White Paper

InterTech

Test Centric Assembly

Test Centric Assembly is a guide to failsafe leak testing for any test-intensive assembly operation. It defines strategies and technology to achieve perfect confidence in test readings. This white paper is for mechanical engineers, quality engineers, management and those whose goal is to detect leaks, avoid unnecessary production cost and anticipate process adjustments for maximum yield.

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About the Author : Jacques Hoffmann, President, InterTech Development Company

Jacques Hoffmann is founder and president of InterTech Development Co., a world leader in test-centric assembly specializing in automated leak and functional testing with mass flow, hydraulic, helium, or pressure decay technology (ISO-17025 accredited). InterTech engineered solutions are used by hundreds of quality management, product design teams, and manufacturers worldwide and the company's worldwide support organization maintains offices in North America, Asia, and Europe.

For more information, contact Gerald Sim at gsim@intertechdevelopment.com, (847) 679-3377, or visit www.intertechdevelopment.com.

Introduction

Test Centric Assembly is the design and engineering of assembly systems with priority to failsafe / foolproof testing. The goal is perfection. The result is improved throughput, yield, system uptime and time-to-market. When leak testing is an afterthought – just another engineering add-on – personal and corporate reputation is needlessly at risk.

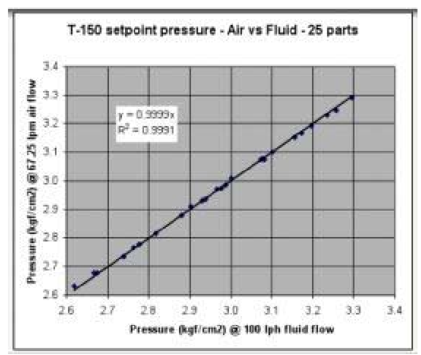
For everyone's sake, Test Centric Assembly requires an uncompromising commitment to reliable leak testing. This is why for more than 40 years, **InterTech Development Company** has developed and refined Test Centric Assembly for leak-testing-intensive production engineering.

Test Centric Assembly as a Strategy

As a strategy (not just a process step), Test Centric Assembly requires that test engineers be granted equal place on the teams that design / engineer production and assembly systems.

Why? Because losing control of quality from bungled implementation of leak testing can be devastating. A few moments of reflection confirms the precious benefits of Test Centric Assembly in terms of…

- The direct costs of rework, re-inspection, and re-testing of rejected shipments (if the shipment was not scrapped).
- Product recalls erode profits and can even trigger a slide into corporate insolvency.
- The myriad negative consequences of a systemic quality failure such as permanent damage to corporate and personal reputations.



… All of which is entirely avoidable.

This white paper is specific to leak testing and examines how to achieve failsafe leak testing. It is Test Centric Assembly for mechanical engineers, test engineers and management. It shows how collaboration of testing expertise and production planning creates faster, more flexible and cost effective assembly. Tools of the trade are set forth in this white paper with a basic review of leak testing technology.

Test Centric Assembly Builds Confidence

It may be difficult to accept that leak testing can be perfect, but that is the goal of Test Centric Assembly. We are not talking about a product; this is a commitment, with emphasis on reliability of the gage. This commitment extends from the instrument to the entire system. Only when the entire system is treated as a gage can there be confidence in test results.

InterTech is asking systems designers – and test engineers – to rethink how they design and build production systems. Leak testing must be upfront in the considerations of all teams involved in production to maximize returns in yield, throughput and time-to-market.

With Test Centric Assembly, specific attention is paid to processes that go into production such as how a product is sealed, filled and stabilized. Everything for the test process is optimized, including considerations for thermal effects such as ambient or part temperature.

For companies with long-entrenched habits of engineering (and devotion to the status quo), it may seem audacious to challenge leak testing tradition. However, modern manufacturing has taught us how important it is to take critical views, innovate and improve.

ROI for Test Centric Assembly

Return on investment from Test Centric Assembly goes very well with new manufacturing trends and automation. It embraces the era of flexible manufacturing and technology such as Ethernet and statistical process control. In full bloom, Test Centric Assembly is a trusted source for data in leak detection, which is one of its greatest values.

Test Centric Assembly pays for itself in many ways…

- Rework is cut by 20% or more, partly because only good parts are shipped to customers; partly because problems are identified early and fixed sooner.
- Insurance against blown budgets and tarnished reputations when leak testing process decisions take place upfront (no more re-engineering of a production line to achieve quality).
- Process improvements include the advantage of fewer test stations (often by half) which leads to CAPEX savings of 50% or more.
- Perfection is attained in details of Gage Repeatability and Reproducibility, creating reliable, useful feedback for more efficiency.
- Less maintenance and sometimes a reduction in consumables such as helium.
- Ethernet capable and network ready for maximum efficiency and asset utilization.

Test Centric Assembly has a ripple effect. It is the central focus of production and radiates to faithful performance of a product throughout its life. Test Centric Assembly is innovative, flexible and intelligent, with instruments that are able to control stations with or without additional PLC's.

If this approach makes it necessary to rethink leak testing technology and processes as a way to lower costs and increase yields then so be it, indeed, all the better for throughput, uptime and bonuses.

Test Centric Assembly is much more than "out of the box" thinking. It is the lean manufacturing equivalent of testing.

Start Dry

Dry air is the testing medium of choice in everything from catheters and assisted breathing devices to heat transfer units, solenoid valves and hydraulic systems. Air is the preferred test medium because in most cases it is more accurate, faster and less mess.

Hydraulic and helium testing require more care and maintenance than dry air testing. If testing cannot for some reason use plain, dry air, then Test Centric Assembly still applies because upfront consideration of pressures, temperatures, flows and consumables provide guidance on production design before lines and budgets are finalized.

There is no standard answer as to which leak testing method is best suited for a particular application. Extreme conditions may call for use of hydraulic fluids, helium or water (for dunk testing), but these are confined to a narrow range of specialized applications. Dry air testing alternatives allow OEM's to ship dry parts thereby saving on dunnage, cleanup, expensive equipment and consumables.

Advances in leak testing technology, particularly mass flow, make it possible to eliminate messy fluids and expensive helium for a growing number of leak test scenarios. See Exhibit 1 for a glimpse into how specialized mass flow leak testing offers economical alternatives to helium in compressed natural gas (CNG) fuel system production.

Direct and Indirect : Comparison of Mass Flow and Pressure Decay

In leak testing, there are two predominant test methodologies with dry air : Mass Flow and Pressure Decay. The first provides a direct measurement of leakage; the latter is indirect.

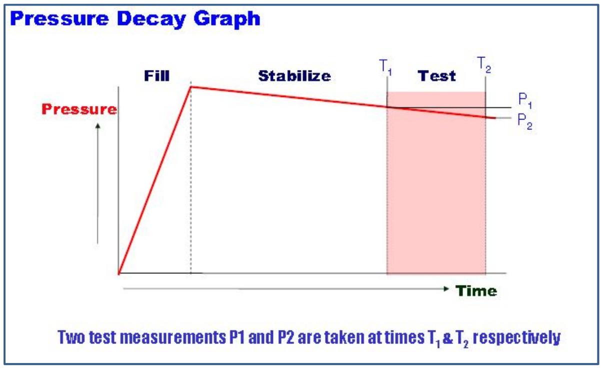
As a direct measurement of leakage, mass flow is a one-step process : the sensor registers pressure change as it happens. An indirect way to measure leakage is with pressure decay, which takes two readings over a set time, thus two steps are required compared to one with mass flow.

When engineered as a Test Centric Assembly system, the leak tester automatically compensates for and manages all variables in the widest range of applications.[1] As speed criteria increases, the one-step, instantaneous nature of mass flow translates to fewer test stations than are needed with pressure decay, which is a revelation in cost savings.

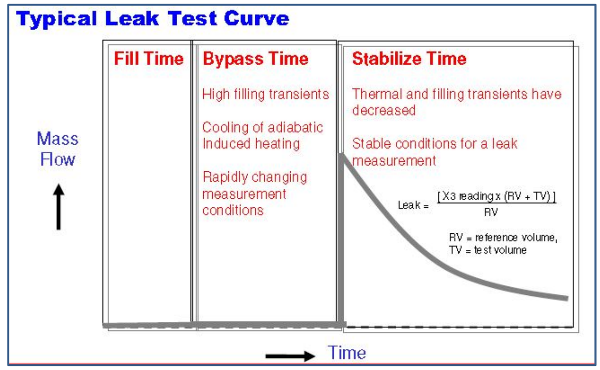
[1] Patented InterTech mass flow systems actually measure leak flow as soon as there is consistent flow after stabilization, allowing real time leak tests to occur. When pressure decay systems start testing, mass flow is already finished. This is a huge time saving advantage (20% to 30%), and the larger the part (more volume) the greater the advantage for mass flow technique.

Graphs 1 and 2 provide a side-by-side comparison of the essential processes for pressure decay and mass flow.

Graph 1 : Pressure Decay



Graph 2 : Mass Flow



With pressure decay it is necessary to calculate how much pressure would decay based on the flow, which is like backtracking to get readings. This technique requires steps to fill, stabilize, test and do the calculations. Since mass flow measures flow in real time, at the end of the stabilization period, it saves time – some 20-percent or more – over pressure decay and differential pressure decay (or rise).

Mass Flow and Resolution

Few realize that commercially available mass flow sensors are not designed for leak testing. They are multipurpose devices with myriad applications, and typically used for leak testing only at high flow rates.

On the other hand, when designed explicitly for leak testing, mass flow transducers can detect leaks as small as 0.01 sccm. Specialized sensors are 5,000 to 10,000 times more sensitive than commercial mass flow sensors, hardy enough for the toughest industrial environment, and specifically engineered to measure very low flows.

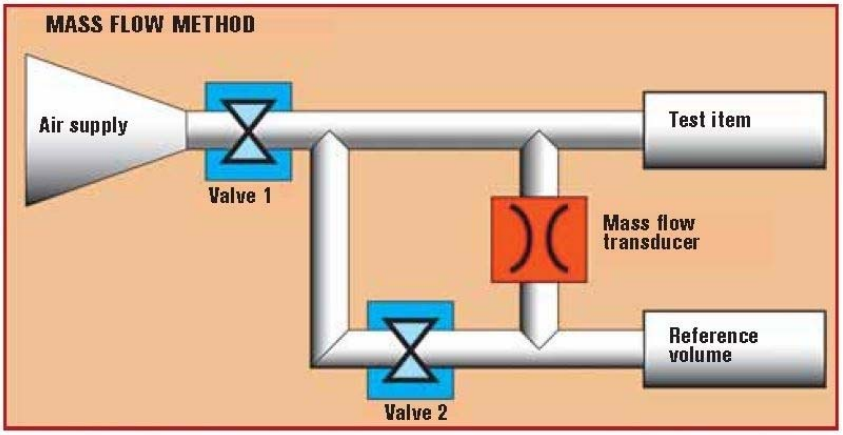
Mass flow leak testing technology for Test Centric Assembly handles temperature effects with built-in ease and speed. Commercial off-the-shelf mass flow transducers do not have this capability and should be avoided.

Once enlightened about Test Centric Assembly and innovative technology, practical application reveals hard savings for the bottom line. In one real world example, a company known for its fuel system parts (carbon canisters) proved to itself the value of Test Centric Assembly. See Exhibit 2.

> “ *To this day, many mistakenly use much more expensive helium leak-testing methods because they do not appreciate that state-of-the-art mass-flow leak detectors can achieve required accuracies.*
>
> –JACQUES E. HOFFMANN, PRESIDENT

Leak Testing Circuits 101

Figure 1 describes the mass flow leak testing process in simple terms. Air is supplied simultaneously to the test item and a reference volume. Valves shut off the flow and isolate the test item from the reference volume. A transducer generates an instant, quantitative measure of leakage derived from a reading of the reference volume and test volume. It is expressed as:



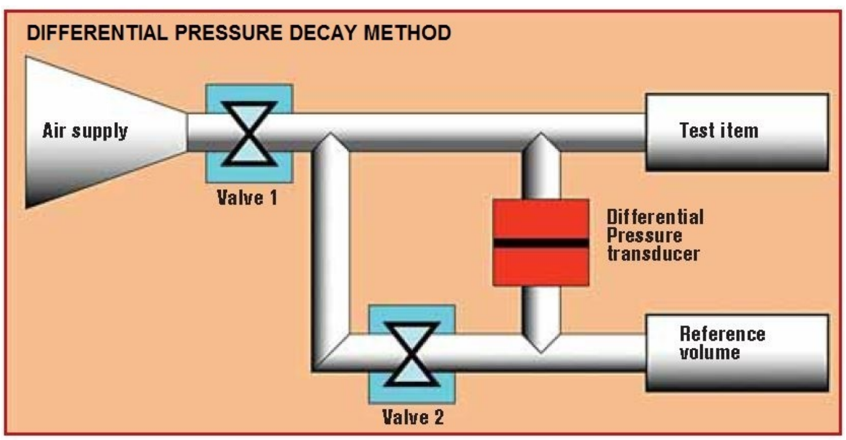
▲**Figure 1 : Mass Flow.** The test item and reference volume are pressurized and then isolated from the source by closing valve 1. Reference volume is then isolated from test item by closing valve 2, but they remain connected through a mass flow transducer. As air leaks from the part, the pressure in the part drops, and air flows through the transducer from the reference volume into the test part. The leakage flow is measured directly in sccm.

$$X1\left[\frac{RV + TV}{RV}\right]$$

X1 = mass flow transducer
RV = reference volume
TV = test volume

An astute observer would wonder about variables that affect accuracy in leak testing. What of adiabatic effects, for instance? Best-in-class mass flow systems manage this and other variables automatically which removes operator error and complements Test Centric Assembly.

Differential mass flow (Figure 2) is a leak testing method well suited to applications where time is in abundance. It requires a substantial pressure drop across the sensor to get a reading and is best suited for measuring large flows.



▲Figure 2 : Pressure Decay - differential pressure. Test item and reference volume are pressurized and then isolated from the source by closing valve 1. Reference volume is then isolated from test item by closing valve 2, but they remain connected by a differential pressure transducer. Transducer reads pressure differential between non-leaking reference volume and leaking test item twice over a known time interval. The leak rate is calculated from the change in pressure and the time over which it occurred.

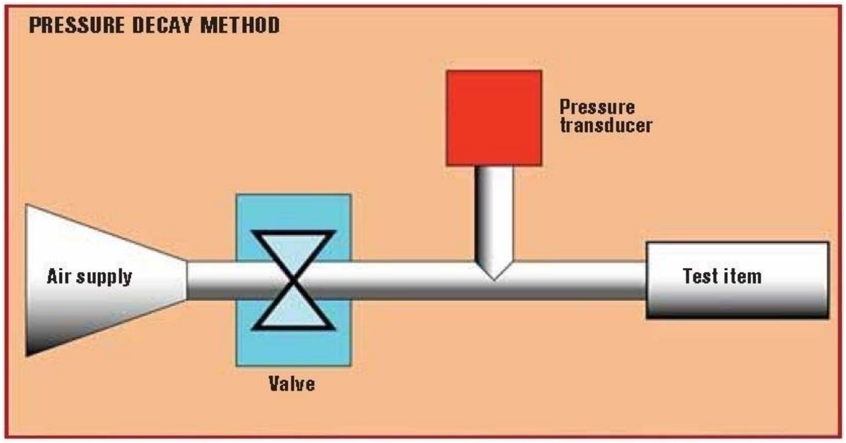
Differential pressure decay systems use commercially available mass flow sensors and are capable of readings no less than 1 sccm, but resolution is hundreds of times better than simple pressure decay (Figure 3).

In both types of pressure decay methods, the leak rate is calculated as…

$$\text{Leak} = \frac{P\Delta \times \text{volume}}{\text{test time}}$$

$P\Delta$ = pressure change

…where: pressure change = pressure @ T0 - pressure @ T1. Computation of the leak rate is a comparison of the change in pressure and the time over which it occurred. As time increases, there is heightened risk of error from singularities such as vibration or drafts.

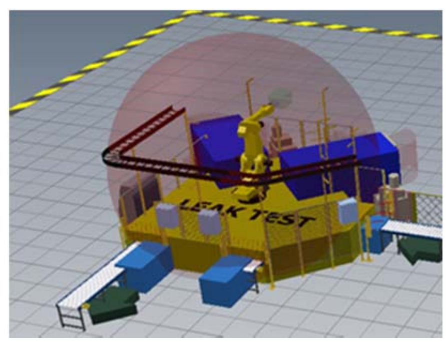


▲Figure 3 : **Pressure Decay.** Test item is pressurized from air supply line then isolated by closing valve. Pressure transducer reads loss in pressure from isolated item twice over a known time interval. The leak rate is calculated from the change in pressure, and the time over which it occurred.

Sophisticated sensors, electronics and specialized programming make leak reading a quantitative measure of product quality. There are many ways to achieve leak testing, but when company and product reputation are on the line, it pays to consider every factor in advance.

Leak Testing with Advanced Automation

Advanced manufacturing with robots, mechatronics and real-time data for statistical process control places difficult and sometimes contradictory demands on test intensive production. For instance, many testing methods cannot reconcile fast test times and rigorous standards of reliability and accuracy. This is compounded by requirements to detect very small leaks economically.



Leak testing is used to measure a variety of attributes, such as:

- Porosity
- Seals
- Assembly deficiencies
- Fit and function
- Fastening and joining

Leak testing is no longer just a tool for pass / fail, but helps with quality and warranty considerations or validates new materials and different assembly methods. Under these conditions, the optimal course is to plan and implement leak testing up-front as prescribed by Test Centric Assembly.

Ethernet and I/O Connections for More Control

With the relentless pursuit of shorter production runs and greater product variety, it is imperative to have fast, accurate, economical assessment of final test results. The best test instruments have Ethernet capability to ensure seamless integration into existing factory networks for maximum traceability and compliance with ISO 16949 requirements.

Leak testing equipment should include I/O ports to work with barcode scanners, sensors and light curtains. Remote diagnostics are another possibility with Ethernet connections. When these considerations are taken in advance, the design team may even use leak testing instruments to replace expensive PLCs.

Today's manufacturing systems generate a prodigious amount of data that can be leveraged to improve the assembly process. For instance, it is possible to correlate quality to torque readings from assembly equipment and other variables such as range settings in vibration welding or press forces. Information from real time graphs helps with diagnosis and process improvement.

Traceability and Test Centric Assembly

More stringent government regulations and higher production standards are drivers for traceability.

Traceability is vastly improved through Test Centric Assembly. Upfront consideration of part testing includes the ability to track product and report the condition of the parts to the control system. Test Centric Assembly uses poka-yoke and other methods to know if the right part is present and if the assembly passed or failed a test.

A Test Centric Assembly system includes a method of handling and tracking good parts versus rejections. For instance, good parts may be laser marked and continue while rejects are identified and diverted.

Test Centric Assembly assures no good part is misclassified as bad, which is just as important as the reverse. Misclassifying good parts as bad ones points to bigger problems in production and assembly.

Failsafe Leak Testing

Failsafe leak testing requires that systems be calibrated and validated frequently.	**Accurate leak testing demands failsafe mechanisms for circuit switching and verification that valves involved in the test circuit are fully operational at every test.**

Gage repeatability and reliability (GR&R) is so ingrained with Test Centric Assembly that it extends from the testing instrument to the entire system, which effectively eliminates wasted time on retests.

Perfection is the goal of failsafe leak testing so it cannot be an afterthought or add-on. Mistakes are intolerable, and as experienced test engineers know, there are best practices that anticipate and neutralize all factors that can undermine leak testing integrity.

Since mass flow designed for Test Centric Assembly is recommended for the widest variety of applications, automatic compensation for temperature effects is essential for reliability. It is important to know this obstacle was overcome decades ago thanks to innovative, solid-state design of specialized anemometers.

Solid-state design allows test instruments to automatically compensate for adiabatic effects, volume changes, cooling rates, and the physics of volumetric flow. There are patented designs for “micro flow” that even regulate turbulence. This improves response rates of leak testers, and there are other techniques used by testing specialists to limit the “noise to reading” ratio.

Calibration and validation are crucial to failsafe leak testing, and it is best when the leak testing system checks itself. Traditional manual methods are prone to operator error, and therefore not optimal for failsafe leak / Test Centric Assembly.

Test Centric Assembly places a premium on reliability, so there must be a failsafe mechanism for circuit switching as well as verification that valves involved in the test circuit are fully operational at every test.

All this and more is explained briefly in this white paper, and engineers who have a singular focus on leak testing can elaborate when called upon, which should be at the very beginning of production line design.

Calibration and Validation

Test systems must be calibrated and validated frequently. Mistakes are common with error-prone mechanical calibration methods, such as pneumatic valves that wear and can stick or small orifices that can clog, expand or contract. Test Centric Assembly systems use electronic calibration methods that are faster and more reliable.

Additionally, regular checks should be built-in to test processes. For example, in mass flow testing, it is impossible to know if a valve is working when tested at zero pressure from atmosphere. A zero leak measurement could be due to a dysfunctional valve or plugged line.

Given these concerns, best-in-class mass flow testing uses a bias leak that verifies the entire system is working. If valves are not operating correctly or test seals are insufficient, the bias leak will not be detected which triggers corrective action.

Importance of Precision Fixtures

Automation engineers are experts at creating fixtures for rapid assembly throughput, but may be surprised to learn their techniques are detrimental to failsafe leak testing. Jigs and fixtures for assembly often have different, even conflicting requirements to those needed for accurate leak testing.

Leak testing a part demands it be constrained securely in position so off-the-shelf fixtures are almost always inadequate. For example, when automatically driving screws through an assembly, it is normally best to have a fixture with some float around holes so screws center themselves. Beware! Any physical dislocation between seals of the testing instrument and the part being tested results in seal creep.

Likewise, excessive clamping force can mask leaks. Consider a welded part (ultrasonic, MIG, TIG or otherwise). If the weld opens up under pressure, testing needs to detect a leak into the atmosphere. If the fixture restrains motion of the weld, a bad part may pass.

There are many concerns with leak testing fixtures. Clamping pressure can mask a leak. Testing creates wear, so the finish on a test fixture may need to be superior to those for assembly. If helium is used for testing, care must be taken so that none is trapped in the seals to contaminate subsequent tests.

Sometimes, a part must be tested in the same orientation it will assume in the field. Automotive valves and respirator components for assisted breathing devices often have this requirement. On another note, O-rings or paper gaskets would never hold up under constant testing so test fixtures must emulate parts like these.

For all these reasons, and to avoid re-engineering costs later, engineers are well advised to consult with test equipment suppliers on fixture design before production plans are frozen. Exhibit 3 provides a real-world example.

Conclusion

Engineers with leak testing expertise are vital to system design of any production line where testing is essential to the production process. With Test Centric Assembly, management is empowered to be proactive, and not forced (so to speak) to react to relentless demand for heightened tolerances and traceability.

When a machine builder offers to provide testing, make sure they understand and are committed to Test Centric Assembly.

Exhibit 1 : CNG Testing with Mass Flow instead of Helium

Some natural gas vehicles are hybrids that utilize gasoline or natural gas with the aid of a retrofit from authorized suppliers. One OEM with a special reputation for being built "- - tough" uses components tested by InterTech for their bi-fuel engine systems. If you've driven one lately, you might not know when it changes from one fuel type to another (except for indicators on the instrument cluster). Nevertheless, whether it is a diesel fuel filter or a CNG valve at work, performance is guaranteed. And, once again, InterTech's patented mass flow sensors and turnkey systems handle the high-pressure application specifications…

In one case, a gas conditioning module is functionally tested for stability:

- Apply high pressure Viscor 1487 to the diesel inlet port and gaseous nitrogen to the CNG inlet port.
- Monitor the CNG outlet pressure and leakage at the vent port for 30 seconds (verify constant pressure of CNG outlet port and no variable leakage at the vent port).

In another case, there is functional testing of outlet pressure vs. dome pressure…

- With a pressure transducer connected at the CNG outlet, apply high pressure Viscor 1487 to the diesel inlet port and GN2 to the gas inlet port.
- Increase the Viscor pressure over 30 seconds and record the CNG outlet pressure with the transducer in 10 Hz increments.
- Repeat this process reducing the dome pressure 30 seconds, and record the outlet pressure with the transducer in 10 Hz increments.

With patented design of mass flow sensors and Test Centric Assembly design, InterTech mass flow systems work in situations often thought to be the domain of more complex (and more expensive) helium mass spectrometry. InterTech mass flow systems have the resolution and GR&R to inspect for internal leakage of the regulator and relief valve, flow change pressure, verification of manifold pressure sensor, bleed flow and torque confirmation and more.

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Exhibit 2 : Case Studies in Test Centric Assembly

An automotive manufacturer of intake manifolds uses Test Centric Assembly to check subassemblies at various steps in the assembly process. In this way, they avoid adding excessive value on defective assemblies.

For instance, after the part is welded a robust, high-pressure leak test is applied. Later in the process, after a number of components are assembled to the intake manifold an assembly leak check is applied with lower test pressure but higher leak rate parameters. This assures the assembled components are indeed assembled correctly.

As for versatility, which is buoyed by Test Centric Assembly, the same instrument is used for both tests.

In another case, a maker of carbon canisters was unhappy with speed and consistency of their leak testing system. To asses cost and timesavings, they conducted a side-by-side cycle time comparison of Test Centric Assembly equipment from InterTech with their incumbent leak testing systems.

An InterTech mass flow instrument was used in all tests to see if it made a difference. When InterTech's Test Centric Assembly system proved to be 27% more efficient with faster cycle times and no retesting, the old leak testing equipment was replaced without hesitation by Test Centric Assembly systems and mass flow instruments from InterTech.

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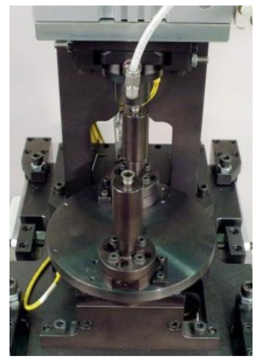
Exhibit 3 : 100% Leak Testing of Fuel Injection Components



Fuel injection components often demand 100% leak testing to limits as low as .01 sccm with cycles as fast as 2.5 seconds, 10% GR&R quality requirements, and significant part temperature variations.

Separate tests with different limits are typically needed in the same test cycle for body welds, seat leakage, and overall leakage. Integration of instrumentation software, fixturing and test circuit is essential, as is complete test documentation.

InterTech's downstream test process features a patented Micro-Flow mass-flow transducer to provide 10 times greater leak sensitivity than any other dry-air test method. A test part is enclosed within a test chamber and pressurized; leakage is measured as a flow increase into the test circuit outside the part, eliminating the need and time for pressure stabilization inside the part. The test circuit is precisely engineered for minimum volume, enabling the Micro-Flow sensor to almost instantaneously measure flows with a resolution of .0001 sccm.

Critical for fast small-leak testing, all fixtures and clamping devices are designed and built for absolute stability to prevent part movement during testing. Seal positioning mechanisms consistently address the test part squarely and firmly, stabilizing their closure forces quickly to shorten cycle times.

Seals are designed for high durability to run thousands of parts per day without replacement. With these unique features, Micro-Flow dry-air test systems deliver .01 sccm testing with less than 10% GR&R.

Special Features

- InterTech's Patented Bias-Leak checking is especially important for fail-safe operation whenever testing to less than 1 sccm. It uses low-level airflow to confirm test-circuit integrity before each test cycle.
- Temperature compensation sharpens test accuracy and repeatability by nullifying test part residual heat from welding, fabrication, washing or even operator handling. Custom algorithms based on the test part's unique cooling characteristics supply appropriate corrective responses across the test cycle.

- InterTech's S-3085 networking/diagnostic software graphically visualizes for greater operator control the factors that can compromise a good baseline zero, trigger false rejects or otherwise disrupt accuracy and repeatability.

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About InterTech Development Company

Founded in 1973, InterTech Development Company is a world leader in test-centric assembly and test specializing in automated leak and functional testing with seven (7) patented mass flow and hydraulic technologies as well as proven expertise in helium mass spectrometry.

InterTech Development Company-engineered solutions are utilized globally by hundreds of manufacturers worldwide in the Automotive, Medical and Industrial Device markets.

InterTech's competitive advantage is leading edge technology, in-depth experience and single source capability for all your testing and application requirements.

Detailed engineering analyses of specific application requirements and best-match test technology, maintaining best of class quality standards at the lowest cost are available from InterTech's Testing Applications Laboratory for no charge.

ISO 17025 accreditation of InterTech's Calibration and Applications Laboratory's quality management system complements its ISO9001 accreditation ensuring customers and end-users are assured of quality and proven standards at all stages within their supply chains. InterTech has sales and service offices worldwide including: US, Mexico, Europe, India, Korea and China.

See more at www.intertechdevelopment.com

US / WORLD HEADQUARTERS
InterTech Development Company
7401 N. Linder Avenue
Skokie, IL 60077 USA
847-679-3377