



Leak Testing 101: A Primer





Industrial products that rely on fluids or air for operation need to be tested for leaks. Whether it's pneumatic equipment, automotive parts, or medical devices, if it will hold or use fluids or air under pressure, then it needs to be leak tested for quality during the production process before it can be approved.

Leak testing is used for products in many industries, including aerospace equipment, automotive parts, battery systems, electronics, household appliances, HVAC parts, medical devices, mechanical systems, and many more. The criteria for leak testing may change for new products and designs based on their functional uses. For example, oil and fluid leakage that may have been deemed acceptable in cars made in the 1970s and 80s are well below today's standards. That's why leak testing continues to evolve, and leak measurement technology becomes more sensitive and sophisticated.

The criteria for leak testing may change for new products and designs based on their functional uses.

Depending on the parts or systems being tested, you can use one or more leak tests. Some of the most common types of leak tests include:

Dunk Testing

The most basic type of leak testing is the submersion or dunk test, in which you pressurize the part, submerge it in water, then look for gas bubbles. The frequency and size of the air bubbles are directly proportional to the size of the leak.



Pros: This is a fast, cost-effective method for basic leak detection and location.



Cons: Dunk tests are not measurable and are dependent on operators. You can guess the leak rate based on bubble size and frequency, but it does not provide exact metrics.

Pressure Decay Leak Testing

This is a common type of leak test in which you pressurize the part or system under test and measure the rate of pressure loss over time, correlated to a known reject rate. Today's leak testing technology allows small, non-water leak rates to be detected and measured.



Pros: The test is fast and highly accurate, and it is less susceptible to changes in environmental conditions.



Cons: This test does not identify the source of leaks and can be slow for large parts with low leak rates. Additionally, testing large parts may take significantly longer because of decreased changes in pressure.

Vacuum Decay Leak Testing

Similar to pressure decay leak testing, vacuum decay leak testing evacuates air from the part or system under test to detect leaks. Vacuum decay leak testing is commonly used with parts that could have leaks from external sources, such as underwater sensors, pipes, or outdoor electrical housings.



Pros: Vacuum decay testing is as sensitive as pressure decay testing and has similar precision. It is also less susceptible to changes in environmental conditions.



Cons: Vacuum decay testing can be affected by liquid evaporation and surface outgassing, reducing sensitivity. This test alone cannot test pressures greater than 14.7 pounds per square inch (psi).

Mass Flow Leak and Functional Flow Testing

For applications such as medical catheters or tubes, you want to measure the volume of flow based on leaks or blockages. With mass flow leak and functional flow testing, you pressurize air into a part, measure the rate of flow going into the part as it is held at constant pressure, and determine the leak integrity of the part or identify blockages.



Pros: Mass flow testing is ideal for large leaks, restrictions in part channels, and blockages.



Cons: The sensitivity of this testing is sometimes too low for smaller leaks. Also, the accuracy of the readings is highly dependent on the flow meter, air temperature, and system pressure.



Tracer Gas Leak Testing

For parts and systems with extremely low leak rate requirements, you can use tracer gas tests such as sniff leak testing, nitrogen purge leak testing, accumulation leak testing, and hard vacuum helium leak testing.



Pros: Trace gas testing is not affected by temperature or pressure changes occurring inside the part.



Cons: The test's sensitivity can be affected by uncontrolled atmospheric trace gas that creates background noise.

This primer provides an overview of the basics of leak testing to help you understand which types of leak testing may be most appropriate for your needs.



Leak Testing Basics

The truth is that everything leaks. No matter how exact the specifications are, every part will experience some degree of leakage. So the question isn't *if* it leaks, but rather *how much* measurable leakage is acceptable for the part or device to perform to specifications. That's why we conduct leak testing—to both detect the presence of leaks and measure the degree of leakage.

Flow amount through a hole is highly dependent on the leak path characteristics related to length, width, and edge finish (i.e., the route of the leak). There are two typical leak paths:

- 1 Thin-wall flow path:** This is a leak in thin-walled material or O-ring seals, such as those used in snap-on connectors.

Thin Wall Flow Path (Hole Dia. > 10 x Length)



- 2 Tortuous path:** This is a longer leak path that may pass through multiple seals and barriers. It is common for most types of leaks.

Tortuous Path (Most Leaks)



The same size hole will yield different leak rates depending on the length of the leak path—the longer the path, the slower the rate.

Other factors that affect flow rates when measuring leaks include:

- **Pressure:** The operating pressure of the part.
- **Temperature:** The operating temperature of the fluid in the part.
- **Viscosity:** The viscosity of the fluid flowing through the part (can be affected by temperature).
- **Surface tension:** The greater the surface tension, the more resistant the fluid is to leaks.
- **Hole size:** The larger the hole, the greater the leak.
- **Length of leak path:** The longer the leak path, the slower the leak.
- **Leak path characteristics:** The part will likely have a tortuous leak path, making measurement more challenging.

Using Pressurized Air for Leak Testing

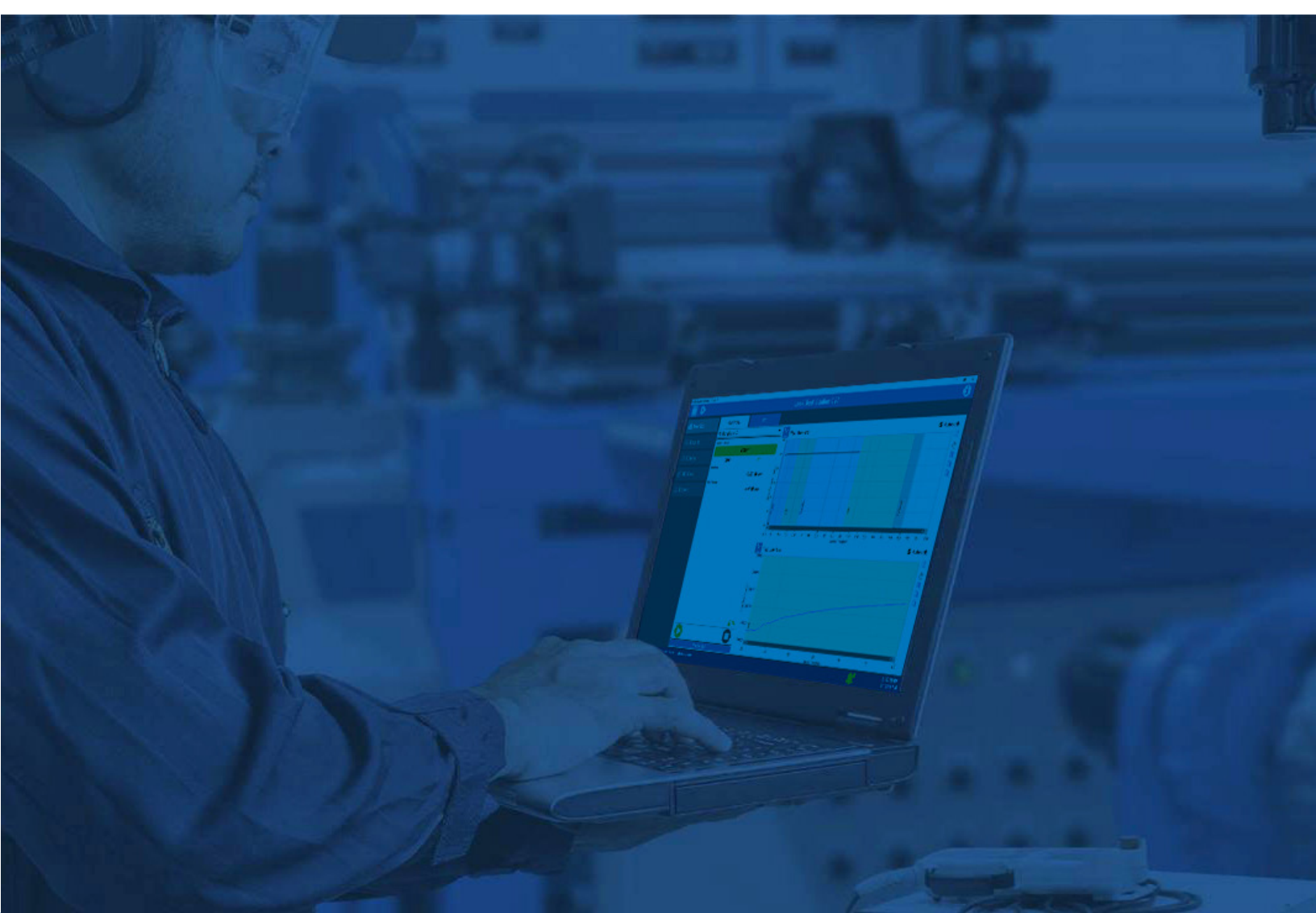
In leak testing, it is impossible to replicate actual leak conditions. However, there are ways to test for leaks that would affect part performance.

For example, using pressurized air for leak rate testing may yield accurate test results. This is because the flow rate of air is 80-100 times greater than fluids, making it better suited for leak detection. However, fluid testing can still be used in basic leak detection as a go/no-go indicator.



Using air or tracer gases—such as nitrogen, helium, or hydrogen—makes for more precise leak detection. The higher the pressure of the gas, the faster the flow rate. There is also a linear relationship between pressure and hole size. For example, if you have a hole that leaks at 20 scc/min at 100 psi, that same hole will leak at 10 scc/min at 50 psi, or 40 scc/min at 200 psi.

When you test under higher pressure, you are subjecting the part to more stress, so you have to increase your margin for safety. It is also important to take other factors into account when you fill a part under high pressure. The compression of gas creates a thermal effect, causing a greater pressure change when the part cools to an ambient temperature and increasing the cycle time for testing.





Choosing the Right Leak Rate Test Technology

Because there are multiple leak rate test options available, you need to know what type of leak test is best for your application. When deciding on the technology you want to use for your leak test, you should evaluate for leak rate, test pressures, and the variables that will affect the test measurement repeatability. You then can choose the type of test that will be least affected by test variation.

Basic Leak Testing: The Dunk Test

Dunk testing is the most basic type of leak testing. With dunk testing, you submerge a pressurized part in water and look for bubbles. Dunk testing is a great choice for simply locating leaks, but it is not a good test to measure leak rate. This is because bubble size alone cannot be used to make an exact determination of leak rate.

One way to measure leak rate with dunk testing is by counting the number of bubbles per minute, then calculating the loss of air from your part to the correlated leak rate. For example, if the bubbles are 3.0 mm, two bubbles per minute is a leak rate of 0.03 scc/m, 10 bubbles per minute is a leak rate of 0.14 scc/m, and so on. So, one scc/m is equivalent to about 75 bubbles per minute.

There is also a second method for volumetric air loss measurement, in which you collect bubbles in a graduated cylinder over a set amount of time, then equate the volume of collected bubbles to a volume of loss over the identified amount of time.

If you are looking for non-water leak rates in the range of one scc/m or greater, you may want to consider whether dunk testing gives you enough granularity.

Air Flow Measurement

When you use air or gas under positive or negative pressure, you achieve greater test sensitivity and measurable test methodologies. Of course, you have to be conscious of test conditions that can affect test results, such as temperature, humidity, or contaminants. The goal is to eliminate conditions and variables that can affect test results, create a leak test platform that has sufficient sensitivity, and provide reliable, repeatable results.

There are various types of airflow tests available:



Pressure and vacuum decay technology require you to pressurize your part or subject it to a vacuum, allow it to stabilize, then measure pressure loss over time. You can generally get a measurement sensitivity of 10^{-3} scc/s or greater, depending on test time, circuit volume, and leak rate.



Mass flow technology is similar to pressure decay technology. You pressurize the part, isolate the pressure, then measure the change in pressure over time. With mass flow, you use a regulated system to pressurize the part, so you have exact control over the amount of psi. As the part achieves test pressure, you hold the pressure constant, then introduce a flow meter to the system. As the part loses air, the flow meter determines how much air has to be added to maintain constant pressure and the system replenishes the air. Sensitivity for mass flow leak testing is typically in the range of 10^{-1} scc/s or more, depending on the sensitivity of the flow meter.



Tracer Gas Leak Testing

Tracer gas technologies are chosen based on the background controls needed for reliable testing and leak rate sensitivity. Tracer gas leak testing is typically used to detect small leaks in critical components.



A handheld sniffer is often used in tracer gas testing to identify leak location.

This is the simplest form of tracer gas testing, in which you evacuate air from the part, replace it with a tracer gas (e.g., helium or forming gas) under pressure, then use a sniffing wand to detect leakage of the tracer gas. You want to be sure to completely evacuate your part first—including pulling air from any leak location—so it immediately leaks when you pressurize. Sniff testing has a practical range of 10^{-4} scc/s when using helium and forming gas (5 percent hydrogen, 95 percent nitrogen).



Trace gas accumulation is used when you want a more controlled test

methodology. You put the part in a chamber and, instead of using a sensor or wand, you accumulate gas in a fixed volume. Then, you can measure the change in gas concentration in the chamber. Trace gas accumulation has a practical test range of 10^{-1} to 10^{-4} scc/c, depending on the volume of the chamber and the time allowed for accumulation.



Nitrogen purge leak testing is a tracer gas approach patented by Cincinnati

Test Systems. This testing is used when greater leak test sensitivity is required. With Nitrogen Purge Leak Testing, we create a nitrogen air seal, flood the chamber with nitrogen to stabilize the atmospheric background with a lower-than-normal trace gas background, then test for leaks as low as 10^{-5} or 10^{-6} scc/c.

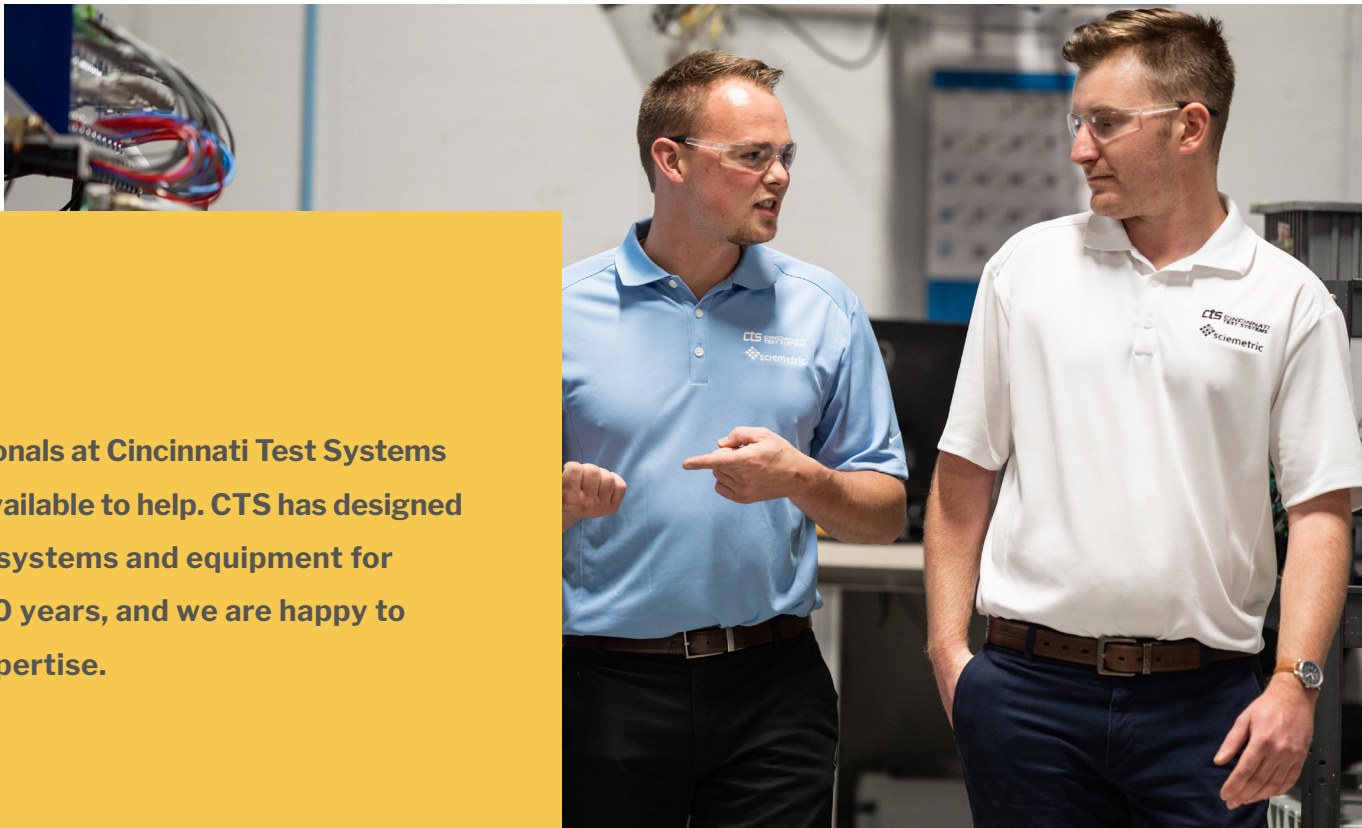
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Tracer gas hard vacuum testing is the most sensitive form of testing. It is used to test at a lower leak rate with more repeatability, and is typically reserved for parts that are not stable, are always hot, or need a faster cycle time. For this test, you use a full vacuum on both the part and the chamber, then inject a tracer gas to measure the leak rate. The gas travels through the vacuum to a spectrometer tube, in which it collides with electrons produced by the spectrometer filament to create ions. The ions are then counted to indicate the leak rate. This type of test has a sensitivity of 10^{-8} or 10^{-11} scc/s and is typically used to test parts with reject rates from 10^{-7} to 1 scc/s.

Even from this basic overview, you can see there are many variables and nuances to leak testing. Once you understand how to apply these principles in your manufacturing process, you will be able to create leak tests that are reliable and repeatable.



The professionals at Cincinnati Test Systems are always available to help. CTS has designed leak testing systems and equipment for more than 40 years, and we are happy to share our expertise.



Your Global Leak and Function Test Solution Experts

Please contact us with any questions you have.

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