Plugging the Gaps: Improving Your Manufacturing Leak Test with Data

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INTRODUCTION

Is your leak test smart enough for Industry 4.0?

The struggle to test for and address leaks that lead to faulty parts and warranty claims is nothing new. But rising expectations for product quality and reliability are putting this test to the test like never before.

Leak never has, and never will be, a cut and dried test. There are so many variables and potential points of failure that can skew the accuracy and consistency of the test. By making the test "smarter" with sensors, software and analytics, quality engineers can manage these variables far faster and more reliably than they ever could before. Data is the key to giving your plant, and your front-line workers, the insight and intelligence they need to take action when it needs to be taken, to maintain output at the highest standard of quality. This is the essence of Industry 4.0.

What you will get out of this e-book

Collecting the *right* data

We explore why the waveform, or *digital process signature*, is the type of data manufacturers must collect from their leak test operations for a faster, more efficient and more reliable leak test, and how waveform data must be managed.

PART 1

What a waveform can tell you

We explain what a digital process signature allows you to do in terms of quality control and continuous process improvement and give specific examples of the kinds of leak test issues it can help you troubleshoot and address.

PART 2

What you can do with the leak test data

Using case examples, we explain how digital process signature analysis can be used to reduce leak test cycle times, hit gage R&R targets, accelerate deployment of new test stations, provide full birth history traceability, enable you to tackle variables like seasonal temperature variations, and make it easy to run data models and simulations for continuous improvement.

PART 3

Our advantage

Lastly, we discuss the competitive advantage we can provide to your production line with our industry-leading test and data analytics systems for leak.

PART 4

PART 1

Collecting the *right* data

On many manufacturing lines, pass/fail for an assembly process or test of a part is determined from only a few specific scalar data points that are recorded during that process or test cycle.

Because only a handful of data points are captured, there are gaps in time. These gaps make it practically impossible to obtain a clear view of what happened *throughout* a process or test. If an anomaly occurs during one of these gaps, operators may never know.

When it comes to leak test, those few data points also make it quite challenging to trace issues within the test to one of those many variables we referenced in the introduction.

Take a hockey game with your favorite team on the ice. A contentious goal is scored and the referees have to go upstairs for a review of the play to decide if the goal will count.

Now, what would you prefer as the basis for that decision – a video instant replay or snapshots of only a few isolated points in time as that puck passed through the goalie's crease?

Only a digital process signature can provide that complete video replay.

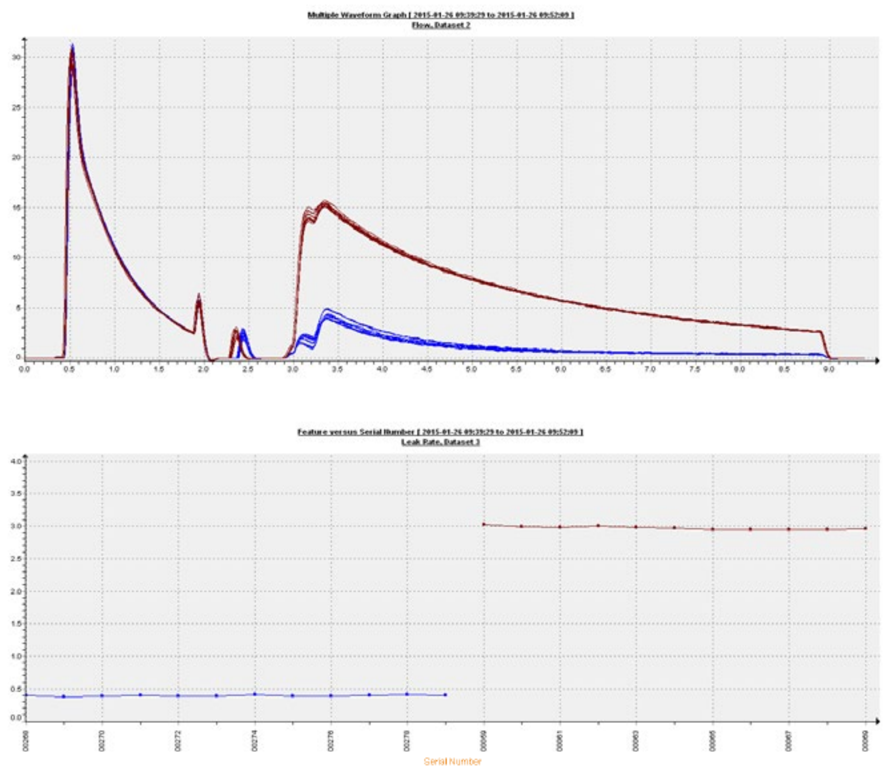

Figure 1: These graphs show the difference between the amount of data collected in multiple overlaid digital process signatures (top picture) as compared to a trend of scalar leak rate values from the same test (bottom picture).

The difference that a waveform makes

Every single manufacturing test or process generates a digital process signature that can be recorded, interpreted and visualized. A single signature can contain hundreds and even thousands of datapoints.

By equipping a manufacturing process, or a test station like leak, with appropriate sensors such as load cells, temperature, position and pressure sensors, or displacement gauges, highly consistent and repeatable signals can be obtained that directly indicate the consistency and quality of the process or product.

These signals can be physical measurements or computed values such as horsepower or efficiency based on specific measurements and mathematical formulae. Assuming the measured variables and sensors are chosen with care, the characteristic signature will be consistent if the manufacturing process or the test station is under control and if product quality levels are being maintained.

Once you have captured the digital process signature, it can be analyzed through signature analysis. In its most simple form, signature analysis is the comparison of a *specific* process response or waveform against an acceptable pre-determined response.

A part failure can easily be distinguished from a test malfunction. The quality team can spot anomalies that require further investigation, pinpoint where problems occur during the process, even optimize the test station by understanding how to shorten the test.

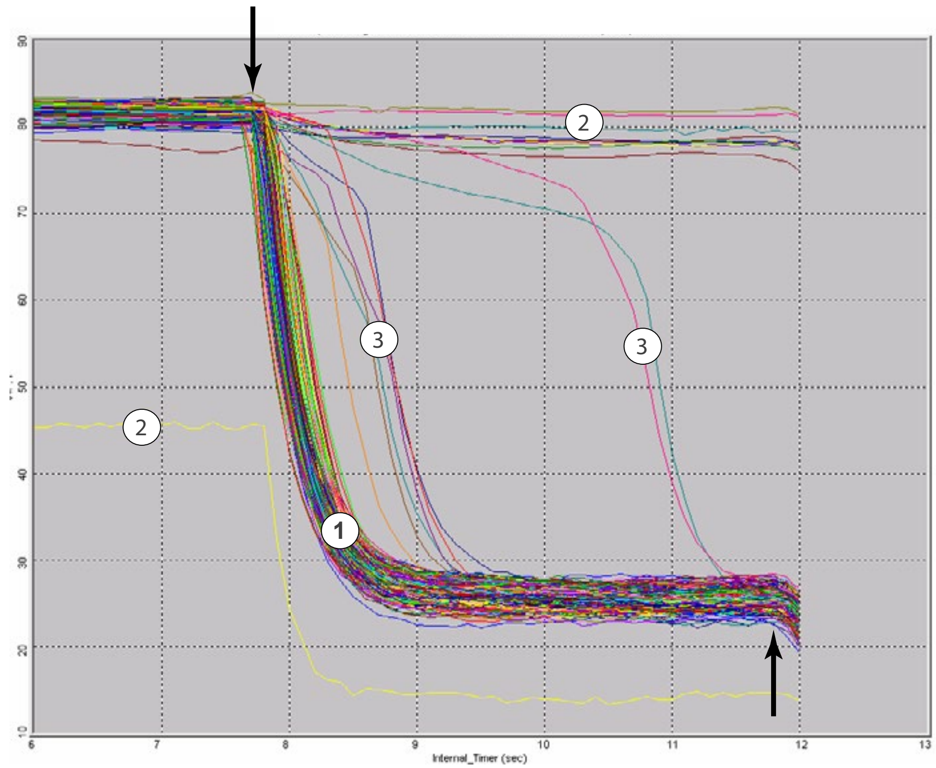

Figure 2: Digital signature analysis quickly analyzes a complete operation to find anomalies in the process that scalar data cannot identify. In this figure, the arrows indicate the start and end of the leak test. The label 1 shows repeatable waveforms of a healthy process producing good parts. The waveforms in 2 are the obvious failures, which are usually caught. The waveforms in 3, however, are often missed by other monitoring systems because they meet the minimal criteria for a "pass". These anomalies can point to process issues and/or problems with parts downstream.

How to handle the data most effectively

Capturing and storing the digital process signatures from a process on the line or from a test station is only the first step. Where many test and data analytics systems fall short is in how they interpret and visualize this data.

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 easy way to overlay or correlate these images. Making any sense of this pile is time-consuming and frustrating. Meanwhile, a possible production or test issue remains undiagnosed and unaddressed – hundreds, even thousands, of faulty parts could be rolling off the line.

For operators to spot issues and for quality engineers to quickly trace the root cause of a problem, you need quick and responsive visualization capability. If the data ends up buried in a format that you only bother to retrieve after a warranty claim indicates a problem, it's counterproductive.

With real-time visualization capability, you can chart the average leak rate throughout the day and how many parts are passing the test on the first run. Best of all, this data can be correlated with the datasets from other processes upstream on the line that could play a role in a leak problem. For example, maybe an increase in leak failures can be tied back to a problem at a press fitting station, or the fitting of a gasket or a missing bolt, or some combination of multiple issues.

Having this kind of power and insight at your fingertips to take quick and decisive action is the very definition of Industry 4.0. It's fundamental to continuous process and quality improvement.

PART 2

What a waveform can tell you

A captured waveform has a distinct signature that displays like the electrocardiogram (ECG) that provides a digital image of a heart's health. 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 waveform that indicate an issue.

The first step is to break down the signature's waveform into the different time periods of the test or process. For leak, this will be a fill phase (the fill typically being air under compression), a stabilization phase, a test phase and the exhaust phase during which time the part is emptied.

Blips or variances in a slope from what is considered normal or optimal can 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 that it occurs.

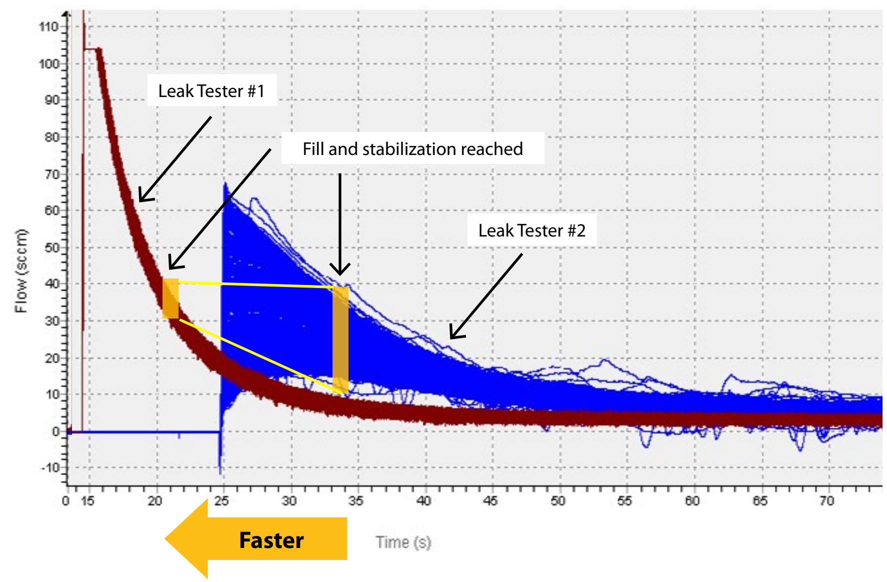

Figure 3: In this example, Leak Tester #1 reaches fill and stabilization 1.7x faster than Leak Tester #2. This kind of speed eliminates the common leak test production bottleneck and can reduce the number of leak test stations that need to be purchased. Also, the tight signatures of Leak Tester #1 show a greater repeatability than Leak Tester #2 was able to achieve.

Anomalies at the fill and stabilization stages

Take the fill and stabilization stages of a leak test. The slope should always be repeatable and consistent, indicating the same steady pressure is being delivered. But 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. Perhaps it's some other debris that could cause internal damage or a failure down the road.

Now, say a part has failed a test. The operator has kept the part connected to the test station, applied soapy water and now runs the test again to see where the air is escaping. Only this time, the part fills faster. What does that mean? It could be that the pressure from the first test wasn't fully expelled so the starting pressure for the retest was higher than normal. The operator could also be experiencing thermal effects, since the compression of air from the fill of the first test had increased the internal temperature of the part. 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.

By reviewing the signature data, you can catch these anomalies, trace the root cause, and make the adjustments to correct.

Anomalies during the test phase

Variations in the signature's waveform during the test phase can point to a number of issues. Any variation indicates a different leak rate. For example, if you are using a pressure decay leak test, a slope that is negative from the norm can indicates a greater leak rate. A slope that is positive, a reduced leak rate.

The question is what's causing the variance in either direction.

A positive change could indicate, again, thermal effects. The part can be heating up more than usual from the compression of air introduced during the fill phase, or the part is coming to the test still warm from a previous process on the line, such as a wash or a drying oven. Or, the same part has been retested too many times in short order without sufficient time for its internal temperature to stabilize.

For parts with low leak limits and high thermal conductivity, such as a radiator, the problem can be something as simple as the operator resting their hand on the part during the test. Their body temperature can be enough to warm the part. This will reduce the amount of pressure required to fill it and result in a false pass. A door opening and cold air flooding in from outside can swing the results the other way, resulting in false failure.

Again, by reviewing the waveform data and comparing the variances in slope and time against the accepted norm, you can catch problems and trace their cause.

Measuring more than just the test itself

You can do more than just capture the signature of the test itself. You can add sensors to monitor every function related to that test.

Start with the supply pressure. Variances in supply pressure that could impact your test cycle could be anything from someone stepping on a hose or pinching it under a box, to a faulty coupling. If you are capturing this signature, you can easily see variances that indicate a disruption of the air supply.

Or, let's say a forklift drops a pallet and gives the whole test station a shake that throws off its calibration and the seal of its connectors. Or parts coming down the line aren't lining up properly with the connectors. By monitoring every aspect of the test, you can always catch and adjust for unexpected variables.

We can also overlay historic data for the leak test to generate trend graphs. These can tell us how the leak test results might vary throughout the day due to changes in ambient air temperature and barometric pressure. You can even determine if human error can be leading to a higher than normal fail rate by tracking operator IDs against your pass/fail rates.

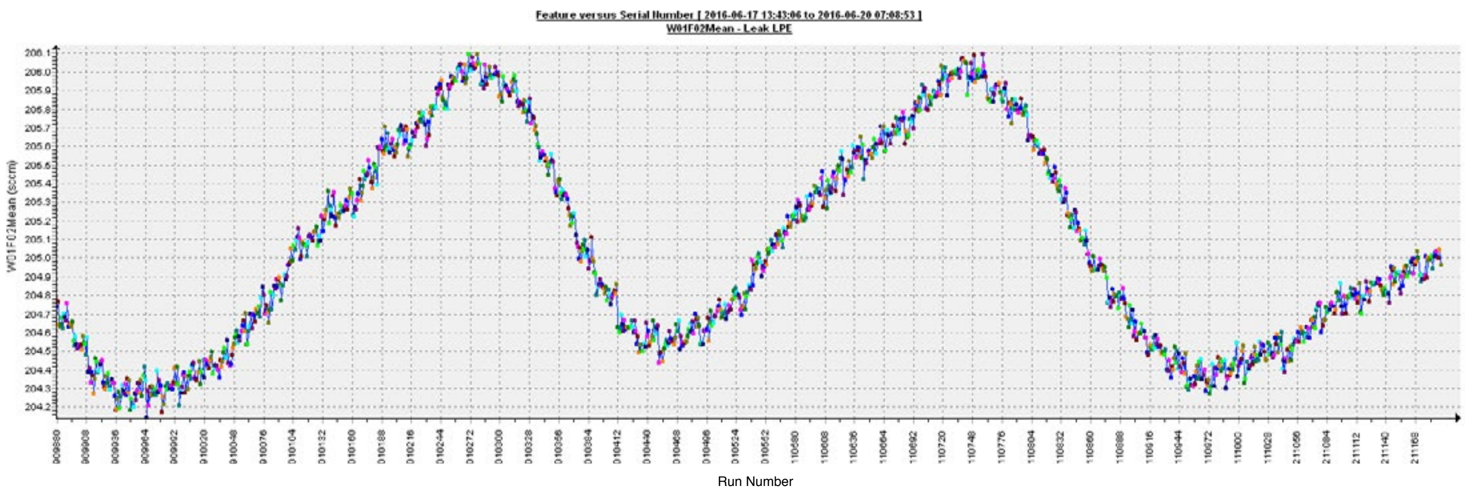

Figure 4: This trend graph depicts the leak rate of the same part taken 1313 times over three days. It shows the effect of changes in temperature or barometric pressure on the part over this time period.

PART 3

What you can do with the data

Now, what can capturing and analyzing the right leak test data do to help you make the quality and efficiency improvements you need to compete in the Industry 4.0 environment?

Finding the right test limits – how data makes it easier

With the signature data, it's easy to see what is happening within a test and determine where the sweet spot is for quality.

There is always that point where running the test longer will not yield further improvement. Or in the case of leak, taking more time to fill or stabilize the part. In the old days, quality engineers had no choice but to rely on archaic methods of trial and error, wading through piles of spreadsheets with manual calculations to find the ideal limits.

They don't have to anymore.

Today's signature analysis tools can automatically calculate statistically based limits. Big data analytics are harnessed to test and review hundreds or thousands of signatures to explore the impact of different test parameter and limit settings on the results. We've seen examples where the correct processing algorithms with associated limits can be established within 30 minutes rather than hours or days.

This was particularly important for one manifold manufacturer that operated a *flexible* plant – its production line had to handle multiple types of models. It needed a real-time visualization of signature data to regularly reset and adjust the leak test's calibration to the specifications of different models.

Signature analysis algorithms were used to reliably and quickly adjust calibration as well as compensate for temperature variations that could skew test results. The *visualization* of this data on a large screen made it much easier to control parameters during the test.

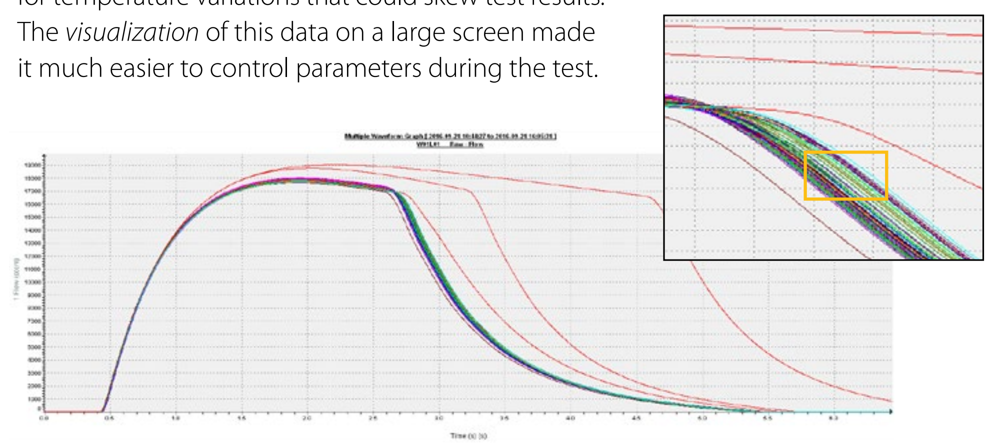

Figure 5: This figure shows 109 runs of a vacuum flow test. Four of those runs are clearly outside the test limits, which means those parts are defective. The box on the zoomed-in image shows where the test limits should be set to most accurately determine pass/fail results.

Hitting Gage R&R / Cycle time targets

The same big data analytics capability can be used to manage gage repeatability and reproducibility (R&R) in your leak test and to shorten cycle times.

Take this example. A small engine manufacturer had to run eight off-line leak test stations to keep up with an annual production volume of 3.2 million assemblies on its carburetor line. The cycle time for a leak test was 16.3 seconds. To bring the test in-line, this had to be cut to less than eight seconds.

The real challenge came when the manufacturer decided to shift production from another plant. The carburetor line had to boost its production by 75 per cent – 2.4 million additional units per year – *without* increasing the number of leak testing stations or the associated costs.

The manufacturer invested in a better standard of leak test equipment. It then harnessed signature analysis to establish the right test limits, improve the efficiency of the test and understand how the test could be shortened.

Leak test cycle times were cut, not to eight seconds, *but to 4.5*. The leak test could now be integrated back into the assembly line. Only four stations had to be staffed to handle testing for all 5.6 million units now being produced.

The new system also addressed a five per cent failure rate that had left thousands of units to be scrapped every week and eroded confidence in the reliability of the leak test. Plant staff had suspected the majority were false failures, but lacked the data capture and data analysis tools at hand to prove it. With the new system, a gage R&R rate that was so high staff stopped measuring it at 30 per cent was cut to just four per cent.

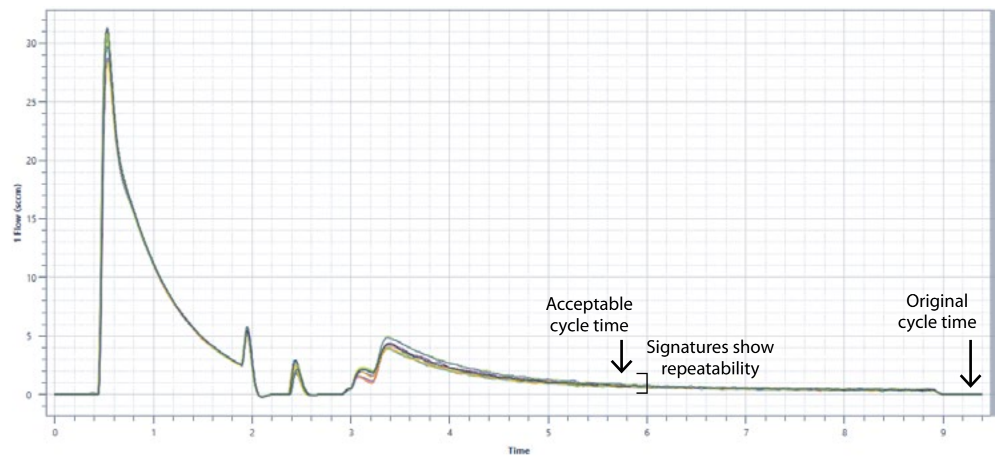

Figure 6: Based on these waveforms and using the QualityWorX manufacturing analytics software from Sciemetric to confirm sigma based on shorter analysis windows, it is apparent that we can reduce the cycle time for this leak station and still maintain a good Gage R. Scalar values would not make it evident how much cycle time could be reduced.

Faster test set-up

Implementing new technology in your plant is rarely a trouble-free experience. It is possible, however, for the technology in question to make its own implementation easier.

The more signatures you capture from any process or test station on the line, the easier it becomes to run data models and simulations that accelerate how quickly you can hit your full production stride.

A robust leak test system that relies on signature analysis is no different. Say you're trying to determine the best cycle time for a leak test. You don't have to run a series of tests. 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.

At one manufacturer of military vehicle parts, this principle was used to determine which of two types of leak test, pressure decay or flow, should be used for shock absorbers. Engineers determined the best option for them was a low pressure test that could offer a faster (read "better") cycle time.

Proof / Traceability

But sometimes, the greatest value of capturing and visualizing that signature data isn't the impact it has within your plant. It's the stamp of quality you can demonstrate to your external stakeholders.

Maybe you're a supplier to a major OEM that demands some assurance you are not the weak link in its supply chain. If a leak problem does arise, you need the means to trace the birth history of a part to find the root cause and take corrective action to ensure it never happens again.

The more signatures you capture from any process or test station on the line, the easier it becomes to run data models and simulations that accelerate how quickly you can hit your full production stride.

Signature analysis gives you this traceability, right down to the specific parts and their serial numbers. Identify a handful of defective units without having to scrap, rework or recall thousands.

Take, for example, that manufacturer of military vehicle parts we mentioned earlier. It is trusted with a contract to build parts meant for rugged and hostile battlefield conditions. People's lives depend on the performance and reliability of what it produces.

A manufacturer of Lithium Ion battery packs for electric vehicles faced the same stringent quality assurance requirements. Any leak in one of these batteries can literally have explosive consequences.

The manufacturer needed to provide regulators and customers with rock solid assurance these batteries will not leak. The batteries must be protected from, and tested for, a risk of penetration by moisture under different environmental conditions and any shock or vibration that could lead to failure.

Only signature analysis could give this critical leak test that degree of assurance.

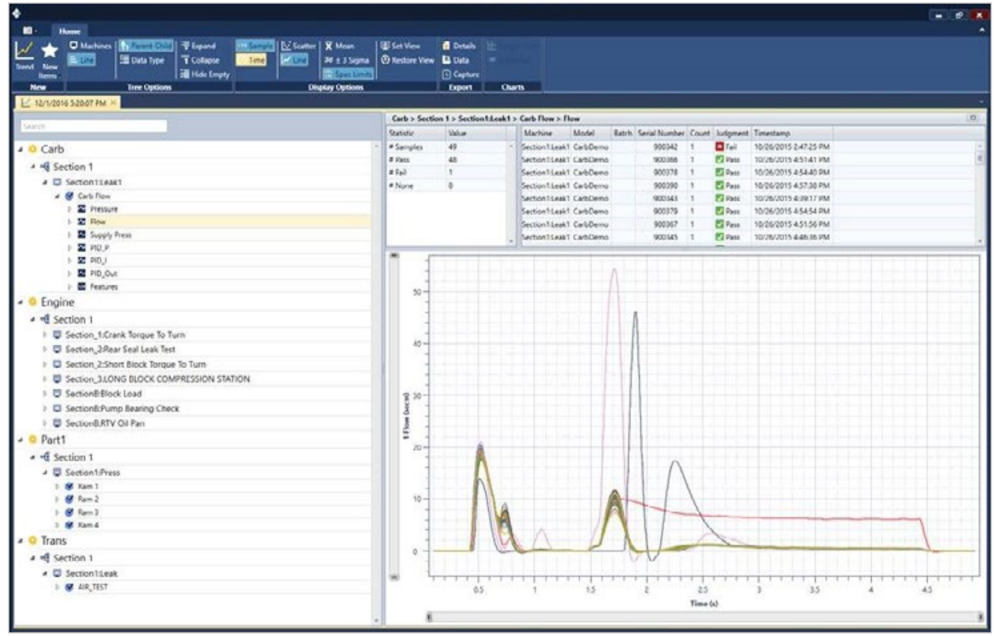

Figure 7: This screen shot taken from Sciemetric Studio shows the complete birth history of a part as it underwent multiple production processes.

Characterize the process

The waveform also helps you wrestle into submission all those complexities that make leak test so challenging.

Take, for example, seasonal temperature variations.

In plants that aren't temperature controlled, the combination of warmer days but still cold nights in spring and fall spells trouble for leak testers. The interiors of cold parts may not warm up as fast as the air in the plant. This may lead leak test equipment to report a lower, and misleading, leak rate throughout the day.

When leak tests return negative values under these conditions, the obvious conclusion is that the leak testers have been compromised and could pass leaking parts. The quality engineer's initial reaction is to lower the testers' leak rate limits to ensure the masters fail the verification test. This is comparable to throwing darts with a blindfold on – the more the plant warms up, and the more extreme the difference with the night-time temperature, the greater the shift in the leak rate. It's quite hard to guestimate the adjustment that needs to be made to maintain test quality and accuracy.

As we discussed in **Part 2**, signature analysis makes it much easier and more scientific to track and adjust for these variations and arrive at a reliable compensated leak rate.

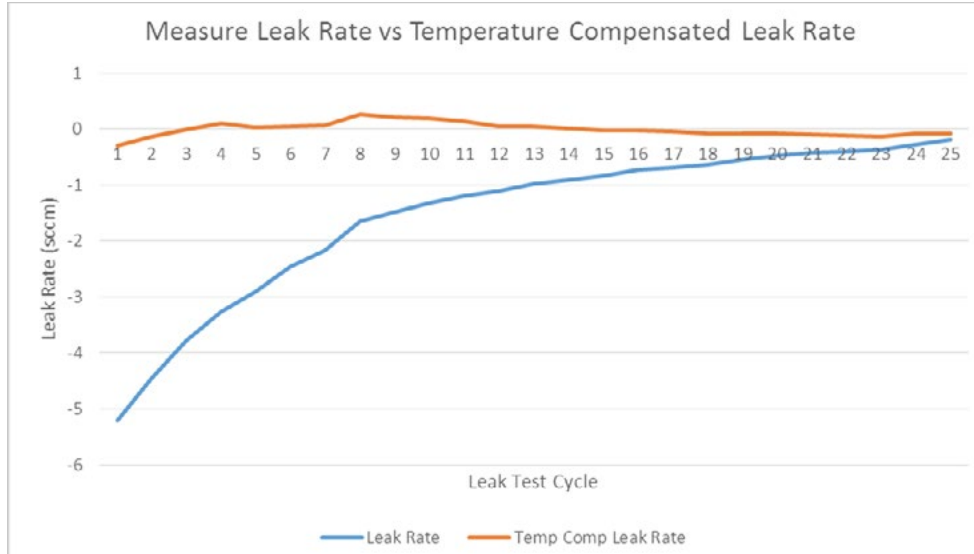

Figure 8: This graph was created while leak testing a part that is cold and warming to ambient temperature. The blue waveform is the inaccurate measurement and the orange waveform shows the corrected leak rate after applying temperature compensation.

Nor must the leak test live alone anymore. As we mentioned in Part 1, every process and test station on your line can be equipped to capture its signature data. These datasets shouldn't be left in silos. In the modern Industry 4.0 plant, they should be collected into a single database, to be cross-referenced and correlated so the root cause of a leak issue can be traced quickly, no matter its origin. In fact, with this level of insight, you can catch a problem early enough to literally stop a leak before it can happen.

The freedom to just try things

Finding the right test limits, hitting gage R&R and cycle time targets, faster set up times, a track record for proof and traceability, characterizing a process to tackle disruptive variables.

These are all things you can do with your data to give your leak test the superior performance demanded by Industry 4.0.

With all that 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 a simulation or data model at any time, just to see what the outcome might be. Play with the numbers, run them again, compare the results. It's almost a game.

The outcome, however, is serious dollars and cents stuff – find out how you can make those little tweaks that can add up to a big impact on quality, efficiency and yield. Understand which performance improvements will yield the greatest result. Do it by letting algorithms achieve in minutes or hours what used to take you days or weeks and reams of spreadsheets. Best of all, it can be done offline so it does not disrupt or interfere with the operation of the line or its test stations, or with anyone doing their job.

It all comes down to collecting the right data and having the right tools to make the most of it.

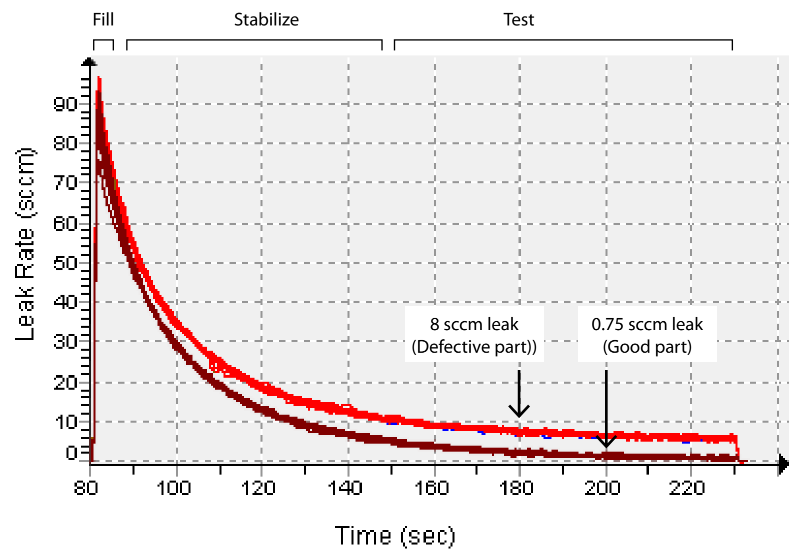

Figure 9: This figure shows the difference between good parts and defective ones. Waveforms clearly indicate what is happening in the leak test process and where best to measure the final leak rate. Sciemetric's QualityWorX tools also help engineers to quickly obtain statistics that make it easier to define the optimum location for leak measurement and what limits should be used.

PART 4

Our advantage

Partnership between CTS, innomatec, and Sciemetric brings your leak testing to the next level

In November 2017, CTS and Sciemetric became partners in the Product Integrity Division of the TASI Group of Companies. In August 2019, innomatec joined this portfolio. We now proudly operate as partners, providing the global manufacturing automation marketplace with the broadest portfolio of leak testers in the industry, strengthened by Sciemetric's manufacturing analytics capabilities.

Cincinnati Test Systems, Inc. (CTS) and innomatec have both earned a reputation as leaders in the global leak testing market. **Cincinnati Test Systems** has been delivering precision leak detection equipment, function test systems, and assembly verification testing to manufacturers across globally since 1981. We are known as the leak detection experts in virtually every major market, including electric vehicles, medical devices, consumer electronics, HVAC-R, and transportation. **innomatec** was founded in 1983 with the idea to replace traditional leak measuring methods, such as underwater testing, with computer-controlled leak testing devices and procedures. Serving mainly Europe and Asia, the company has since grown to deliver customized systems and test benches for leak checks, flow monitoring and function tests for water, air, helium, inert gas and SF6.

Sciemetric has been leading the industry in data-driven analysis on the production line since the 1990s, pioneering process signature analysis with a major North American automaker to find a better alternative to the end-of-line hot test for engines. Today, digital process signatures (waveforms) can be captured from every process and testing station up and down a manufacturing line using our technology for data management, analysis, and visualization.

Together, CTS, innomatec, and Sciemetric are bringing this technology to our respective companies' customers, showing them how process signature analysis can be applied to tackle the complexities of leak testing, as well as virtually any in-process test on the production line, using Sciemetric's QualityWorX suite of data management and manufacturing analytics software. As more and more manufacturers learn about the potential of Industry 4.0 technologies to reveal greater insight into their production challenges, CTS, innomatec, and Sciemetric are poised to help you implement powerful data-driven test solutions for the connected factory.

It's all about the data

Data makes all the difference when it comes to continuous improvement in manufacturing. Visibility into the process – what's working and where the problems lie – is a powerful tool for reducing cycle time, controlling costs, and improving productivity across the plant.

And the more data you have, the better the insight you'll derive. So, how do you get that copious data and what do you use to wrangle it into information that can drive decision-making?

Sciemetric's **QualityWorX** is a suite of **data management** and manufacturing analytics software that lets you acquire and store production data from assembly processes, easily view and analyze it, and create reports. It brings together the full picture gathered from digital signatures, which means **every second**, of **every process** that goes into building a part. Armed with that information, you can:

- Gain immediate visibility into problem areas by comparing signatures and examining pass/fail data
- Correlate downstream failures to upstream assembly operations
- Spot trends that indicate a recurring issue
- Quickly test and re-test alternative scenarios and adjustments to make improvements in your limits, and balance cycle time with Gage R
- Establish full birth history information and apply it when 100% traceability is a requirement, such as in recall, warranty or compliance situations
- Conduct actionable analysis in minutes or hours instead of days or weeks of poring over spreadsheets

If you're interested in uncovering the wealth of data that exists on your production line, or making more of the data you already collect, take a closer look at **QualityWorX**.

Contact us to learn more about our solutions for your productione line.

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