Application Bulletin #143

Managing External Forces to Achieve Desired Leak Rate, Test Cycle Time

What is an acceptable leak rate for a particular device or component? **The answer, as always, is that it depends.**

Standardized leak rates are measured as scc/m (standard cubic centimeters per minute) in North America, the benchmark is atmospheric pressure at sea level and an ambient temperature of 20 degrees C. In Europe, it's common to use 0 degrees C (identified as Normalized flow).

But context matters. If the device or component will be used under conditions that are notably colder, hotter, wetter or of different pressure, the leak rate that passes muster under controlled conditions will no longer be relevant.

Deriving an ideal leak rate formula is a function of the ideal gas law

In all scenarios and usage contexts, we are governed by the Ideal Gas Law. We know that pressure, volume, and temperature are all related in a closed system (which a leak test is). If the temperature of a part is changed during a test, the pressure within the part will also change.

Leak rate formula is derived from the ideal gas law

$$LR_{[scc/min]} = \frac{(V_{[cc]} \; x \; \Delta P_{[psi]})}{(t_{[sec]} \; x \; 14.69_{[psi]})} \; x \; 60_{[sec/min]}$$

LR	Calculated Leak Rate	[standard cubic centimeters per minute]	***t***	Test time (not overall cycle time)	[seconds]
V	Test Circuit Volume (free air space within part, test line, and instrument pneumatics)	[cubic centimeters]	***14.69***	Atmospheric Pressure (at Sea Level, 20°C)	[pounds per square inch]
ΔP	Pressure Loss (measured during test time)	[pounds per square inch]	***60***	Conversion constant	[seconds per minute]

Ideal gas law

PV = nRT

P (pressure), **V** (volume), **n** (number of moles of gas), **T** (temperature), **R** (constant)

After **t** seconds, if the leak rate is **L.R.** (**volume of gas that escapes per second**), the moles of gas lost from the test volume will be:

$$N_{lost} = \frac{L.R.\ (t)\ P_{atm}}{RT}$$

And the moles remaining in the volume will be:

$$n' = n - N_1 = \frac{PV}{RT} - \frac{L.R.\ (t)\ P_{atm}}{RT}$$

Assuming a constant temperature, the pressure after time (t) is:

$$P' = \frac{n'\ RT}{V} = \left\{ \frac{\dfrac{PV}{RT} - \dfrac{L.R.\ (t)\ P_{atm}}{RT}}{V} \right\} RT = P - \frac{L.R.\ (t)\ P_{atm}}{V}$$

$$dP_{Leak} = P - P' = \frac{L.R.\ (t)\ P_{atm}}{V}$$

Solving for L.R. yields:

$$L.R. = \frac{V\ \ dP_{Leak}}{t\ \ P_{atm}}$$

The test volume, temperature, and Patm are considered constants under test conditions. The leak rate is calculated for the volume of gas (measured under standard atmospheric conditions) that escapes from the part during a specified time period. Standard atmospheric conditions (i.e., 14.696 psi, at 20 C are defined within the Non-Destructive Testing Handbook, Second Edition, Volume One Leak Testing, by the American Society of Nondestructive Testing.

The ‘tare’ factor

Because most testing is performed without adequate fill and stabilization time to allow for all the dynamic, exponential effects of temperature, volume change, and virtual leaks produced by the testing process to completely stop, there will be a small and fairly consistent pressure loss associated with a non-leaking master part.

To correct the calculation for the consistent temperature, volume, and /or virtual leak changes that occur during the test cycle, there is a “tare” factor that offsets the pressure loss measurement. This tare factor is called the “No Leak Loss” value or the pressure loss that occurs during the test time “t” for a Master-No-Leak-Part. The tare factor is determined during the calibration process that also establishes the part and test system volume (V) for the test. The equation that considers the tare factor is:

$$L.Rsccs. = \frac{V \times (dPmeas - dPno\text{-}leak)}{t \times Patm}$$

The units of measurement are:

LRsccs	Leak rate (in scc/s)
V	Volume (in cubic centimeters)
t	Test time (in seconds)
dPmeas	Pressure loss measured during test cycle (in psi or other pressure units)
dPNo-Leak	Pressure loss for a non-leaking part measured during test cycle (in psi or other pressure units)
Patm	Standard atmospheric pressure (in psi or other pressure units) All three pressure units must be the same.

Pressure decay usually states leak rates as scc/m (standard cubic centimeter per minute). For LR leak rate (in scc/m), the formula above is converted to:

$$L.Rsccm = \frac{V \times (dPmeas - dPno\text{-}leak) \times 60\ sec/min}{t \times Patm}$$

Ideal leak testing method must always be determined on a case-by-case basis

In reference to the “Technology Choice” chart, part characteristics, leak paths, usage context, and risk of failure will always dictate actual required reject leak rates.

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Controlling the ambient variables that also impact test cycle time

A reliable and repeatable leak test must also meet a desired cycle time to keep pace with production. How the test part is connected to the test instrument is key. The primary cause of misleading test results is leaking seals and fittings.

- **Sealing:** The best seals have a mechanical component that physically locks them to the part and ensures proper orientation. They should also provide feedback to indicate that proper seating pressure and orientation has been achieved before the test cycle begins.
- **Pressure control:** Fluctuating pressure in the air supply line can impact fill time and test accuracy. It can also impact seal performance. Utilizing a regulated accumulation tank at the test station will help fix this effect.
- **Seal durometer:** A softer material makes it quicker and easier to achieve a proper seal but will wear faster. A harder seal material will last longer but may require more time and diligence by the operator to ensure a good seal. Choosing the right durometer seal depends on the production environment and the contact surface, the desired test pressure, and how many test cycles the seal must endure in a production shift.
- **Plumbing:** The closer the part is to the test instrument, the more accurate the leak test and the shorter the test cycle. A shorter hose means there is less air volume in the test circuit – less air must enter the test volume and less air must reach thermal equilibrium within the part. Hose diameter and material is also important to reduce fill time.
- **Fixturing:** Consider how the part will be held and controlled during the test cycle to avoid any movement that would compromise seal integrity.
- **Internal geometry of the part:** If the test part has numerous internal chambers that are separated by restrictions or small diameters, connect to both sides of those chambers to fill them without having to fill through that internal restriction.
- **Fast fill the part through large valves:** Large valves (1/2") will supply less restrictions in the system and larger flow rates in the system and the larger flow rates will fill the part quickly. Plus the system will exhaust itself more quickly at the end of test using the same valves.
- **Employ digital technology:** Use modern electronics and low noise circuitry to control and measure test pressure and the flow. The faster you can achieve a stable, consistent, and accurate pressure and flow, the shorter the necessary cycle time to achieve a reliable pass/fail on the part.

Technology Choice

Choose a technology that can resolve the leak measurement without the variables affecting the test.

- **Pressure Decay:** Open parts that will be sealed and pressurized internally.
- **Differential Pressure Decay:** Ingress protection testing to standards such as IP67, or for high test pressures. Also, very small leak rates that require shortened cycle times.
- **Volumetric Fill Pressure Decay:** Sealed part that cannot be pressurized internally.
- **Tracer Gas Sniff/Accumulation/Hard Vac Mass Spec:**
  - Large parts with low leak rates
  - Parts that expand due to Pressure
  - Testing repeatability is affected by variables like temperature and test pressure.

Have questions about leak testing?

Leak testing can be complex with so many factors affecting accuracy, test repeatability and cycle time. Contact the experts at CTS to discuss your leak test challenges and to get the right test for your requirements.

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