# Technical considerations when testing hydrogen valves with air

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**A paper on how leak tightness tests for valves and mechanical fittings for the supply of hydrogen as a gaseous fuel up to and including 16 bar can be performed with air or nitrogen**.

The product standards ISO 4437-4 (and its European counterpart EN 1555-4) and ISO 17885 are well known documents to confirm the functional requirements of, respectively, valves and mechanical fittings in the field of the supply of gaseous fuels up to and including 16 bar(g). The documents describe various leak tightness tests, which are performed with air or nitrogen, on new valves or mechanical fittings.

Thanks to these requirements, there are currently high quality products on the market which have been successfully used for many years in applications with natural gas. Although the application is natural gas, the tests are performed with air/nitrogen. This means that it is currently generally accepted that testing 'leak tightness in air' is an suitable method for testing the 'leak tightness in natural gas'. Hydrogen produced from renewable energy sources can make an important contribution to reducing greenhouse gas emissions. When hydrogen gas is to be transported through the existing gas pipelines, the safety level has to be at least the same as for the transportation of natural gas. This means that important questions need to be answered, such as: how would the leak tightness in air translate to the leak tightness in hydrogen gas?

This paper contains technical considerations explaining why air can safely be used to test the leak tightness of mechanical fittings and valves, which are to be used in the field of the supply hydrogen as an gaseous fuels up to 16 bar(g), without impacting the quality of the tests.

## How is leak tight described in the standards?

The various test standards use a different definition of the term 'leak tightness'. For instance, EN 4437-4 Annex A just states to use '*a device capable of detecting leakage*' and to '*observe and record any signs of leakage*'. EN 1704 describes that the test piece has to be submerged in water and a pneumatic pressure is applied to '*monitor the test piece for, and record, any [external/internal] leakage*'. This means a visual check for air bubbles is required. In ISO 3458 it is described that a leak can be detected with leak detection fluid, if air is used as test medium. As a final example ISO 3459 states that '*the assembly shall be considered to be leak tight if the change in vacuum pressure is ≤50 mbar*'. All requirements in the product standards (ISO 4437-4 and ISO 17885) are simply: '*No leakage during the test period*' or '*Leak tight*'.

## What is leak tight?

It is often thought that hydrogen is a small molecule and will therefore pass easier through an opening. However, leaks involve openings that are many times the size of the molecule. This means that leaks are much bigger than the size of the molecule. If the opening is in the same order of magnitude in size as the molecule, we talk about permeation, not leak tightness.

Discussing molecule sizes with respect to leakage is similar to discussing if a grain of sand could pass easier through an enormous hallway compared to a grain of gravel. It is not relevant, because the size of the hallway is many times the size of the grains. This means that if 'leak tight' is considered, the opening must be so small, that only permeation could occur.

Extensive research in two separate projects in the UK [1, 2] demonstrated that:

- A non-leaking fitting in methane will be non-leaking in hydrogen;
- A leak in methane will result in a leak in hydrogen.

The same is found in research with valves in the transmission grid. This showed that all valves were externally leak tight in both natural gas and hydrogen [3], so these were *not* leaking with hydrogen *and* they were leak tight with natural gas. It is also found that small leaks are very difficult to create [4]. A coupler is normally either leaking (a lot) or it is not. This means that a leak will be visible anyway, irrespective of the type of gas. So, leak tight in nitrogen is leak tight in natural gas and leak tight in hydrogen. This conclusion is even supported with evidence from a real-world installation [5].

## Conclusion

The product standards ISO 4437-4/EN 1555-4 and ISO 17885 don't allow leakage. In this case the type of gas is irrelevant. This means that air can safely be used to test the leak tightness of mechanical fittings and valves, which are to be used in the field of the supply hydrogen as an gaseous fuels up to 16 bar(g), without impacting the quality of the tests.

## Difference in permeation

As mentioned above, mechanical fittings or valves which are leak tight may still permeate a very small amount of gas. The permeation rate of a gas through a physical barrier depends on:

- The difference in partial pressure over the barrier;
- The surface area of the barrier;
- The thickness of the barrier;
- The temperature;
- The permeation coefficient of the barrier for the specific gas.

The permeation coefficient of hydrogen is generally higher than the permeation coefficient of methane or nitrogen for a barrier, because of the smaller size of the molecule. This means that the permeation rate will be slightly higher. Nevertheless, in the field of the supply of gaseous fuels up to and including 16 bar(g), permeation is not measured with the leak tightness tests, because the volume is too small. This is confirmed by the fact that that a non-leaking fitting in methane is found to be non-leaking in hydrogen [1].

## Difference in leakage

Please note that the product standards ISO 4437-4/ EN 1555-4 and ISO 17885 don't allow leakage. But if we would consider that there is a leak (that can be detected), there is a difference between gases! This is discussed in great detail in a Hy4Heat and HyDeploy report [1, 2]. If the leak is very small and long, the flow will be laminar. The volumetric leak rate is therefore inversely proportional to the viscosity of the gas. For a wide and small leak, the flow will be turbulent and the leak rate is inversely proportional to the square root of the density of the gas. Again, this is only when a certain leak rate is allowed and is measured, which is **not** the case for valves and mechanical fittings in the field of the supply of gaseous fuels up to and including 16 bar(g).

In a standard for fuel cell technologies [6] it is explained as well how the leakage rate must be calculated using formulas for the viscosity or the density. Using these formulas the flow of hydrogen through a leak is about three times higher than for natural gas based on the density ($\rho_{natural\ gas} = 0.83\ kg/m^3$, $\rho_{hydrogen} = 0.08988\ kg/m^3$) and 1.2 times based on the viscosity ($\mu_{methane} = 10.87\ \mu Pa\cdot s$, $\mu_{hydrogen} = 8.748\ \mu Pa\cdot s$).

Research in Hy4Heat has shown that the volumetric leak ratio of hydrogen to methane in piping systems fluctuates between values of 1.2 and 2.8 [1]. Research in HyDeploy has shown a ratio between 1.1 and 2.2 [2]. Another research varied the length and diameter of an opening and resulted in factors of 1.4 and 2.2 for hydrogen and natural gas [7]. In HyDelta it is found that the flow of hydrogen through a leak in service lines (at a maximum pressure of 200 mbar) is about 1.4 to 1.8 times higher than for natural gas [4].

This means that when a certain leak rate is allowed, the type of gas that is used for testing is of importance. It will therefore result in different requirements for the leak rate depending on the gas. Please note that there is no visible difference between bubbles in leak detection fluid produced by hydrogen leaks and those from methane leaks [2].

Finally, in case of leaks, not only the volume of the gas is important, but also other safety aspects such as the energy content, the ignition energy and temperature, the flammability and explosion limits and the mixture and dilution of the gasses. At high pressures the resistance against rapid gas decompression is a factor as well.

## More information?

Feel free to contact us by phone (+31 (0)88 998 35 21) or e-mail (technology@kiwa.com) if you have any questions. Or find out more on www.kiwa.nl/hydrogen.

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