SETTING AN AIR LEAK TESTING QUALITY CONTROL SPECIFICATION

Leak Testing Academy
Measurement Education and Studies

PURPOSE: To provide a basic understanding of how to define an air leak test specification for testing a manufacturers' components.

LEAK TESTING is an important quality control test in the manufacturing industry. Since there is no such thing as a completely leak-free component, the key is to determine what leak rate is acceptable in order to manufacture products that are safe and adequate for the customer's needs.

This article will help provide a guideline on how to determine leak testing specifications. It will provide testing specification examples, theoretical models, and address various considerations such as the consequences of a failed part, test scenarios, test conditions, component material, shelf life, surface tension, hole geometry, air flow models and other leak testing methods.

Once the consequence of a leaking product is determined, it can help guide what type of test method is most practical based on budget and technology required to perform testing at the determined specifications.

ABOUT THE AUTHOR

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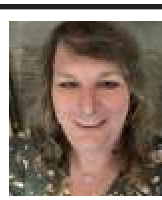

Anne-Marie Dewailly is ATEQ's North American Technical Director responsible for carrying out feasibility studies, training customers and employees. Currently residing in Nashville Tennessee, she has 32 years of experience in industrial leak testing. Originally from France, Anne-Marie started with ATEQ in 1988 as a product development engineer acquiring extensive experience in industrial leak test applications and instrumentation. She is a listed inventor in patents in the air leak test field.
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ATEQ is the leading global manufacturer of fast and accurate leak testing equipment. Since 1975, ATEQ has been building a leak testing knowledge portfolio filled with hundreds of renowned manufacturing companies and how to leak test thousands of different manufactured components.

ATEQ provides leak testing instruments to all manufacturing industries including: automotive, medical, electronics, valves, packaging, appliances, aerospace, HVAC, agricultural and batteries.

ATEQ has experienced application engineers in more than 40 countries all around the world that can provide consulting and leak testing instruments to create efficient leak or flow testing solutions. ATEQ can assist with teaching the science of leak testing, application studies, developing testing specifications, selecting the right leak tester, integrating leak testers into automated production lines, training, instrument calibrations, technical support, repairs and preventative maintenance.

WHY SPECIFICATIONS ARE IMPORTANT

"Why can't I just say that I want my product to have zero leaks?"

AIR LEAK TESTING

An air leak test is the first choice for an industrial quality control leak test method. This is because it is one of the least expensive test methods since atmospheric air is still free. Also, as opposed to a primitive water dunk test, an air leak test does not require an operator's time to count bubbles or dry the part after testing.

Air leak testing includes a variety of testing technologies including: air gauge pressure decay, air absolute pressure decay, differential pressure decay, air mass flow, differential air mass flow, mass flow in vacuum/extraction and laminar flow. Reputable leak testing companies, like ATEQ, offer a range of testers with various technologies. Each test method has advantages and disadvantages, but they all require an air leak test specification.

SPECIFICATIONS

Often times, manufacturers will know that their product needs to be airtight so they show the test equipment provider their component and say it needs to be leak free. However, there is no such thing as a product with a completely zero leak rate. Defining a precise acceptable leak rate and test pressure specification from the beginning can help avoid unnecessary quality control costs in rejected parts and manufacturing changes.

Even if the leak rate is so small, like 0.01 cubic centimeters per minute, it is still important to specify. It is no different than requiring a perfect manufacturing machining tolerance, plus or minus 1 micron, on a ruler.

CONSIDER MATERIAL

Not only is it necessary to specify test pressure and leak rates, it is also important to note the test component material. There are different strategies to testing various metals, versus plastic, wood, glass, etc.

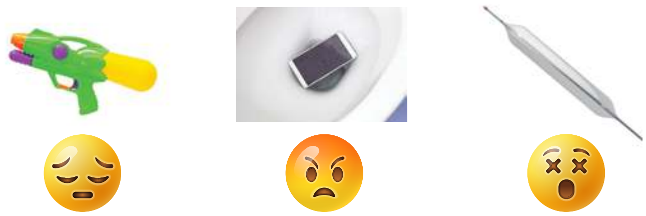
Take a traditional wine glass bottle with a natural cork seal, for example. Cork is a naturally porous material from an oak tree. If there was a 'no leak' air specification for testing the cork, than cork would be an impossible material to use. The glass also has permeation to helium. However, a glass bottle with a cork is a known acceptable leak-tight container for wine even though it technically 'leaks'. This goes to show the importance of clearly defining a specification since "no leak" to some people technically actually means "a specified acceptable amount of air leakage".

SPECIFICATION CONSIDERATIONS

"Before getting into leak testing specification details, there are lot of preliminary questions to

CONSEQUENCES

If a product leaks, how detrimental is the leak to the consumer?



CONDITIONS

A product should be tested at ambient temperature at the the normal pressure(s) that the device will experience while it is in use.

Example: A diving watch will be submitted to a range of pressure from zero differential between inside and outside to the maximum depth specified (ie. 50 m) at temperatures ranging from 60 Celsius to -30 Celsius.

SHELF LIFE

How long is the device expected to remain at peak condition?

TEST SCENARIOS

Liquid from getting out of a container
beverage containers, radiator, pharmaceutical vials

Liquid from getting inside a container
waterproof electronics

Hazardous gases getting out of a container
gas range

Air pressure getting out of a container
tires, CO2 bottle

Bacteria getting into a container
sterile solutions, medical, cosmetics, food

AIR LEAK TEST SPECIFICATIONS

"Air leak testing specifications typically include an acceptable leak rate at a given test pressure"

WHAT TO SPECIFY

Air test leak rates are generally specified by one of two methods:

Air Flow (in standard temperature & atmospheric pressure conditions) at a given Test Pressure (relative/gauge pressure)

EXAMPLE:

1 sccm (standard cubic centimeter per minute) at **15 PSIG** (pounds per square inch gauge pressure)

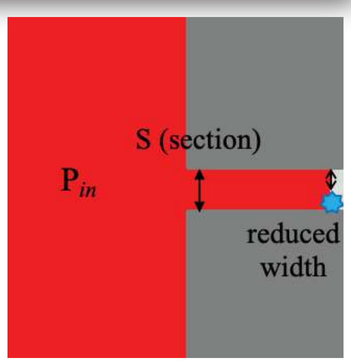
Other times, leak rates are specified by: Leak hole path geometry/dimensions and surface texture/alignment and a test pressure/vacuum.

EXAMPLE:

40 micron diameter perfect perpendicular cylinder on a smooth surface, with sharp edges 3mm long, at + 500 mbarG

300 micron diameter hole in a 30 micron thick wall at -4 inches of mercury relative (gauge) in vacuum.

The two geometric specifications above have to be translated to an air flow type specification before being used by the air leak tester so it is ideal to directly specify the air flow type.



TEST SPECIFICATION EXAMPLES

An experienced, established leak testing company, like ATEQ, has seen thousands of applications that cannot all be listed in this document. There is no one size fits all specification for a given application, however, it is possible to provide some examples of specification ranges for a variety of applications to give a starting point for guiding engineers who are required to determine testing specifications.

Auto Oil Pan:
0.5 to 4 sccm at 500 mbar

Auto Muffler/Catalytic Converter:
20 to 300 sccm at +500 mbar

Radiator:
0.5 to 10 sccm at 1 bar

Stove Gas Valve:
0.05 to 1 sccm at 20 mbar.

THEORETICAL APPROACHES

"When these parameters are known, the easiest way to develop test specifications is to compare it to a product with similar known parameters from ATEQ's existing global applications portfolio."

NO COMPARABLE COMPONENTS

If the test product is not similar to the examples or a purely theoretical approach is desired, there are other ways to define a test specification. The simplest specification is containing air pressure for a given amount of time.

USING CO_2 INSTEAD OF AIR

What if that same tire was to be filled with CO_2 instead of standard compressed air? How would that affect the leak testing specification?

THEORETICAL APPROACH #1

WHEEL/TIRE FILLED WITH AIR:

The end goal is to keep 30 PSIG in the wheel for 1 year while allowing up to 3 PSI of drop in 6 months.

Use the air volume of the smallest tire/wheel that would be most affected by a leak.

The approximate relation of pressure drop to leak is :
Leak in sccm= 0.0006x test volume in cc x pressure drop in Pa/time (in seconds)

Leak in sccm= 0.0006 x 30 000x 3x 6890/15,552,000 = 0.024 sccm

So the components on the tire/wheel assembly, like your tire valve, should be tested for 0.024 sccm at 30 PSI

THEORETICAL APPROACH #2

WHEEL/TIRE FILLED WITH C02:

The CO_2 leak of 0.024 sccm at 30 PSI is known.

A laminar flow model for very small leaks (porosity or long leak path) can be used.

Leak in air = leak of CO_2 x dynamic viscosity of air/dynamic viscosity of C02

Dynamic viscosity of air at 20 Celsius = 1.8205* exp -5 Pa/s

Dynamic viscosity of CO_2 at 20 Celsius=1.47 exp-5 Pa/s

Therefore using an air leak test would measure:
A leak in air = .024 * 1.82/1.47=0.029 sccm

CONTAINMENT OF LIQUID

"Whether you want to keep a liquid out or contain a liquid in, the problem is the same."

POROUS MATERIALS

How is it possible that a porous material like a wine cork does not allow liquids out?

This is due to the property of a liquid interfacing with materials, like air, called surface tension. Surface tension allows some insects to walk on water because if the force exerted by the weight of the insect is less than the surface tension, the insect does not sink.

The same thing happens with the wine. If the pore size of the natural cork is small enough, the wine surface tension will be more than the weight of wine, and the wine will stay inside the bottle.

For sparkling wine, the stopper material is either plastic or engineered cork since it has to keep the liquid AND pressure inside the bottle.

SURFACE TENSION ON MATERIALS

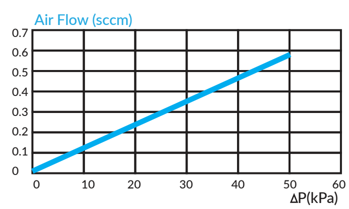
Surface tension makes some materials Hydrophilic (ex. cellulose paper towel, glass windshield) or Hydrophobic (cellulose cotton fabric treated with Scotch guard, cork, windshield treated with Rain X).

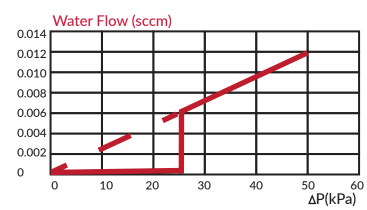
TESTING AROUND SURFACE TENSION

Depending on the surface treatment, the same material can repel water or absorb it. Hydrophobic materials contain water better than hydrophilic materials.

Some woven and non-woven fabrics, like Gore-tex or Tyvek, use this property to let the fabric breathe through thousands of tiny holes without letting liquid water through.

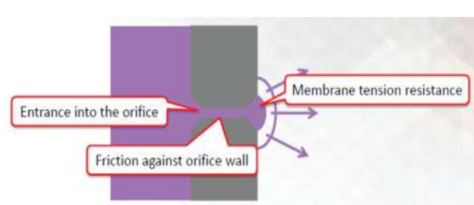
So for an air leak test, it means that at a pressure below the surface tension, air can flow but not water .At pressures above the surface tension, both air and water can flow which is crucial to understand for giving a good air leak test specification.





In order to know if the test for air flow is at a pressure below the surface tension, it is essential to evaluate the source of leaks on your product. Is the leak due to a multi-hole porosity in a casting, or a single leak path through a gasket?

Surface tension will seal more easily on a porous component than on a single hole component even if they flow the same amount of air under the same pressure.

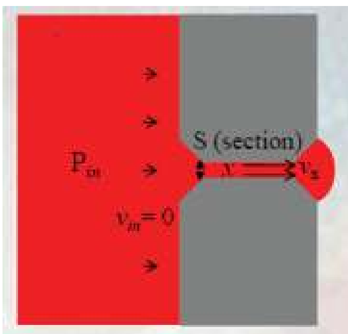


QUANTIFYING SURFACE TENSION EFFECTS

"There is a distinctive relationship between the pressure needed to break the surface tension and the diameter of a hole that should be taken into consideration when developing test specifications."

TYPICAL SURFACE TENSION MODELS

The most common surface tension model uses a perfect cylindrical hole, perpendicular to two parallel smooth surfaces, and with a sharp edge. However, it rarely fits the reality of a leak, as it is only a theoretical model.



The effect of surface tension of a liquid on a surface is quantified by a physical property called contact angle.

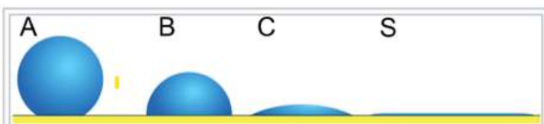


Figure 2: Wetting of different fluids: *A* shows a fluid with very little wetting, while *C* shows a fluid with more wetting. *A* has a large contact angle, and *C* has a small contact angle.

If we take the example of pure water, the contact angle varies a lot depending on materials. Some hydrophobic materials, like Teflon, have a contact angle of more than 90 degrees, some hydrophilic materials, like glass, have a low contact angle.

Fig. 2	Contact angle	Degree of wetting	Interaction strength	
			Solid–liquid	Liquid–liquid
S	θ = 0	Perfect wetting	Strong	Weak
C	0 < θ < 90°	High wettability	Strong	Strong
			Weak	Weak
B	90° ≤ θ < 180°	Low wettability	Weak	Strong
A	θ = 180°	Non-wetting	Weak	Strong

BREAKING THE TENSION

The relation between the pressure needed to break the surface tension and the diameter of the hole is as follows:

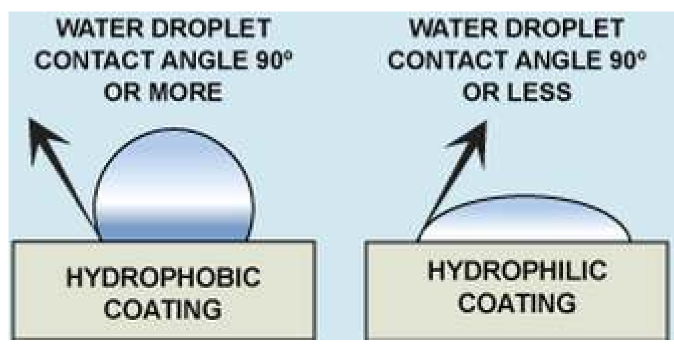
Hydrophobic Materials, with theta θ more than 90 degrees

$$P=2\gamma/r$$
$$\gamma=0.073N/m$$

P being the pressure necessary to break the surface tension, r the radius of the hole, and the surface tension of water

Hydrophilic Materials, with theta θ less than 90 degrees

$$2\gamma\sin\theta/r$$



Once the diameter of the theoretical hole is known, you need to know the length of the hole.

For the length of the hole, you need to choose the wall thickness of your likely leak path in the device you want to test.

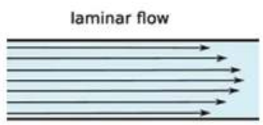
THEORETICAL FLOW MODELS FOR AIR

"The three theoretical flow models or air are laminar, turbulent and supersonic"

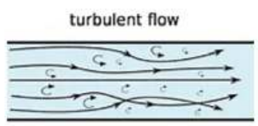
AIR FLOW MODELS

The three theoretical flow models for air are:

Laminar: the most commonly used on thick wall leak path



Turbulent: commonly used on thin wall leak paths, below 2 atmospheres of absolute pressure, or vacuum above ½ atmosphere



Supersonic: commonly used on high pressures above 2 atmospheres absolute or in vacuum less than ½ atmosphere

$$AirFlow = \left[\begin{array}{l} \dfrac{\pi \times d^4}{128 \times L \times \eta} \times \dfrac{(P_2^2 - P_1^2)}{2 P_{std}} \\ \dfrac{\pi \times d^2}{4} \sqrt{2 \dfrac{P_2 (P_2 - P_1)}{P_{std} \rho_{std}}} \\ \dfrac{\pi \times d^2}{8} \dfrac{P_1}{P_{std}} .Mach \end{array} \right.$$

d: diameter of the hole in meters

L: the length of the hole in meters

P2: absolute pressure upstream the hole (your test pressure) in Pa (Pascals)

P1: absolute pressure downstream the hole (atmosphere in general) in Pa (Pascals)

Pstd= standard pressure (101325 Pascals)

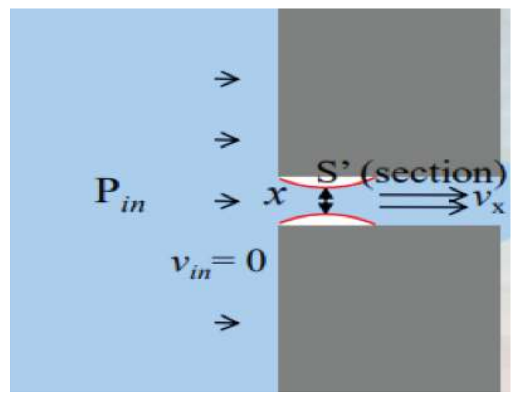
Mach: the speed of sound

ρ: the density of the gas in Kg/m3

μ: Is the dynamic viscosity of the gas at ambient temperature in Pa/s

VENA CONTRACTA

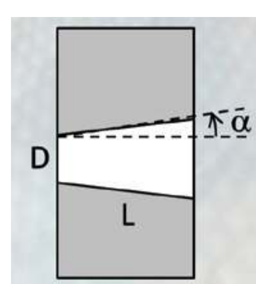
Most theoretical flow models do not fit 100% to reality. For example, in a thick wall, a straight cylindrical leak path actually has two types of air flow. The entrance of the leak path has turbulent flow then there is a path with a reduced diameter that changes the air flow to laminar.



This reduced diameter path is called a "vena contracta" which, on sharp angle cylindrical path, typically reduces the apparent diameter of the hole by 15% to 25%.

ATEQ applications engineers have a sophisticated calculator that allows them to calculate the compound flow regimes.

This calculator also takes into account if the leak hole is not a perfect cylinder and has a truncated cone shape with a tapered angle.

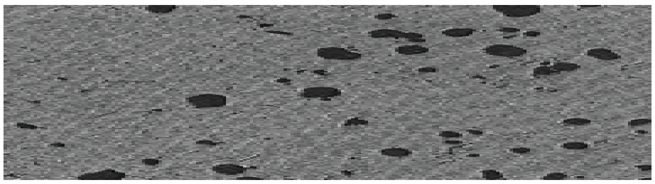


KEEPING MATERIALS IN, OUT, OR SEPARATED

"Sometimes products need leak testing for other reasons than just keeping liquids in or out of a single opening "

POROUS MATERIALS

ATEQ can also factor more than one hole to make a leak, like in this porous casting.



This result would give a theoretical flow value on a theoretical hole in the test material, at a given pressure.

A theoretical approach is a good starting point for an air leak test specification study. However, it should be validated by simple liquid tests in order to compare the bubble test results to the air test results. This helps to ensure that not too many parts are being rejected that would otherwise have been considered acceptable and that the test does not miss any water leaks.

KEEPING LIQUIDS SEPARATE

What if the desire is to make sure that two liquids do not mix, like two colors of ink? When liquid is on both sides of the hole, the surface tension with air does not help keep the liquids separate. There could be differences of salt content between two water-based liquids, so the theoretical air flow theories would not apply. Only a comparison between liquid mixing tests and air test results can help determine a test specification.

KEEPING BACTERIA OUT

The test specification for packaging would be derived from the hole size in the packaging. The hole has to be small enough to not let in any aerosol droplets or dust that could contain bacteria through the packaging and onto the medical device.

Medical packaging frequently uses materials that are porous to air but repellent to water. This means a zero air leak specification could reject all pieces so air leak specifications have to take this into consideration to be sure the specifications aren't too stringent.

CONTAINING FLAMMABLE GAS

Some countries have standard requirements for flammable gases like natural gas, liquefied petroleum gas, propane, or butane. If no standard testing was mandated, the ancient practice was to test for a low enough leak that will never maintain any flame in a well-ventilated area. Below a given amount, natural gas would just dissipate without ever reaching a concentration where ignition can happen.

Before air leak test systems became a mainstream form of leak testing, gas range manufacturers filled the range with natural gas and used an open flame to ignite the leaks.

OTHER FORMS OF LEAK TESTING

"Occasionally, air leak tests can't achieve the desired specifications and other methods must be considered "

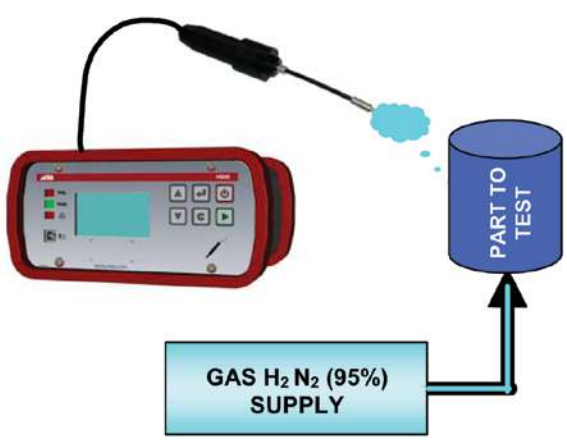
The flame tests detected gas leaks in the range of 1 sccm of air.

A large leak was very dangerous for the operator. Air leak testers replaced these dangerous flame tests, and air leak rate specifications have been lowered for added safety in case there is a situation with slow accumulation of gas in a poorly ventilated space.

CONTAINING TOXIC GAS

If the gas being tested is toxic, like for a nerve agent, no leaks are acceptable. The test specification becomes way too low and a tracer gas test has to be used instead of a less expensive air leak test.

If this is the case and a leak test specification is not achievable with an air leak test, the test specification needs to be converted to a tracer gas test specification. This specification could be either tested with forming tracer gas (5% H2 95% N2) or a helium tracer gas test which is a more expensive test system to purchase and operate.



USING IONIZATION

There are some testing situations where an air leak test may be too slow but a tracer gas test may not be the best fit either. ATEQ offers a type of electrical leak test that is ideal to test a large number of small plastic parts very quickly.

ATEQ's Ioniq or B28 electrical leak testers use safe low ionization voltages to ionize oxygen molecules in the air around the test part and display an insulation percentage to see if the part is within specification.

VALIDATION

Even if your test specification is achievable with an air leak test, there is still a need to validate the specifications by comparing the air test results to the practical tests (like a liquid visual test) on the same parts, and fine tune your test specification to your needs.

CONCLUSION

"Thousands of smartphones, transmissions, valves, syringes, batteries, bottle caps etc. are tested each day with ATEQ equipment."

Common sense is often the best method to figure out the optimal approach to leak test your device. People often set outrageously low test specifications and end up not having the budget to implement such a extensive test system, or they could not dependably manufacture parts to these tight test specifications. Some dependable leak testing that fits into a company's budget is better than no testing at all or testing specifications that are over-stringent without reason which causes the test to reject usable parts.

NEXT STEPS

If a leak test specification has been determined, the next step is to contact an leak test supplier and they can advise if the specification is achievable within the designated budget. If the experts confirm that the specifications are achievable, they can guide you through the next steps of selecting the appropriate leak test method whether it be an air leak test, a tracer gas test or an electrical leak test. Once a method is chosen, depending on the test pressure, and options needed, a specific testing instrument can be recommended. If the leak test is intended to be automated into a production line, the leak testing supplier can offer guidance regarding machine building and system integration resources.

Since 1975, ATEQ has been building an extensive applications portfolio comprised of thousands of components manufactured by world renowned companies from around the globe. Because of this vast experience, ATEQ has become a trusted expert in the field of leak testing and can guide a company from any manufacturing industry towards the best solution for its testing needs.

ATEQ has around 40 locations worldwide which makes it easy for local companies to work with nearby ATEQ offices who best understand the native language and business culture. Many manufacturers also have multiple global locations so ATEQ can provide a project assistance network between our subsidiaries around the world.

Innovation is a driving force behind ATEQ's passion to help manufacturers produce safe and trusted products. ATEQ has been a leader in creating a variety of new technologies and testing methods always seeking to develop faster, more efficient solutions.

ATEQ's Leak Testing Academy has taught hundreds of people around the world a variety of topics from Intro to Leak Testing Fundamentals to Advanced Fixture Design.

After a project is complete, ATEQ's global support network will continue to remain readily available to our customers for repairs, troubleshooting, calibrations and preventative maintenance with on-site options available.

Contact ATEQ if you would like to learn more about testing specifications or need guidance towards an application testing solution.
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