Permeability Tests with Helium and Hydrogen on Soft Gasket Materials

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A perfect fit

For some time, hydrogen (H_2) has been widely advocated as the future optimal alternative fuel. If H_2 were to substitute methane even partially in this sector, H_2-running systems will become commonplace and their leak-proof certification a must. Therefore, DONIT engineers undertook the creation of a reliable and practical database, purpose-made for the H_2 barrier/permeability property of the company materials' portfolio, under its TESNIT® brand. This would result from actual real corresponding leakage performance measurements using H_2 as the test medium, which would then correlate with the ones obtained with the helium (He) conventional test medium.

In the sealing sector, gasket materials should be, by definition, compatible with the transiting or contained fluid and should withstand the operating conditions. These requirements cannot be overstated in the case of corrosive, hazardous, or flammable fluids. In fact, H_2 is one of the most difficult gases to contain and prevent from leaking. Besides, knowing that the explosive limit of H_2 gas is approximately 20% lower than that of methane and combined with a lower ignition temperature (**Table 1**), this translates into a significantly higher explosion risk for the former and a greater hazard for the installation and operating site. And naturally, one cannot tolerate a greater gasket leak of H_2 than of methane. Therefore, it is crucial to determine the actual gasket material sealability for H_2 itself.

To the best of our knowledge, not many practical studies have been conducted to date, and we were interested in obtaining such data for our TESNIT® BA soft gasket material.

Gas	Lower Explosive Limit (vol.%/Air)	Higher Explosive Limit (vol.%/Air)	Ignition Temperature (°C)
Hydrogen (H_2)	4.0	75.6	560
Methane (CH_4)	5.0	15.0	595
Ethanol (C_2H_5OH)	3.5	15.0	425

Table 1. Explosion limits and ignition temperatures of some gases.

Conventional Standards for Gasket Leakage Measurements

Considering gasket functionality in applications, conventional fluid leakage tests are conducted according to established standards typified by the following ones:

- Acc. to **DIN 3535-6,** the specific leak rates are tested using nitrogen (N_2), the leaked gas volume is measured at room temperature (23°C), 32 MPa gasket surface load under 40 bar internal pressure, e.g. with a gas burette, mass flow detector or differential pressure method. The "DVGW criterion" applies here to a leakage of <0.1 mg/(s*m) for 2 mm thick gasket materials.
- In **DIN EN 13555,** the leak of He gas (as the test medium) is measured at room temperature (RT). Accordingly, the obtained Q_{min} values represent the surface loads required for the gasket installation, whereas the Q_{smin} simulate the leakage in-service conditions. As this technique has recourse to a sensitive mass spectrometer as the detector, very low leaks can be detected. Gasket data according to DIN EN 13555 are the basis for the flange-calculation acc. to EN 1591-1, and allow the validation of flanged connections for TA-Luft.
- In **TA-Luft** and **VDI 2440–VDI 2200 (VDI 2440/2200)** and following a defined heat treatment cycle applied to the gasket, the He gas (as the test medium) leak is measured at RT under 1 bar (internal pressure) and 30 MPa of gasket surface load. Here also this technique employs a mass spectrometer for the fine leakages with a sensitivity equivalent to the latter test.

Note that all the aforementioned standard test methods call upon either N_2 or He gas as the test medium (non-H_2 environments). In general, it is commonly accepted that if the sealability threshold is determined for He or N_2, this would be valid as well for methane; in practice, it is admitted that a gasket material with an $L_{0.1}$ tightness class for He could serve to tightly seal other gases too.

But does that also apply to hydrogen?

New Test System for Determining H_2 Leakage

From DONIT R&D Application Engineering labs, a gasket testing setup for H_2 permeability emerged in 2021 (**Fig. 1**). Its design is based on a further improvement of the **VDI 2440/2200** standard. This latter well-established standard can now be extended to the testing of sealing materials for their H_2 permeability and resistance.

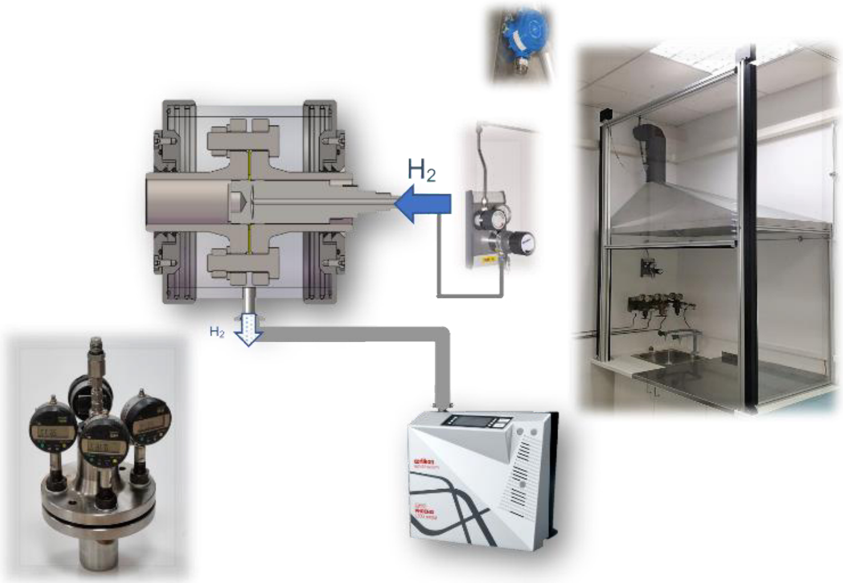


Fig 1. DONIT test system for determining H_2 leakage.

H_2 Testing Setup Technical Characteristics

- *Gasket Dimensions/Format:* accommodates DN40/PN40.
- *H_2 Gas Medium Composition:* up to 100% (i.e. pure H_2).
- *Testing Temperature:* room temperature
- *Internal Pressure (of the fluid medium):* up to 140 bar
- *Gasket Surface Stress:* can be optionally varied.
- *Leak Detection:* by mass spectrometry

H_2 Testing Setup Special Features & Advantages

- Direct data acquisition for He or H_2 leak per gasket obviating the need for gasket exchange and excluding comparison errors
- Comparable simulation to actual in-field service parameters for flanged installations

DONIT Gasket Materials for He & H_2 Gases

Gasket permeability to He or H_2 was performed on representative soft gasket materials: **TESNIT® BA-U** and **TESNIT® BA-SOFT**. These exclusive materials from DONIT are based on aramid fiber with NBR.

TESNIT® BA-U is a renowned brand that is well-suited for gas (air, methane, propane, butane) installations, while the latest innovation, **TESNIT® BA-SOFT,** combines excellent adaptability and sealability with very good thermomechanical properties.

Mass and volume leakages of **TESNIT® BA-U** and **TESNIT® BA-SOFT** were determined under 30 MPa of surface stress and 5-40 bar of internal pressure. **Figure 2** shows the comparison between leakage values of He and H_2 as mass and volume leakage of **TESNIT® BA-SOFT.** The gasket was installed with 30 MPa surface pressure. The leakage was measured at different internal pressures ranging from 5 to 40 bar. In both diagrams, the H_2 leakage at 40 bar internal pressure is slightly, but not significantly higher than the He leakage.

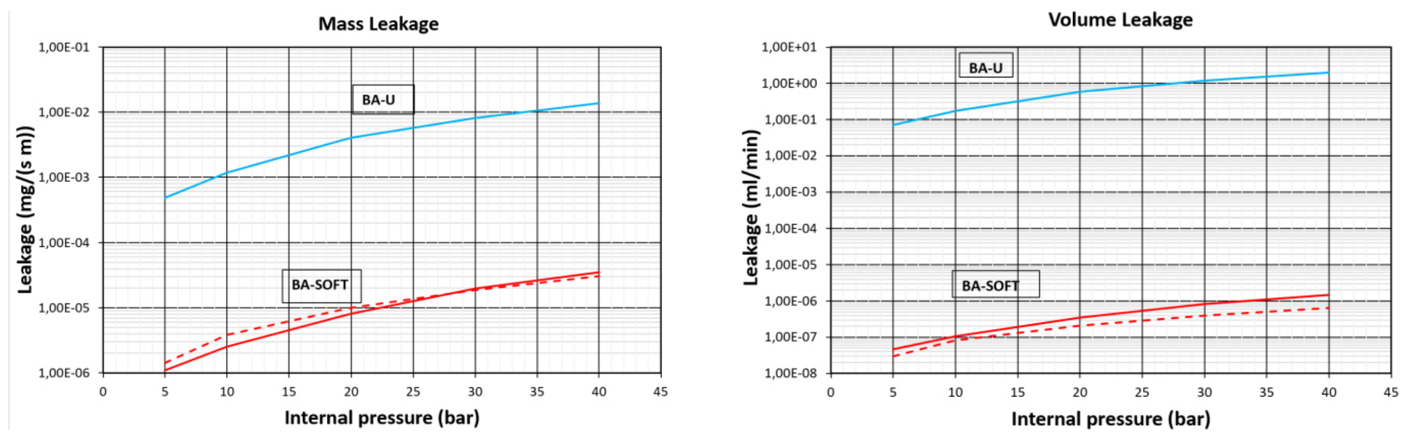


Fig 2. He (dashed line) and H_2 (full line) leakage curves for **TESNIT® BA-SOFT** (red) and **BA-U** (blue) at 30 MPa installation surface stress.

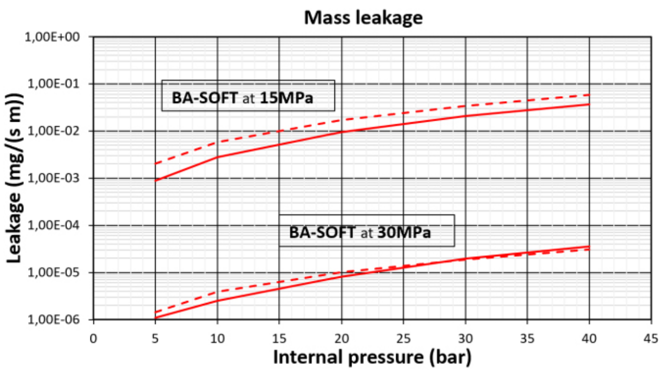
Having an isolated view on the larger kinetic diameter of H_2 compared to He, one would expect a lower leakage of H_2, while with an isolated view on the higher effusion rate of H_2 compared to He, leakage of H_2 would be higher. Our results show that the effusion rate is the governing factor.

Gas		Molecular weight	Kinetic diameter (picometer)	Relative kinetic diameter	Relative rates of effusion
Name	**Formula**				
Hydrogen	H_2	2	289	1.1	1.4
Helium	He	4	260	1	1
Nitrogen	N_2	28	364	1.4	0.37

Table 2. Data of some fluids.

Interestingly, under 30 MPa of surface stress, **TESNIT® BA-SOFT** displayed a 1000-times superior sealing performance to **TESNIT® BA-U** with mass leakages of ca. 10^{-5} and 10^{-2} mg/(s*m), respectively.

In a trial simulating a sub-optimal installation of **TESNIT® BA-SOFT** (i.e. under 15 MPa of surface stress), a significant increase in the leakage was observed (**Fig. 3**). However, this leakage remained within the same level as that of **TESNIT® BA-U** which was installed under the optimal conditions (i.e. 30 MPa); this demonstrates the practical functionality and advantages of **TESNIT® BA-SOFT.**



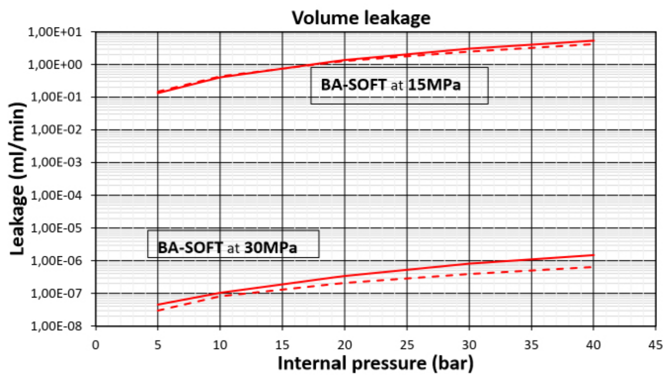


Fig 3. He (dashed line) and H_2 (full line) leakage curves for **TESNIT® BA-SOFT** at different installation surface stresses.

Prospects

DONIT is committed to providing reliable and practical performance data concerning its gasket materials, especially the ones which were purpose-built for high-risk applications. For the sake of increased safety, reducing the H_2 emissions in an installation using it is a top priority due to the hazardous nature of this fluid.

We have established a safe and valuable H_2 leakage testing method and applied it to **TESNIT® BA-U** and **TESNIT® BA-SOFT** gasket materials as examples. This method, which is based on a further improvement of the **VDI 2440/2200** standard, offers concrete and reliable data for the evaluation of gasket materials destined for sealing H_2. This work demonstrates that the determination of mass or volume leakage according to **EN 1591-1** standard with He as the test medium, is valid as well for the H_2 medium.

TESNIT® BA-SOFT gasket material proved its superior sealing performance as it exhibited a 1000-fold lower mass leakage vs **TESNIT® BA-U** – the latter exemplifies a common material within its category of applications. In addition, in a trial simulation, the former displayed higher tolerance to poor installation conditions. Therefore, we recommend the use of **TESNIT® BA-SOFT** in H_2 sealing applications.

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