Practicing leakage testing with air the procedure of measuring pressure decrease or increase is widely used:

1. Decrease or Increase of Pressure, Basic Definitions:

The procedure is based on the measurement of the decrease or increase of the pressure in a closed test volume V according to the gas law. The air or the gas inside the volume has an absolute static pressure P1 and an absolute temperature T_1.
In the first approximation it follows the ideal gas law:

$$P_1 \cdot V = m \cdot R_i \cdot T_1 \quad \text{and/or density} \quad \rho = m / V = P_1 / (R_i \cdot T_1) \qquad (1)$$

At V and T_1 = constant the pressure decrease or increase in the volume depend directly on the mass loss or gain created from the leakage:

$$d/dt\,(P_1) = d/dt\,(m) \cdot R_i \cdot T_1 / V \qquad (2)$$

where for the mass flow (loss or gain) of the leakage is also valid:

$$d/dt\,(m) = \rho_{act} \cdot Q_{Lact} = P_1 / (R_i \cdot T_1) \cdot Q_{Lact} \qquad (3)$$

The pressure decrease or increase of pressure with a given absolute inside pressure P1 is proportional to the (actual) leakage volume flow Q_{Lact} from or into the test volume and corresponds to:

$$d/dt\,(P_1) / P_1 = d/dt\,(m) / m = Q_{Lact} / V \qquad (4)$$

To identify the mutual dependency on test volume, test pressure, input leakage volume flow, standard volume flow and pressure decrease in a single quantity, the **leakage rate L_q** is defined according to DIN EN 1330-08 at an assumed constant temperature as a coefficient:

$$L_q = d/dt\,(P_1) \cdot V = P_1 \cdot Q_{Lact} = P_{norm} \cdot Q_{norm} \qquad (5)$$

It has the physical unit [mbar · L / s].
Gas tightness is accepted for a leakage rate of smaller or equal to 10^{-7} [mbar · L/s].
This means: With a test volume of 1 mL and a test pressure of 10^3 mbar = 1 bar gauge pressure, which is equal to an absolute test pressure of approx. 2 bar abs. = $2 \cdot 10^3$ mbar abs by adding the atmospheric pressure of about 1 bar abs, a pressure decrease is measured from 10^{-4} [mbar/s] = 0,01 [Pa/s], if the leakage amounts to $5 \cdot 10^{-8}$ mL/s, or, expressed as a standard volume flow (= mass flow), amounts to approx. 10^{-7} SmL/s.

Most tightness tests are performed at a critical pressure ratio:

$$P_1 > 2 \cdot P_{atm.} \text{ or } P_{atm} > 2 \cdot P_1 \qquad (6)$$

This especially is true for micro holes and short gaps if the geometry of the leakage is in length and diameter L <120·d. In this case the actual leakage volume flow Q_{Lact} on the pressure side is limited by the speed of sound as a maximum flow speed through the leakage spot. The actual leakage volume flow is thereby dependent mainly on the temperature T and the leaky cross section surface A and hardly on the test pressure:

$$Q_{Lact} = K \cdot A \cdot c_s\,; \qquad c_s = \sqrt{R_i \cdot \kappa \cdot T} \qquad (7)$$

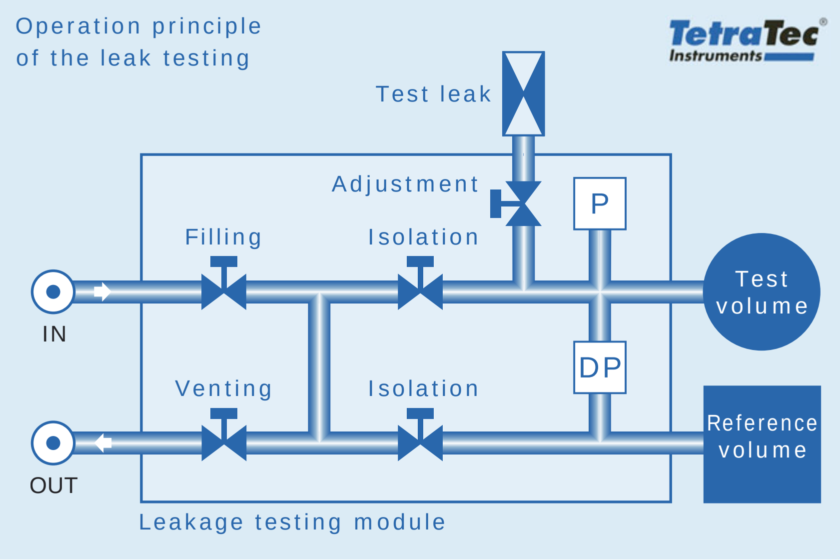
But because of the correlation between the actual volume flow and the gas density the mass and standard volume flow of the leakage remains dependent on the density. However, with small pressure decreases and short measuring times a virtually steady leakage-mass flow and with it also according (4) a rather steady pressure decrease appears which has a direct correlation with the leaky cross section surface A:

$$d/dt\,(P_1) = K \cdot A \cdot c_s \cdot P_1 / V \qquad (8)$$

K is the flow coefficient (profile factor). It is for a perfectly circular hole about 2/3rd = 0,666

2. Measurement Set-up and Limitations:

Practicing leakage testing the **procedure of measuring the differential pressure** is mostly applied to achieve a better resolution of the decrease or increase of the pressure. When it is applied a second reference volume V_{ref} is filled at the same time with the test volume. After the filling of both volumes they are separated by switching valves and the appearing decrease or increase of pressure is measured as a differential pressure between both volumes. Thus faster and more accurate results for small leakages are achieved.



However, due to leakages belonging to system and temperature effects as well as long stabilisation times one can detect leakage flows by measuring the pressure decrease or increase in the range below or equal to 10^{-6} [mbar · L / s] in very rare cases only. The typical own tightness of a tightness test block is in the range of 10^{-5} to 10^{-6} [mbar · L / s]. Hence, in the application one should hold a security distance of 1-2 in the exponent of ten of the system-own tightness. The lowest measurable leakage rate for an application is normally at about 10^{-3} to 10^{-4} [mbar · L / s]. Attention should not only be paid to a small test volume and a similar sized reference volume but also to the fact that both volumes are separated by two separate valves which are both vented to the atmosphere on the source side after the filling period. If a possible leakage of the valves appears, a self test of the system-own tightness is guaranteed. The alternative procedure for measuring the pressure decrease at the entrance of the unit under test is measuring the increase of the pressure at the exit. The latter will depend less on temperature effects from the filling process and will react much faster, if the test volume is kept small.

3. Measurement Results and Repeatability:

The tightness test is normally carried out in 4 test steps:
Filling, Calming, Measuring and Venting.
The measuring procedure is dependent on pressure and temperature. Pressure changes spread out very fast and are quickly measurable (1-10 milliseconds). Temperature changes and measurements are, however, very slow processes (1-10 seconds).
Small temperature changes created by the compression (relaxation) of the air in the filling phase are cut out in a tightness test mostly by using long filling and calming times (10-12s). In the next relatively short measuring phase for the pressure decrease (increase) of 1-3 seconds the consequences of the leakage on the pressure become measurable.
Recorded values are also dependent on long time effects in pressure and temperature of the environment. The test pressure is mostly measured as gauge pressure against atmospheric pressure. Under high- and low-pressure weather conditions atmospheric pressure can vary ±50 mbar.

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The temperature can vary accordingly ±20°C depending on the day time and season. In addition there are variations in the control stability of the test pressure from e.g. ±5mbar and unbalanced temperature effects from e.g. ±2°C.
Evaluating the repeatability with respect to the influences of temperature and pressure on the density and the speed of sound, one can expect:

	density change	speed of sound change
Temperature +/-2°C	±0,6%	±0,3%
Temperature +/-20°C	±6,0%	±3,0%
Pressure +/- 5mbar	±0,4%	±0,0%
Pressure +/- 50mbar	±4,0%	±0,1%
Total possible change	±1,0 to 10%	±0,3 to 3,1%

To give a rough idea: 1°C causes the same density change as 4 mbar, about 0.3%. At the speed of sound 1°C causes a change of about 0.15%, the pressure effect being almost zero.

To adjust, calibrate and control tightness test equipment **calibration leaks** are used.
Because the exact volume size is normally not known it is impossible to determine the leakage volume flow correlated with the pressure change. Hence, this setting is a necessary requirement to determine a correlation between leakage flow and pressure change. The calibration leaks are mostly calibrated on the basis of standard volume or mass flow at a certain test pressure. By an everyday comparison of the tightness test device with the calibration leak the measured pressure decrease can be recorded and problems in the device will be soon visible.
Furthermore, one gets a good impression of the daily and seasonal variations and correlations of the measured leakage on the environment conditions can be recognized and corrected, if necessary

4. Best Possible Test Conditions:

In every tightness test set-up the same good measuring conditions are required to achieve repeatable measurement results:
The test air must be dry, not condensing, free of oil and well filtered with a 5µm equivalent.
The volume of the test device must be kept as small as possible.
The units under test must be acclimatised at least for 1-2 hours before the test in the test room, so that there won't be big differences in temperature between Uut and test air as well as test device.

Condensate and dirt can destroy parts of the measuring device.
Excessive volumes with small leakage rates will increase the test time.
Temperature effects between unit under test and test air will make the repeatability worse.

When the units under test are either too warm and too cold and when the surface of the Uut is big, this can lead to a heat exchange between the test air and the environment and thus to temperature changes. Because of the bigger mass and the lower coefficient of temperature expansion in relation to the test air the test volume does not normally change its size during the test.
Slow heat conductivity effects between environment, Uut and test medium in an adiabatic running process lead to pressure increase or decrease caused by the temperature.
This adds to the increase or decrease of pressure due to an existing leakage.
Unsteady states in the test volume, leakages in the adaptation and electric magnet valves as "heating sources" make the repeatability worse and may even make a leakage test all together impossible.

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