Running out of helium for your leak detection?
What about Hydrogen?

In this first part of the FAQ collection, we answer our customers most frequently asked questions about switching from helium to hydrogen as a tracer gas.

Part 1: Basics

PFEIFFER VACUUM

The most important questions regarding the switch from helium to hydrogen as a tracer gas

Want to get started right away and learn how to convert your leak detection process to hydrogen?

Then read Part 2 "Practical Tips" of this FAQ, which is available for free on our knowledge platform:

Part 2 contains:

- How to prepare your leak detector for the change from helium to hydrogen tracer gas.
- What performance you can expect in terms of background, sensitivity, and test speed.
- How you can alternatively reduce your tracer gas costs in leak detection.

What is this FAQ collection about?

Leak testing not only plays an important role in our daily safety and environmental protection, but also in the reliability of production processes and the quality of our everyday products. They represent an important step in the quality control of a product, for example in the automotive industry, in the pharmaceutical industry and in future technologies such as electromobility. The most commonly used specific tracer gas for leak detection is helium. In recent years, there have been regular reports that the global supply availability of helium is decreasing while demand is increasing. As a result, the price has risen rapidly, and distribution has been prioritized. The use of liquid helium in nuclear magnetic resonance scanners or in gaseous form as an additive to breathing gases enjoys higher priority than industrial use. Availability has become critical. In particular, small companies with limited helium requirements have difficulties in procuring helium. There is general concern about disruption to the helium supply chain and the resulting (costly) disruption to leak testing in production, even though this only consumes around 4–5% of the world's annual helium production.

As a result of this supply chain problem, alternative test gases are being identified. One of the most important alternative solutions is "forming gas 95/5" (95% nitrogen – N_2 / 5% hydrogen – H_2), which is becoming increasingly popular due to its lower price and high availability, as it is cheaper and easier to obtain. However, there is still little published information available on the results that can be achieved in leak testing with forming gas and the potential and limitations of using this tracer gas.

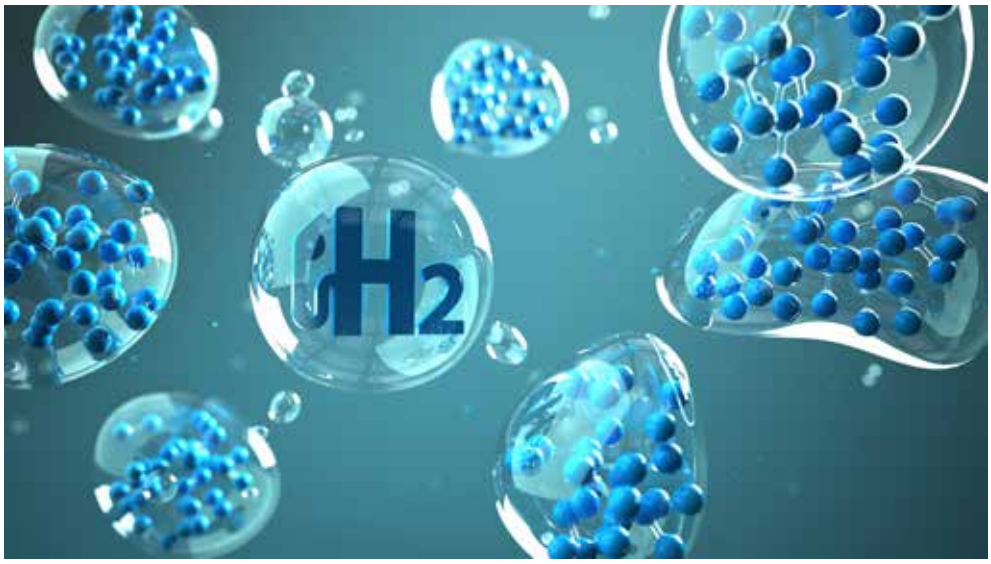
Part 1 and 2 of this FAQ collection therefore explain the possibilities and limitations of forming gas as a tracer gas for leak testing. It is therefore particularly important to understand the properties, advantages and aspects such as safety measures and calibration of the gas mixture in order to use it successfully. This FAQ collection concludes with a checklist. This checklist summarizes the FAQ collection and supports you in a potential switch from helium to forming gas as a tracer gas and contains all the relevant facts you need to know about the use of forming gas as a tracer gas in leak detection.

If you have more in-depth questions or need further advice, Pfeiffer Vacuum's application experts will be happy to help you find the right tracer gas for your leak testing needs. If you have any questions or would like to discuss the transition from helium to forming gas in leak detection, please contact our team of application experts: **leak-testing-services@pfeiffer-vacuum.com**

What is the difference between hydrogen/forming gas and other tracer gases?

Hydrogen is the third most abundant element on Earth. It is a naturally occurring gas which is totally non-toxic and has no adverse effects. It can be found naturally or produced with very simple methods. In fact, we all produce small amounts of hydrogen in our stomachs! Large-scale processes such as the steam reforming of hydrocarbons or the recovery of by-products in chemical production are used to produce hydrogen. For local use, hydrogen can be produced by decomposing acids or electrolysis, for example.

The normal background level of hydrogen in air is as low as 0.5 ppm. Because it is quite small (nuclear distance 74.14 pm in H_2, molecular radius 120 pm) it easily flows through leaks. These properties make it a suitable tracer gas for many applications. In leak detection applications, hydrogen is mainly used in the form of forming gas 95/5 – a gas mixture of 5% H_2 and 95% N_2. In some cases, hydrogen can be used in a higher concentration – up to 100% pure hydrogen, e.g. for tank testing in fuel cell applications.



Another tracer gas, often referred to as the simplest tracer gas in leak detection, is air. Compressed air is used to pressurize samples and measure pressure decay with a simple total pressure gauge. Some variants of this method exist, such as vacuum decay or differential pressure, and offer a slightly better sensitivity. A part from the lower purchase and operating costs and the simple construction, air leak testing has some disadvantages. Environmental influences like temperature changes may affect the measurement. The limited sensitivity is not suitable for more demanding applications. Moreover, it is not possible to locate a leak with the pressure decay or rise method.

To improve the leak detection capabilities, it is necessary to improve the selectivity for leak location and sensitivity for leakage rate measurements. There may also be a need for a faster method than air-based leak detection methods. All of these requirements lead to the use of special tracer gases. The most common tracer gas for leak testing is helium, followed by hydrogen in the form of forming gas 95/5. In this mixture the hydrogen is so highly diluted that it is neither explosive nor flammable and thus safe as a tracer gas.

Other tracer gases are often also operating fluids in special applications, including various refrigerants in the HVAC-R industry or sulphur hexafluoride SF_6 in switchgear. All of these gases either come from finite sources, are expensive to produce, harmful to the environment or even toxic. This clearly distinguishes them from hydrogen.

To be used for proper leak testing a tracer gas must fulfill several requirements:

- Low ambient concentration
- High sensitivity detector technology
- Highly selective sensor technology
- Environmentally friendly
- Inert
- Non-toxic
- Affordable
- Good availability

All of these requirements are perfectly met by the dominant tracer gas helium, but cost and availability have become an issue in the recent years, which is not the case with forming gas, although it does have some other drawbacks that we will discuss later.

Let's now review the pros and cons of forming gas as a tracer gas, by taking you through our answers to the most common questions!

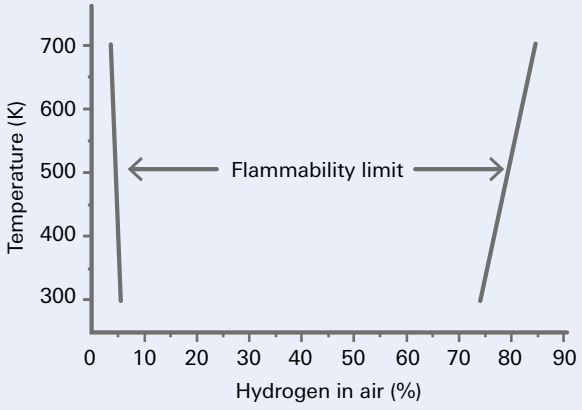
Do I need to consider safety measures and what are the limitations of hydrogen as a tracer gas?

In fact, hydrogen is flammable in the concentration range between 4%–77% in air or oxygen, and can only detonate in the range of 18%–59% in air or oxygen. Figure 1 shows the flammability limits of hydrogen as a function of temperature. By using pre-diluted hydrogen, the flammable concentration range can be avoided altogether. Standard hydrogen-nitrogen mixtures available on an industrial scale are often used as shielding gases for welding purposes, for example. Hydrogen can therefore be used without hesitation for leak testing when highly diluted. A suitable concentration to use is the standard 5 % hydrogen / 95% nitrogen mixture which is available in industrial grade from most gas suppliers. According to the international standard ISO 10156, hydrogen-nitrogen mixtures in which the hydrogen content is less than 5.5% are classified as non-flammable, regardless of how this mixture is mixed with air.

"Hydrogen is explosive and we don't want to use it in our production"

When using the recommended tracer gas, however, three important safety aspects must be taken into account:

1. Compressed gas contains significant amounts of energy. This is true for all compressed gases, including air. Therefore, any failure in connections, hoses or related components can consequently result in serious injury.
2. There is a lack of oxygen in the test gas mixture. If large quantities of this gas are introduced into confined spaces, it will displace oxygen and poses a risk of asphyxiation. This is applicable to all oxygen-free gases, such as nitrogen and helium.
3. Pure hydrogen is both flammable and explosive. Hence, it is crucial to always check the H_2 concentration on the compressed gas cylinder.



Flammability limit of hydrogen in regard to temperature

What are the advantages and capabilities of hydrogen as a tracer gas?

The use of hydrogen as a tracer gas for leak detection offers several advantages and is therefore a suitable alternative to the more expensive helium. Among the various specific tracer gases, hydrogen is the most cost-effective option. However, it is not only its cost-effectiveness that makes hydrogen so attractive, its specific properties also make it well suited for leak detection:

1. **Lightness:** Due to its light weight and associated high thermal velocity, hydrogen molecules can easily penetrate tight spaces and detect leaks with ease. However, for the same reason, hydrogen can be difficult to pump down, resulting in a longer signal recovery time after a leak test compared to helium. It is important to consider this point and adjust the process if necessary.
2. **Safety:** As hydrogen is a naturally occurring element, it does not pose a health risk to people using the tracer gas in diluted form.
3. **Environmentally friendly:** When used as a tracer gas, hydrogen does not produce harmful emissions, making it an environmentally friendly choice.

The following table summarizes the properties of helium and hydrogen with regard to their suitability as tracer gases:

Characteristics	Helium	Hydrogen
Ambient concentration	5 ppm in air	0.5 ppm in air*
Sensor technology	Mass Spectrometry	Mass Spectrometry, others
Detection limit vacuum test	$Q < 5 \cdot 10^{-12}$ mbar·l/s	$Q < 5 \cdot 10^{-6}$ mbar·l/s
Detection limit sniffing test	$Q < 5 \cdot 10^{-6}$ mbar·l/s	$Q < 5 \cdot 10^{-5}$ mbar·l/s
Selectivity	Very high, no cross sensitivity on mass 4u	High, natural gas sources on mass 2u
Environmental friendliness	Noble gas, naturally in air, no direct greenhouse potential	Naturally in air, no direct greenhouse potential
Affordability	High/Medium gas cost	Low gas cost
Safety	Inert, non-flammable, non explosive	Non-flammable and non-explosive in gas mixtures below lower explosion limit (i.e. forming gas)
Availability	Medium to low	High

* May differ for industrial environments

Overall, hydrogen and helium offer various advantages as tracer gases for leak detection. The decision to use one of the gases depends on the specific leak detection requirements, the available resources, and the type of objects to be tested.

What does hydrogen cost?

The main reason for the attractiveness of hydrogen as a tracer gas is its comparatively low price and excellent availability. Since 2006, there have been at least three helium shortages worldwide and a total of seven years of shortages between 2006 and 2019! This shortage has been accompanied by a significant price increase.

An analysis of consumer prices shows that the price per cubic meter of helium is often three to four times higher than the price per cubic meter of forming gas - depending on the purity of the helium used.

The price for helium often is 3 to 4 times higher compared to forming gas

Checklist: These are key takeaways about hydrogen as a tracer gas in leak detection

- ☐ **Stay safe!** Always use diluted hydrogen with a concentration < 5 %, ensure safe handling of pressure vessels and ventilate the test room.
- ☐ **Can you do it?** Before you develop your leak test method with hydrogen/forming gas, you should make sure that you can achieve the required sensitivity: Hydrogen has higher detection limits than helium!
- ☐ **Keep costs low and availability high!** Hydrogen is much cheaper and easier to obtain than helium
- ☐ **Decide on the right method!** Different methods and different test gases offer different sensitivities, different achievable cycle times, etc. Make sure you choose the right method for your individual needs.
- ☐ **Watch your accuracy!** Pay attention to the correct conversion when changing your test recipe. Make sure that regular calibration is integrated into your process.
- ☐ **Stay in touch!** If in doubt, contact Pfeiffer Vacuum, our team of specialists will be happy to help you: **leak-testing-services@pfeiffer-vacuum.com**

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