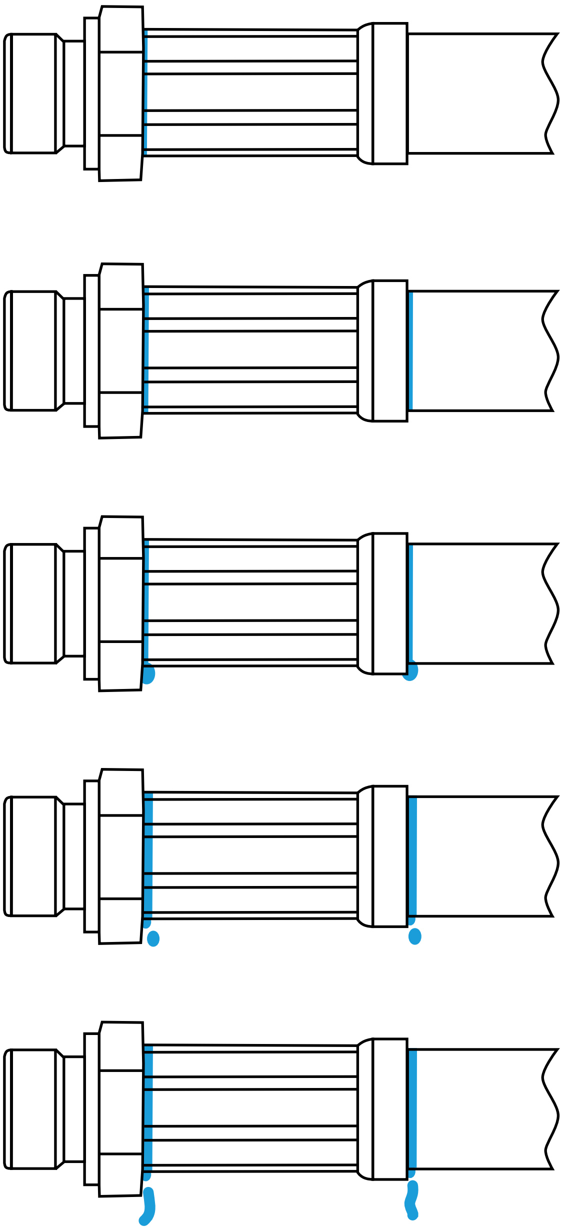
TIPS AND TRICKS FROM THE EXPERTS

The expression „water tightness“ leaves room for interpretation

The expression “watertight“ has established itself as a description for the features of parts and designs in our colloquial language. Very often, expressions like “watertight” are used in construction plans as specifications of the leakage rate. But when taking a closer look, it becomes obvious that this expression leaves a great scope for interpretation. It is not specified how this demand set on the degree of tightness is to be understood: Is the accumulation of a drop or liquid film on the surface of the component being tested still acceptable when it is described as “watertight”? Or is any escape of water to be excluded at all? These counter-questions clearly show that the colloquial term “watertight“ is not suitable for defining tightness specification. Therefore, information on the water tightness of parts and components must be differentiated more intently.

Distinction of six classes

According to “ISO/TR 11340:1994-07, Rubber and rubber products - Hydraulic hose assemblies – External leakage classification for hydraulic systems”, the leakage of fluids can be classified into six different classes (see figure 1). This allows for making an evaluation but does not provide any quantification.



Class 1:
No moisture escaping

Class 2:
Fluid escaping without droplet accumulation

Class 3:
Fluid escaping with non-falling droplet accumulation

Class 4:
Fluid escaping falling drops

Class 5:
Fluid escaping, whereby the frequency of falling drops amount to a measurable liquid stream

Figure 1: Leakage classification according to ISO/TR 11340: 1994 (E)

To derive quantification for a tightness test by observing leaking water, the formulas compiled in the Pfeiffer Vacuum “Leak Detection Compendium“ to convert a fluid leak rate into a tracer gas leak rate can be applied. For illustrationg this derivation, an example from the everyday life can be applied: If colored drops on a slope shall be avoided while skiing, a snow groomer must not lose any drops from its cooling water line. Therefore, the cooling water line can be classified as class 3 of ISO/TR 11340.

If the leaking water bubble is spherical and has a diameter of 2 mm, its volume is approximately 4.2 mm^3. Once this bubble emerges, it will either freeze in low temperatures or it will vaporize within 10 minutes in temperatures above 0°C. This gives us a maximum fluid leak rate of 4.2 mm^3 in 10 minutes, or approximately 7 mm^3 per second.

The conversion to a helium leak rate is done with the formula:

$$Q_{He} = \frac{\eta_{liquid}}{\eta_{gas}} \cdot Q_{Water} \cdot \frac{p_1 + p_2}{2}$$

η_{liquid} = Dynamic viscosity of the liquid [Pa·s]
η_{gas} = Dynamic viscosity of the tracer gas [Pa·s]
p_1 = Supply line pressure (abs) [bar]
p_2 = External pressure (abs) [bar]

Mit den Zahlenwerten
η_{liquid} = $1.0 \cdot 10^{-3}$ [Pa·s]
η_{gas} = $1.86 \cdot 10^{-5}$ [Pa·s]
p_1 = 3 [bar]
p_2 = 1 [bar]

gives us a helium leak rate of approx. 0.75 mbar·l·s^{-1}. If this rate is then calculated for a test pressure of 1 bar against vacuum, approx. 0.1 mbar·l·s^{-1} are obtained. If we consider the case of steam-sterilization of optical medical devices, then the water drop should of course be substantially smaller than the resolution that the treating physician's eye can register. By assuming a droplet diameter of ¼ mm, we will arrive at helium leak rates in the vicinity of a couple of 10^{-6} mbar·l·s-1.

In the above examples, we have water in liquid and steam form. But does "watertight" really cover such a broad area, particular with respect to the liquid aggregate state?

A literature search procures the representative statements on watertightness shown in table 1 (www.dgzfp.de/Fachausschüsse/Dichtheitsprüfung/faq; FAQ 22, in German):

These are mostly calculated values, also resulting in differences in published tables for leak channels, which is a leak in a relatively thick wall, and aperture leaks, i.e. a leak in a very thin wall. The values of the abovementioned table certainly provide clues for a sensible range of the specification. However, they do not suffice for an actual quantification.

The maximum diameter of an opening through which a liquid can no longer escape is calculated with the following equation:

$$d_{\max} = \frac{4 \cdot \sigma \cdot \cos\phi}{\Delta p}$$

σ = Surface tension [N·m-1]
ϕ = Wetting angle
Δp = Pressure difference between beginning and end of the leak channel [bar]

As the wetting angle is usually unknown, it is assumed to be 1 - this is the largest value a cosine can take and thus also the worst case scenario for a leak rate. The surface tension of water at 20 °C is stated as $72.8 \cdot 10^{-3}$ N·m^{-1} in reference tables. However, this only applies at this temperature for non-low surface tension water on aluminum.

If one changes the temperature, adds a drop of a surfactant (dishwashing detergent) to the water or uses a water-repellent plastic as a surface, the water will crawl through channels. The surface tension would otherwise easily block – then, "watertight" can change from 10^{-2} mbar·l·s-1 to 10^{-5} mbar·l·s^{-1} in no time.

It gets even worse if minute quantities of water evaporate from the surface of a calotte of a small water filled leak channel, increasing the weight of oscillating crystals or corroding contacts and electrical lines inside the enclosed housing of an electronic component – it doesn't take long here to get into the 10^{-8} mbar·l·s^{-1} range.

These examples are intended to illustrate that "watertight" really covers a broad and dynamic range of leak rates, and that a catchword can never be used as a quantitative tightness specification.

You are welcome to reproduce the estimations of this tip with the formulas found in the Pfeiffer Vacuum Leak Detection Compendium.

We would be happy to assist you in optimizing your vacuum solutions for specific applications – go ahead and ask us!

Leak rate / mbar·l·s^{-1}	Leak rate / Pa·m^3·s^{-1}	Diameter of the leak channel / m	Leakage at 1 bar differential pressure
10^2	10^1	$1.0 \cdot 10^{-3}$	Water escapes
$10^0 = 1$	10^{-1}	$1.0 \cdot 10^{-4}$	Water spigot starts dripping
10^{-2}	10^{-3}	$3.5 \cdot 10^{-5}$	Approximately the diameter of a hair; minimum requirement of "won't drip"
10^{-3}	10^{-4}	$2.0 \cdot 10^{-5}$	"waterproof"

Tabelle 1: Representative statements on watertightness

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