7 practical steps to a better manufacturing leak test

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INTRODUCTION

Leak testing is often an art as much as it is a science. Manufacturing quality engineers and machine operators on the production line must contend with variations in air supply, thermal effects, swings in ambient temperature, station setup and so on. Confidence in your leak test begins by mitigating all the external factors that can undermine accuracy and repeatability.

That takes experience, armed with the right tools and process methodology. On today's factory floor, digital process signature, or waveform, analysis, coupled with powerful applications for big data analysis and visualization, can be used to eliminate much of the uncertainty and guesswork that plagued leak testing in the past.

What you will get out of this e-book

In this e-book, we will explore best practices and offer practical steps to achieve a better leak test starting today:

5 things to check to get the setup right:

Even the best digital technology to make a leak test smarter won't help if the test station suffers from mechanical issues.

PART 1 →

Address these 4 details to ensure repeatability:

Understand and address the culprits responsible when a leak test must be run a second time to get a pass, or results differ between repeated tests of the same part.

PART 2 →

What to look for in the data:

Understanding what digital process signature analysis can tell you.

PART 3 →

The fastest way to set the right test limits:

Use that signature data to find the sweet spot for quality so your test cycles are not a second longer than they need to be.

PART 4 →

6 tips to shorten cycle time:

Use manufacturing analytics to focus, refine and chart the impact of the changes made by your team to make your leak test faster.

PART 5 →

4 ways to keep your leak tester honest:

Trust your test station is running optimally at the start of each shift by using a master part and employing the right verification procedures.

PART 6 →

Use your warranty claims for continuous improvement:

Historic signature data is key to limit recalls to specific serial numbers and minimize the financial and public relations impact.

PART 7 →

And lastly: The Sciemetric advantage

What does Sciemetric bring to the table when it comes to leak test?

PART 8 →

PART 1

5 things to check to get the setup right

Digital technology, no matter how good, just can't compensate for poor test station setup. In this digital age, it's easy to overlook that the challenge is often mechanical.

Shorten the distance between the test station and the part

The more complex your test station set up – the more hoses, valves and connections – the greater the odds the test will suffer from poor reliability and repeatability. Achieving a higher standard of leak testing often starts with simplifying the mechanical complexity of your test stations.

Check the orientation of the part to the station

Depending on the size and shape of the part, consider how it is conveyed and oriented for its connection to the test station. Over time, this orientation and the fixturing can drift out of alignment.

Use the right seal for the job

The best seals have a mechanical component that physically locks them to the part and ensures proper orientation. This can come in the form of:

- A mechanical or pneumatically (air) activated seal that is physically deformed to provide the mechanical lock
- A bolted connection
- An automated seal on the end of a ram or robot that is locked into position during testing.

Whether mechanical or pneumatic, the best seal designs provide feedback to indicate that proper seating pressure and orientation was obtained after installation. An electronic sensor internal to the seal, proximity switches for automated rams and simple travel stops on manually actuated seals provide tactile feedback that ensures the seal is properly inserted.

Consider the hardness of the seal

The durometer, or hardness, of the seal must also be selected for the environment and part type involved, the test pressure and how many test cycles the seal must endure in a production shift. Too soft, and the seal material will wear too quickly. Too hard and it will not allow the operator to make a quick and reliable seal.

Calculate the ideal safety pressure ratio

The force holding the seal must be three times the force acting against the seal from the test pressure within the part. This prevents false leaks through the opening. A 3-1 ratio ensures the seal is "crushed" or compressed enough to be air tight, without being too tight and contributing to seal creep (the gradual wear and weakening of the seal, or movement of the seal during test).

This is determined by Force = Pressure X Interior Area.

For example, a 1-inch diameter circular hole being sealed by a face seal mounted on a pneumatic ram with a test pressure of 5 PSI would give a total force of Area (πr^2) X Pressure, or π X 0.5^2 X 5, or 3.14 X 0.25 X 5, or 3.9 pound force (lbf). This means the pressure applied to the seal must be 3.9 X 3 (safety factor) to assure no false leak, or at least 11.7 lbf.

This guideline is used to size the cylinder that will hold the seal that will seal the hole:

- A 1/4-inch diameter bore cylinder X 60 PSI shop air pressure yields 2.94 lbf (too low)
- A 1/2-inch diameter bore cylinder X 60 PSI shop air pressure yields 11.78 lbf (just right)
- A 3/4-inch diameter bore cylinder X 60 PSI shop pressure yields 26.49 lbf (OK, but may cause seal wear)

Once the setup is verified, you're ready to tackle the other areas where improvements can be made.

PART 2

Address these 4 details to ensure repeatability

Achieving repeatability is a common challenge with leak testing. Changes in test results can cause your team to mistrust their leak test and even throw out test results altogether.

As discussed in **Part 1**, setup can contribute to poor repeatability. Here are other factors that can't be overlooked.

Manage your test pressure

Variances in pressure that could impact your test cycle can be caused by anything from someone stepping on a hose or pinching it under a box, to a faulty coupling. Another common cause is the test station being starved because its source of compressed air is shared with another station.

Even slight changes in pressure can lead you to have wildly different results when nothing else about the part has changed. Equip the leak test station with the software and smart sensors that can constantly monitor and adjust the pressure to compensate for any variations.

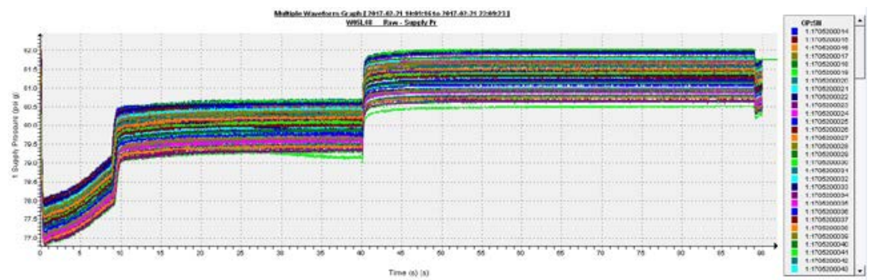

Figure 1: This figure shows how supply pressure varies throughout fast fill, fill and stabilization/ test portions of a leak test.

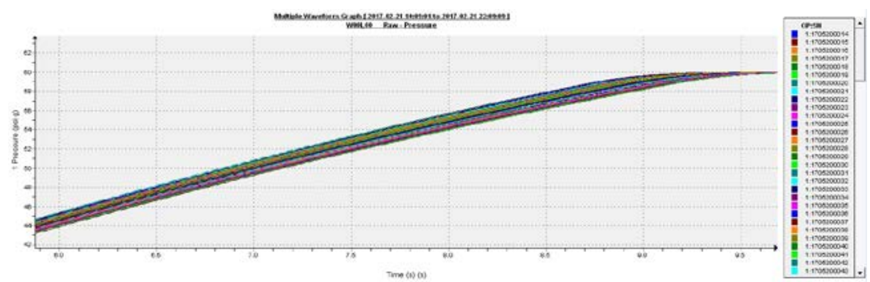

Figure 2: When you have variations in your supply pressure, the speed of fill will vary. This can cause changes in how quickly adiabatic settling happens. (Adiabatic settling occurs when heat from the fill stage dissipates into the part and comes into equilibrium within the part.)

Inspect connection points and plugs

Look for damage, leaks or any other flaws. The actual connection to the leak test system is often the greatest variable. Sometimes, it's a matter of design – different leak test systems use different sized ports, which impacts the fill and empty cycles for a test.

Manage temperature – time for a probe?

As we will discuss in **Part 3**, variances between the temperature of the ambient air and the part can have a drastic impact on repeatability.

In the perfect world, parts are large enough and production lines are slow enough to manually place temperature probes inside the part for the most accurate reading of internal temperature. In the real world, this isn't always possible. The next best option is to use a probe with a copper tip in contact with the exterior surface of the part. But be aware that accuracy will suffer, depending on the thickness and type of material in question. Controlled testing is key to understand the degree of variation under predictable conditions.

Use air-actuated seals

Operators will sometimes make errors, or prefer to do things a certain way, like using a looser fit to make the part easier to clamp and unclamp from the test station. This can introduce an unacceptable margin for error in the test results. For example, if the test station uses a softer seal, a looser fit can lead to a leaky connection.

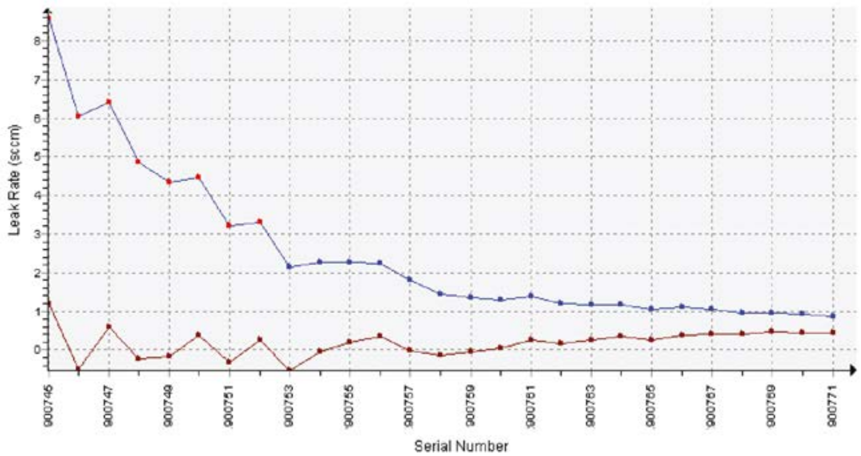

Figure 3: A manufacturer was having trouble achieving repeatable test results in the required time for a die-cast aluminum transmission case that came to the test stand warm from a wash. Signature analysis was used to correlate part temperature with the measured leak rate, to eliminate the false failures and arrive at the actual leak rate within the required test time.

Probes are used to provide as accurate a temperature reading as possible for a part.

Operator training is important to address this. Another step is to use air-actuated connectors with positive stops. These allow for fast, safe and repeatable connections that all but eliminate the human element.

PART 3

What to look for in the data

Now that you have dealt with the mechanical variables, it's time to look at what the test data is telling you.

A test cycle's waveform, or digital process signature, displays like an electrocardiogram (ECG). A healthy manufacturing process or test cycle – just like a heart – always has the same signature. It's easy to visualize and spot minor or even subtle variations in the slopes of the waveform that indicate an issue.

Each leak test cycle has three primary phases: the fill phase (the fill typically being air under compression), a stabilization phase, and the test phase. What the data can tell you will differ depending on which of the two types of leak test you are using.

Pressure decay leak tests

With a pressure decay leak test, the slope angle of the waveform tells you how much a part is leaking. The greater the slope angle, the greater the leak. Blips or variances in a signature's slope mean different things depending on whether the variation is a positive value (higher than normal) a negative value (lower than normal) and in which phase of the test it occurs.

Anomalies at the fill and stabilization stages

Let's say the pressure suddenly rises then drops again. This could indicate an internal obstruction. Perhaps it was a gob of oil that moved, or some other debris that could cause internal damage and a failure down the road.

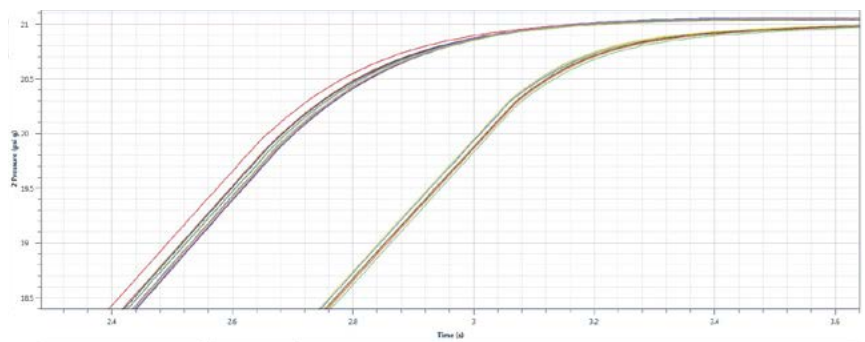

Figure 4: Ramped fill keeps the rate of fill more consistent and can help mitigate supply pressure variations. The waveform on the left shows a non-ramped fill which demonstrates less control. The waveform on the right shows the tighter control of a ramped fill.

Anomalies during the test phase

A reduced slope angle or even a positive slope indicates a lower than normal leak rate, which can be caused by a thermal effect.

The part can be heating up more than usual from the compression of air introduced during the fill phase, or because it's still warm from a previous process on the line, such as a wash or a drying oven. The part could have also been retested too many times in short order without sufficient time for its internal temperature to stabilize.

Warmer parts take less pressure to fill than cooler ones and display a lower leak rate. Without enough time to cool off, the warmed part may give a false pass reading on the retest.

An increased slope angle indicates a higher than normal leak rate and the possibility of a faulty part. It could also indicate a different kind of thermal effect – the part may not be warmer than normal, but there could have been a drop in the ambient air temperature around the test station. For example, an HVAC system may have switched on or cold air flooded in from outside when a door was opened.

Flow-based leak tests

Flow-based tests are a different beast. The leak system is taking a reading directly from the flow rate sensor of how much air flow is required to maintain the desired pressure within the part. There is no "slope" to look at – after the stabilization phase, the reading should be a flat line.

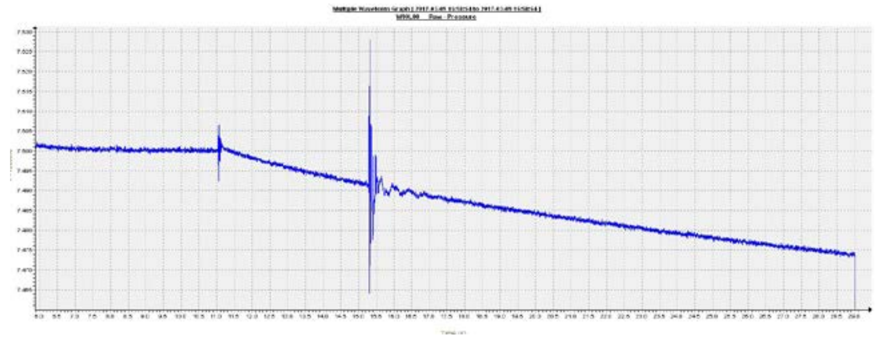

Figure 5: When measuring leak rate, if you have a hose kick (movement of the hose) during the test portion you can end up with an incorrect reading. By testing peak to peak, you can identify a hose kick or event that may have affected the test.

So, it just comes down to watching the flow rate across that sensor. A lower than normal flow, suggesting a lower than normal leak rate, could again red flag a thermal effect within the part. If more air flow than normal is required to maintain the desired pressure, it may indicate a leak issue, or a drop in the ambient air temperature around the test station.

Each leak test cycle has three primary phases: the fill phase (the fill typically being air under compression), a stabilization phase, and the test phase.

A flawed test, or operator error?

During a head-to-head trial at a major automaker's plant, two leak test stations with two different testing systems were set up for an objective panel-to-panel comparison using a pressure decay leak test. The same operator took five parts through each station six times. They manually clamped and unclamped the parts from each station for each test cycle, just as they would do during a regular production shift.

The trial yielded surprising results – documented air pressure variances that suggested some parts were leaking enough to be considered a fail.

But then we looked at how the operator clamped and unclamped the parts. We ran the tests again without unclamping and saw a substantial increase in the consistency of the results when we applied process signature analysis to compare the data. The problem hadn't been leaky parts but leaky seals. The cause was operator error.

How did we determine this?

The waveforms from the base test were overlaid with those of the unclamped retests. This showed that the pressure decay curves were inconsistent for the re-clamped tests. Not only were the slopes of the waveforms different, but there were abrupt changes in the pressure that indicate a physical part movement – in this case, the seal was "burping" and moving position (see Figures 6 & 7). The fixture which held the part had lost alignment. This allowed the part to move if the operator did not take great care in positioning the part and engaging the seal.

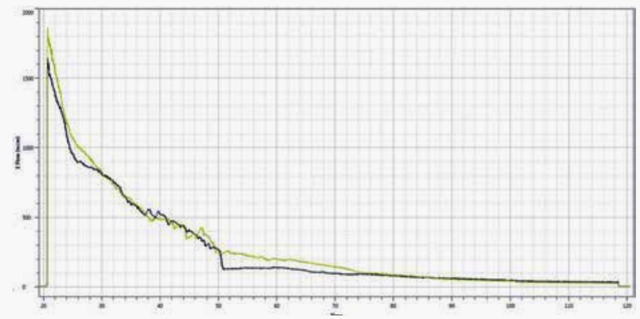

Fig. 6: In this waveform of a flow rate leak test cycle, the green line indicates the expected process signature. The blue line indicates pressure deviations due to the movement of the part at the 50-second mark that affected its seal to the test station. This deviation could be mistaken for an actual leak that could lead to a false fail for the part.

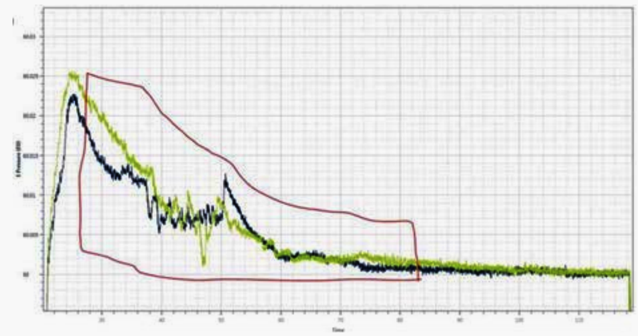

Fig 7: In this waveform image, the inconsistency in the flow rate of the leak test, as indicated by the volatility in pressure readings (blue line in the area circled in red), again indicates part movement that is affecting the seal between the part and the test station.

PART 4

The fastest way to set the right test limits

Leak test systems typically come with limits preset by the manufacturer. And different parts will have different specifications that in some cases might even be regulated by law, such as fuel rails.

To customize and establish limits for a test:

Visualize your data

Opt for a data analysis platform that provides quick and responsive visualization capability. Many systems capture and store signatures as flat image files and lack on-demand visualization tools. Data must be exported into spreadsheets, in which each test or part has its own tab with its signature's waveform image. There is no way to overlay or correlate these images. Making any sense of this pile is time-consuming and frustrating.

Create a histogram

With the right data management tools, signatures can be converted into a histogram of leak rates to show the waveform for a good part and the range of acceptable deviation. This makes it easy to create and visualize a baseline against which to compare all parts. The more signatures you have, the easier it becomes to understand what waveform anomalies to watch for and what they signify. In addition to distinguishing good parts from bad, you can also spot problems with the test station itself.

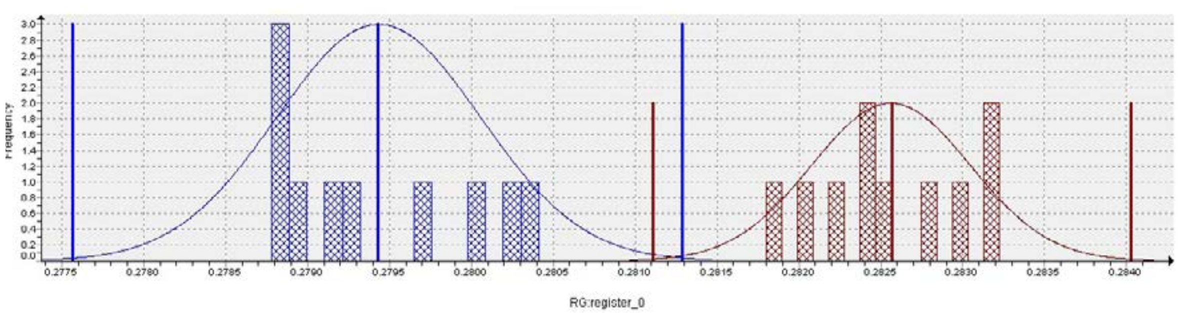

Figure 8: This figure and Figure 9 are taken from the same test, but at different analysis times. Both were repeatable, but visualization of the data shows the impact of different cycle times on the ability to differentiate between a good and a bad part.

Use a mapping exercise

Mapping involves taking a few known good parts and running them through the test station 20 times each to create a baseline. Specific defects, flaws or even test station setup problems are then introduced to see if and how they show up in the resulting test data. This takes the guesswork out of determining which limits to set to catch specific issues.

Do your math

Apply mathematical techniques directly to the process signature in the form of a "feature."

Applying post-processing features such as Slope, Peak to Peak values, Mean and Standard Deviation will help to quantify sections of the signature for further analysis.

With all this signature data at your fingertips, you don't have to wait until you know you have a problem or a new requirement to implement before taking action. You can run any simulation or data model at any time, just to see what the outcome might be, without disrupting production.

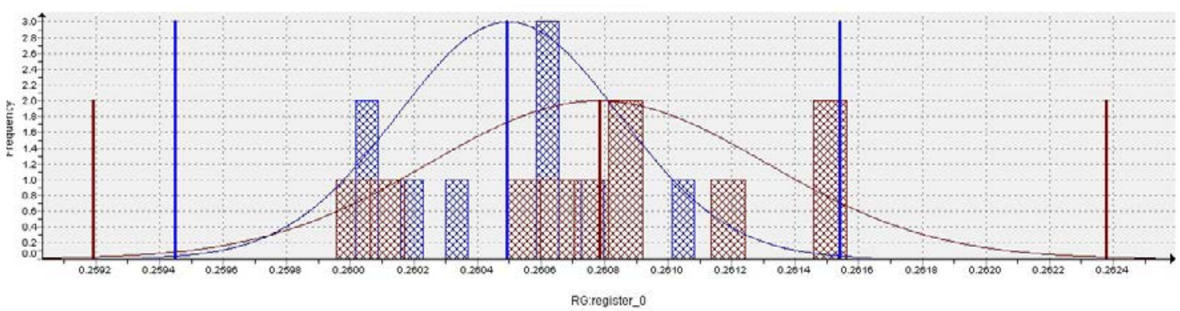

Figure 9: Even though the test is repeatable, with a shorter test time there isn't enough separation in the results to distinguish between a good part and bad part (which means the limits are flawed).

PART 5

6 tips to shorten cycle time

In **Part 4**, we talked about using process signature data to take the guesswork out of setting test limits. The same can be done to shorten the test cycle.

Shorten fill time by making the part 'smaller'

All the air volume in the leak tester and in the fixturing that is connecting it to the part, in addition to the part's own internal volume, can contribute to a longer fill time.

To cut that fill time, we must make the part, in effect, smaller. Engineer the fixturing to limit the internal volume that you need to fill for the test. As we said in **Part 1**, reduce the mechanical complexity of your test by shortening the distance, and simplifying the connections, between the part and the tester. Larger diameters and shorter lengths of hose are ideal.

Here are three important things you can do to trim cycle time.

Match the fill port to the supply line

Care must also be taken to select the right hose and connections to link the leak tester to the part without effecting the seal's performance. It's best to match the diameter of the fill port seal with the supply line from the leak tester. This maximizes the speed at which the part can be filled.

Consider the internal geometry of the part

If the part has numerous internal chambers that are separated by restrictions or small diameters, it's typically better to connect to both sides of those chambers to fill them without having to fill through that internal restriction.

Fast fill the part

The higher the supply pressure, the greater the pressure drop across the regulators in the system and the larger flow rates you will be able to have to fill your part.

You can take advantage of this to fast fill the part. Pressurize the panel much higher than the test pressure you want in the part (even double) to overcome the pressure drop between the tester and the part. This allows you to fill the part quicker. You can then revert to maintain the desired leak test pressure in the case of a flow rate leak test.

Reducing the time it takes to fill a part is critical if you want to reduce overall cycle time.

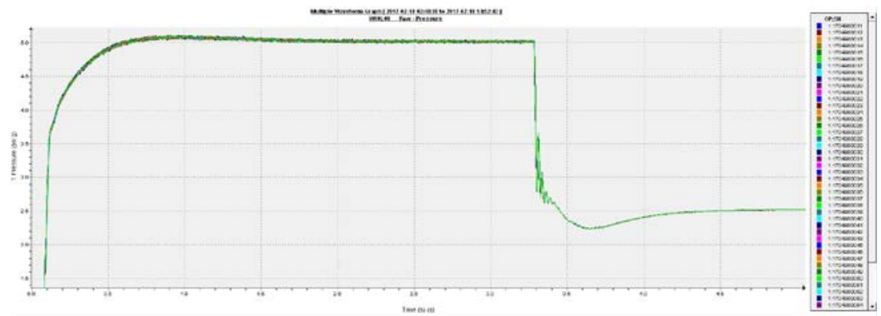

Figure 10: This waveform shows how by fast filling at 5 PSI for approximately 3 seconds you can put more air into the part in a shorter amount of time without overfilling the part, and then drop down to the test pressure of 2.5 PSI.

Employ digital technology

Take advantage of optimized, modern electronics and low noise circuitry to control and measure the pressure and the flow. The faster you can achieve a stable, consistent and accurate pressure and flow signature, the faster you can make a reliable pass/fail decision on a part.

Software is key. Yes, you can improve the electronics, but it's the software that allows you to achieve better pressure regulation, or to measure with greater accuracy to smaller increments. It's software that will turn a conventional pressure gauge into a more sensitive and responsive piece of instrumentation.

Use the longest test cycle to find the best cycle time

You don't have to run a series of tests to determine the best cycle time. Run the test just once at the longest cycle and then review the data that's been generated. Do that and you have the visual record that illustrates the results of running the test at only five seconds, or 10 or 25, without having to run the test again at those cycle times.

PART 6

4 ways to keep your leak tester honest

Any station on a manufacturing line may drift out of calibration or suffer other deviations after running through hundreds or thousands of cycles during a shift. Leak test is no different. Tests of the test station should be run at the beginning and end of each shift.

Verify the system

This test checks the overall health of the test station including the leak tester, part seals, fill ports and connection hoses. All part seals and fill ports are connected to a verification tool, typically a machined manifold that simulates all connections to the test part. This verifies there are no leaking seals or hoses and that any leak measured in a part is correct.
If a leak is measured, seals can then be individually checked to find the failure.

Records of each system verification and individual seal test should be stored alongside the rest of the signature data from the test station.

Internal diagnostics are the ideal way to confirm that your leak tester isn't the source of a problem.

Use, and properly maintain, a master part

Also, known as a zero-leak master, this is a perfect part that is used to verify the leak tester and all associated fixturing. It's like the control in a lab experiment, used to directly simulate the actual test requirements.

Maintaining master parts is a practice that is often overlooked. Few parts maintain the same characteristics over time. Machined surfaces will tarnish, which changes thermal conductivity, impacting the stabilization period of the test. Assembly lube will drain out of oil passages, possibly unplugging a leak in the part. Seals will harden over time.

It's therefore crucial that test results of each master part be databased and tracked over time so that proper maintenance can be scheduled as the master parts degrade and a test failure isn't wrongly attributed to the leak test system.

Verify orifices

The most common external check for leak test instruments is a calibrated flow orifice. Designed and certified to flow a set amount of air at a set pressure, orifices are a robust, cost-effective way to verify that the leak tester is reading the proper flow rate. Orifices do have a few limitations that must be considered. The accuracy of standards can vary depending on the style of the orifice. Temperature and barometric pressure variations must also be accounted for to ensure accurate measurement.

Use digital gauges

Pressure gauges and flow meters provide a higher precision check of a test station's sensors than is possible with a flow orifice alone. While high quality analog pressure gauges are available, the best precision gauges and flow meters are digital. For leak test verification, it's important to choose a gauge that has high accuracy and is robust enough for an industrial environment. The best models correct for temperature and atmospheric pressure.

Maintaining master parts is a practice that is often overlooked. Few parts maintain the same characteristics over time. Machined surfaces will tarnish, which changes thermal conductivity, impacting the stabilization period of the test.

PART 7

Use your warranty claims for continuous improvement

In Part 4, we discussed how to obtain and use baseline histograms to catch flawed parts. When a part comes back from the field with a warranty issue, you now have an extensive archive of data, traceable by serial number, with which to trace root cause.

Pull all the waveform data for the leaking part

See if there is anything off about the part's original leak test signature, even within the range of standard deviation. And look at the signature data from the other processes upstream that touched the part. Sometimes, a problem just doesn't show up at the leak test station.

For example, maybe a pressing operation was flawed and this can show up in the force versus distance reading of that process. The part may still pass its leak test, but will eventually leak like a sieve when subjected to the conditions of normal use over time.

Test the part again

Run the problem part through the test again to see how its signature compares to its original test. Look for correlating anomalies, compare this to your baselines for that type of part and see if you can identify the cause of the problem.

Use an algorithm to assess the scope of the problem

Create an algorithm to screen your archive of signature data for that type of part to see if any others have the same anomaly.

Review and compare

Now review the histories of these parts that all display the same anomaly. Have there been similar warranty claims? It's time to decide if a recall is warranted. But now you have zeroed in on the problem parts to limit the scope of a recall.

Refine your test limits and upstream quality control benchmarks

Now consider how to avoid this same flaw from occurring again. It's back to **Part 4** and engaging in another mapping exercise to determine where and how test limits should be tweaked. You must also look at what other changes should be made to whatever processes upstream contributed to the leak problem.

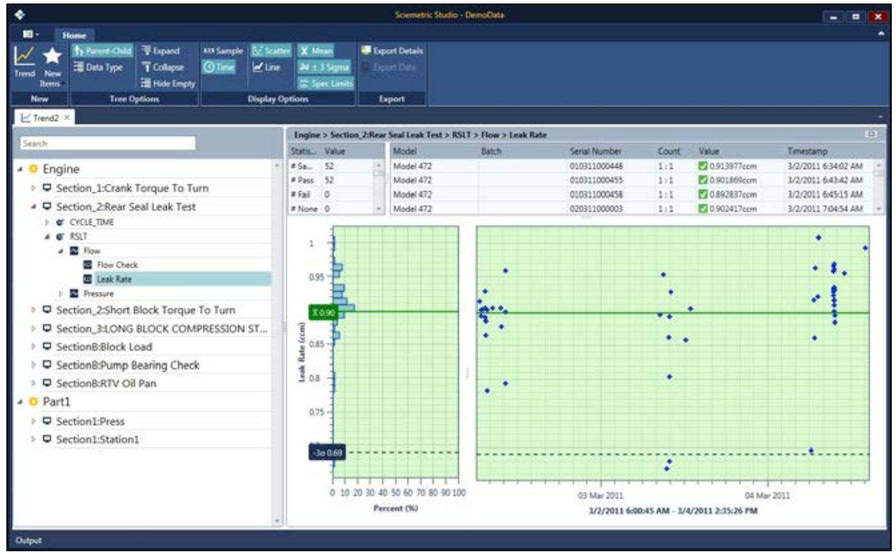

Figure 11: This figure shows a statistical distribution of processing changes as they affect part limits and the ability to sort out good and bad parts. You can see that at the bottom of the histogram, 3 parts fall near the lower limit of the test.

PART 8

And lastly: The Sciemetric advantage

What does Sciemetric bring to the table when it comes to leak test?

Sciemetric pioneered digital process signature analysis in the 1990s with a major North American automaker to find a better alternative to the end-of-line hot test for engines. Unlocking the full potential of your data is baked into our DNA.

The Sciemetric team realized early on how process signature analysis could be used to tackle the complexities of leak testing in any discrete manufacturing industry, from automotive and off-highway, to medical devices and consumer products.

Our 3520 Series Leak Test provides both high accuracy and fast cycle times. In 2016, we filed a landmark patent that covers many of the innovations contained in the 3520. Sciemetric is the only vendor offering leak test with manufacturing analytics that can work with process signatures from every station on a manufacturing line. Manufacturers can improve test quality, reliability and the speed of decision making, and often budget for fewer test stations to reduce costs, with our proven signature analysis technology.

Check out this video for an **overview of the 3520's competitive advantages** versus other leak test systems.

For many companies that deliver leak testing products and services, it's difficult to bring fresh thinking to the challenge. Our unique combination of skills in pneumatics, sensors, electronics, signature analysis and enterprise-grade software for big data analytics helps manufacturers in many industries carry out leak testing far more accurately and efficiently than they ever thought possible.

Contact us to learn more about the Sciemetric advantage.

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