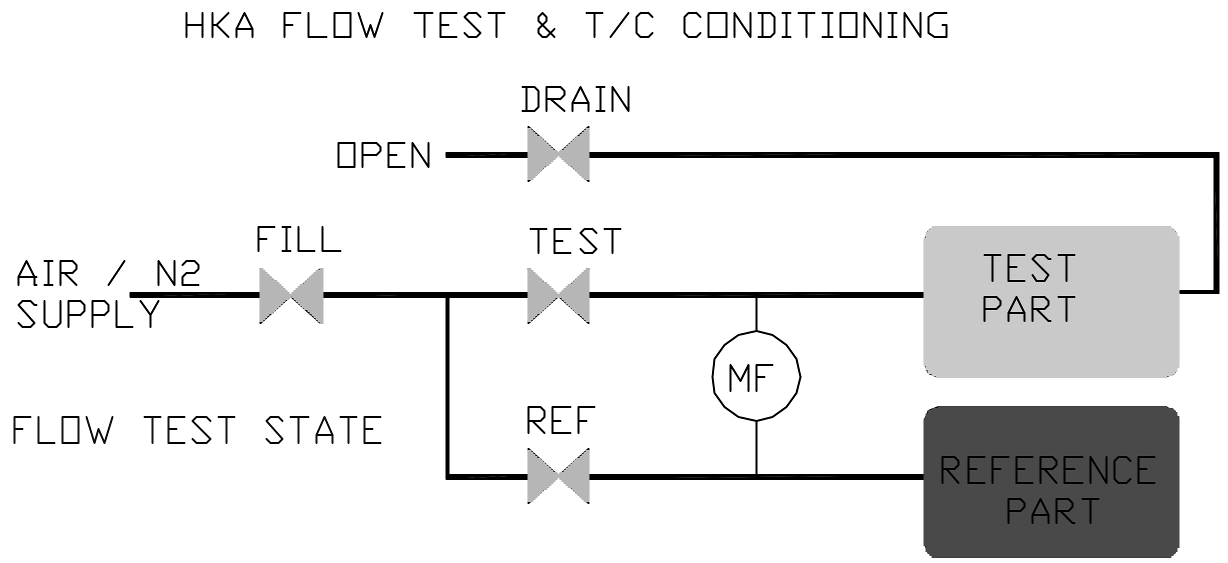
HKA Temperature Compensation

- We have always noticed a slightly higher leak reading of the first test of a given part relative to subsequent tests done in succession on the same part. This effect was more evident with heat exchangers.
- Diesel fuel coolers which have restricted flow passages (higher flow restrictions), have a significantly higher first leak reading compared to subsequent tests.
- We have found that by passing substantial air flow through the cooler prior to the initial flow measurement, the measured flow for temperature compensation purposes is accurate.
- We have also found that if we have this initial air flow through the cooler prior to leak testing, the initial value is no longer higher than subsequent values.

HKA Temperature Compensation

- There appears to be a need to condition the cooler prior to leak testing or temperature compensation reading.
- We are looking at having this initial flow controlled by the CT-1000 rather than a PLC. We will be able to upgrade existing CT-1000 units for this feature.
- We are also looking at adding a flow test to the CT-1000 to ensure that there are no obstructions and we can fail coolers with partially blocked passages.

HKA Temperature Compensation



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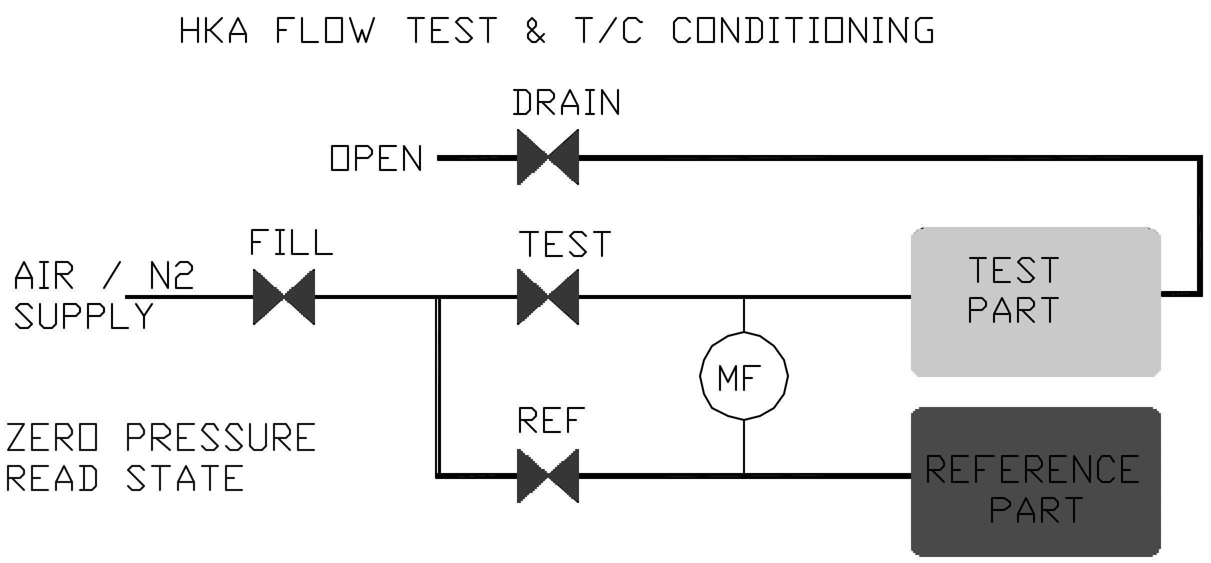

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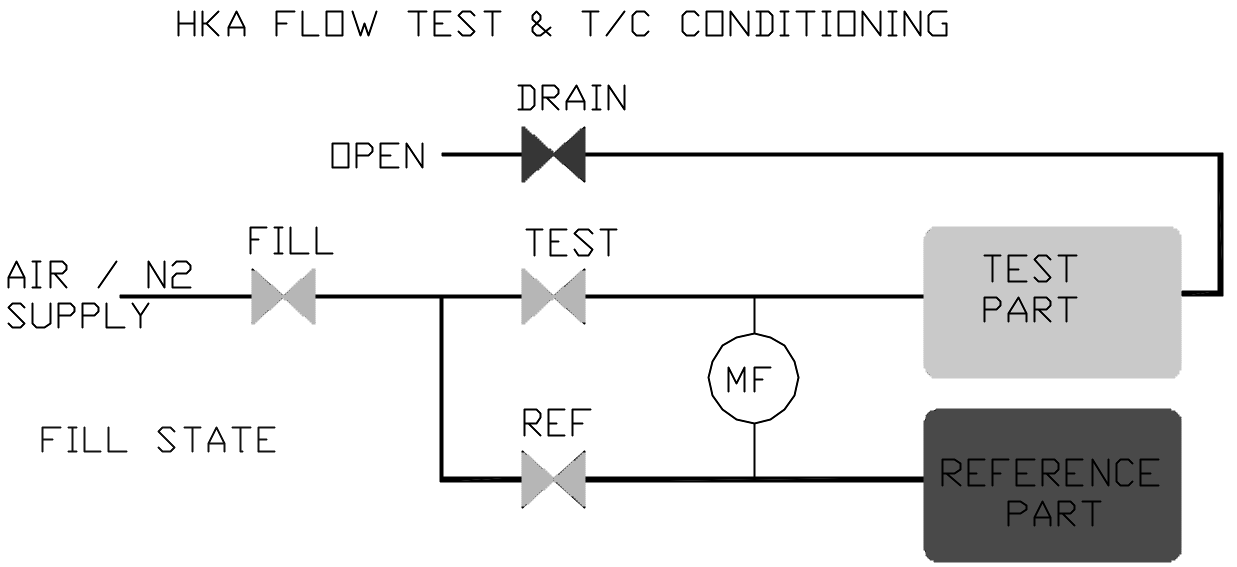

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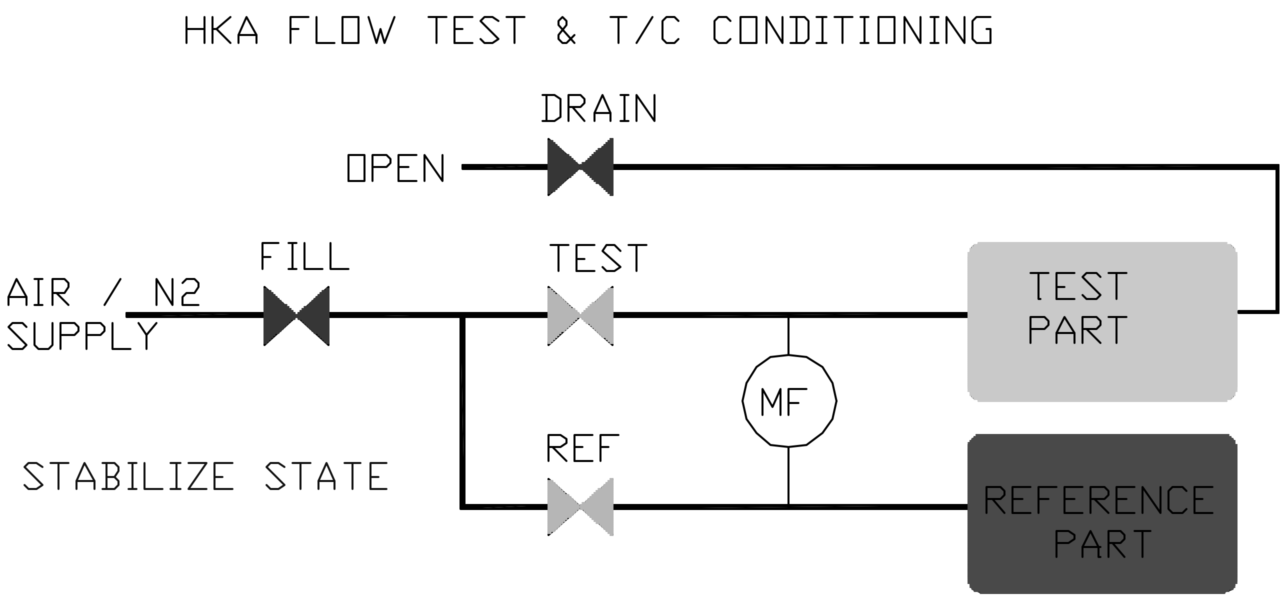

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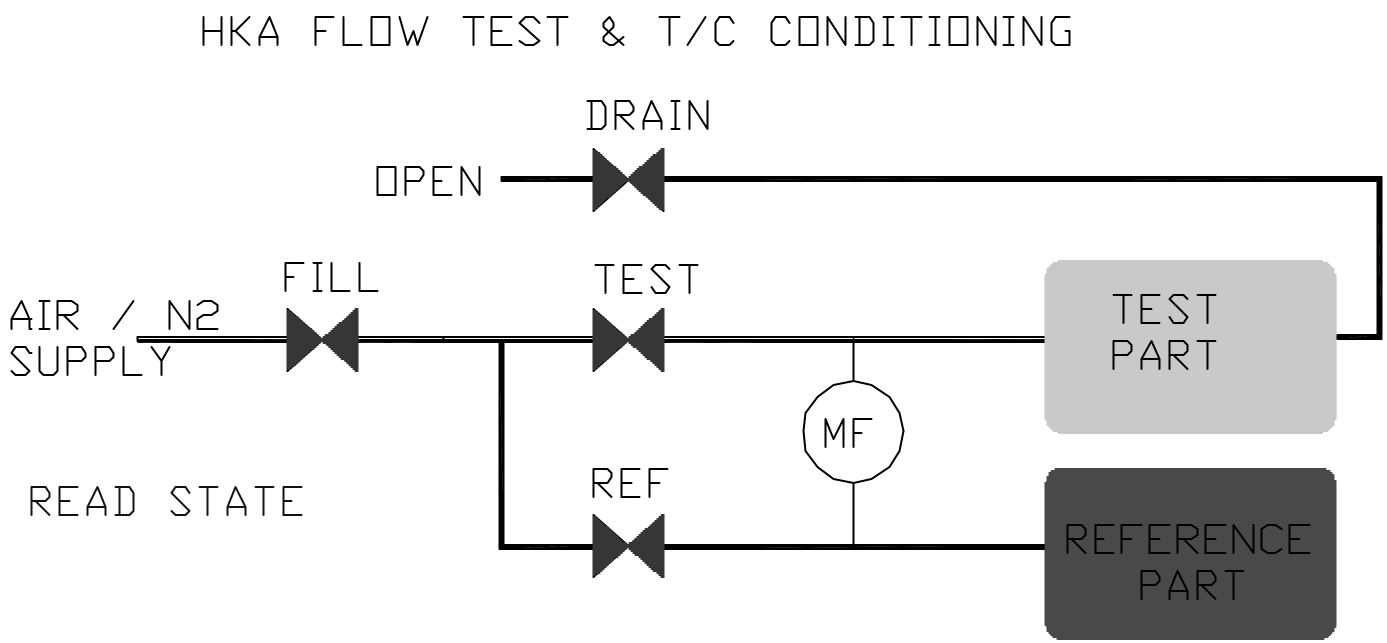

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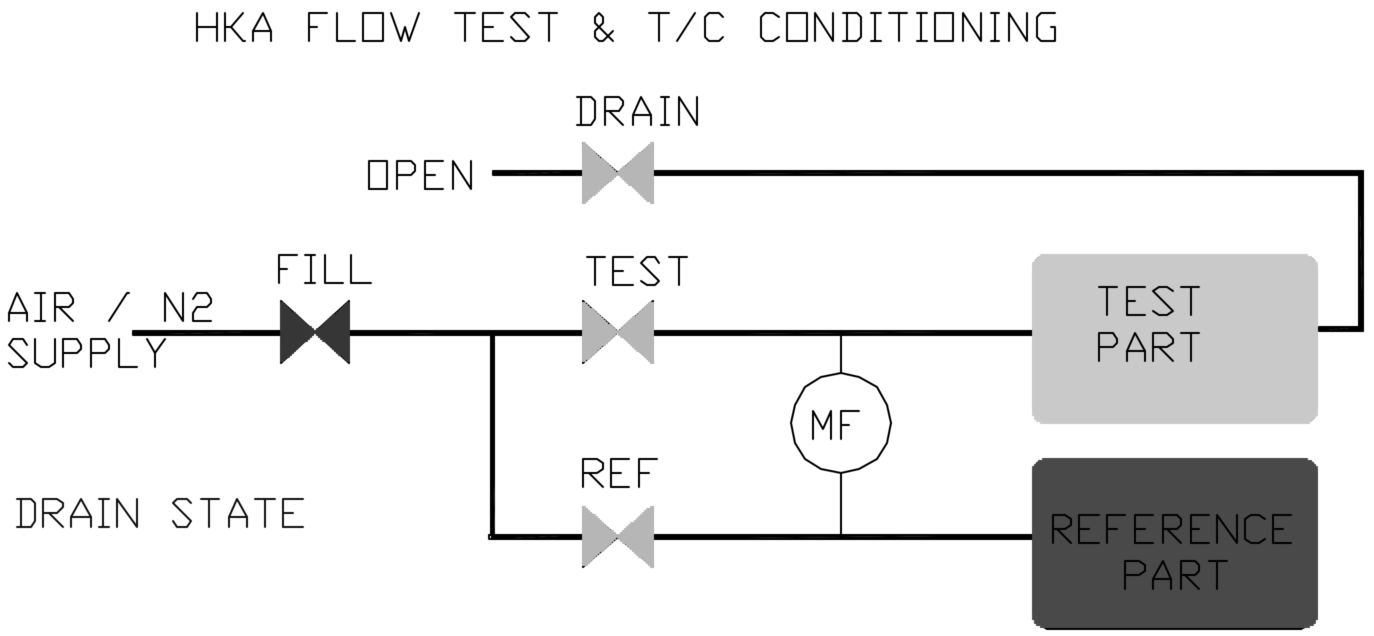

Thank you!

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