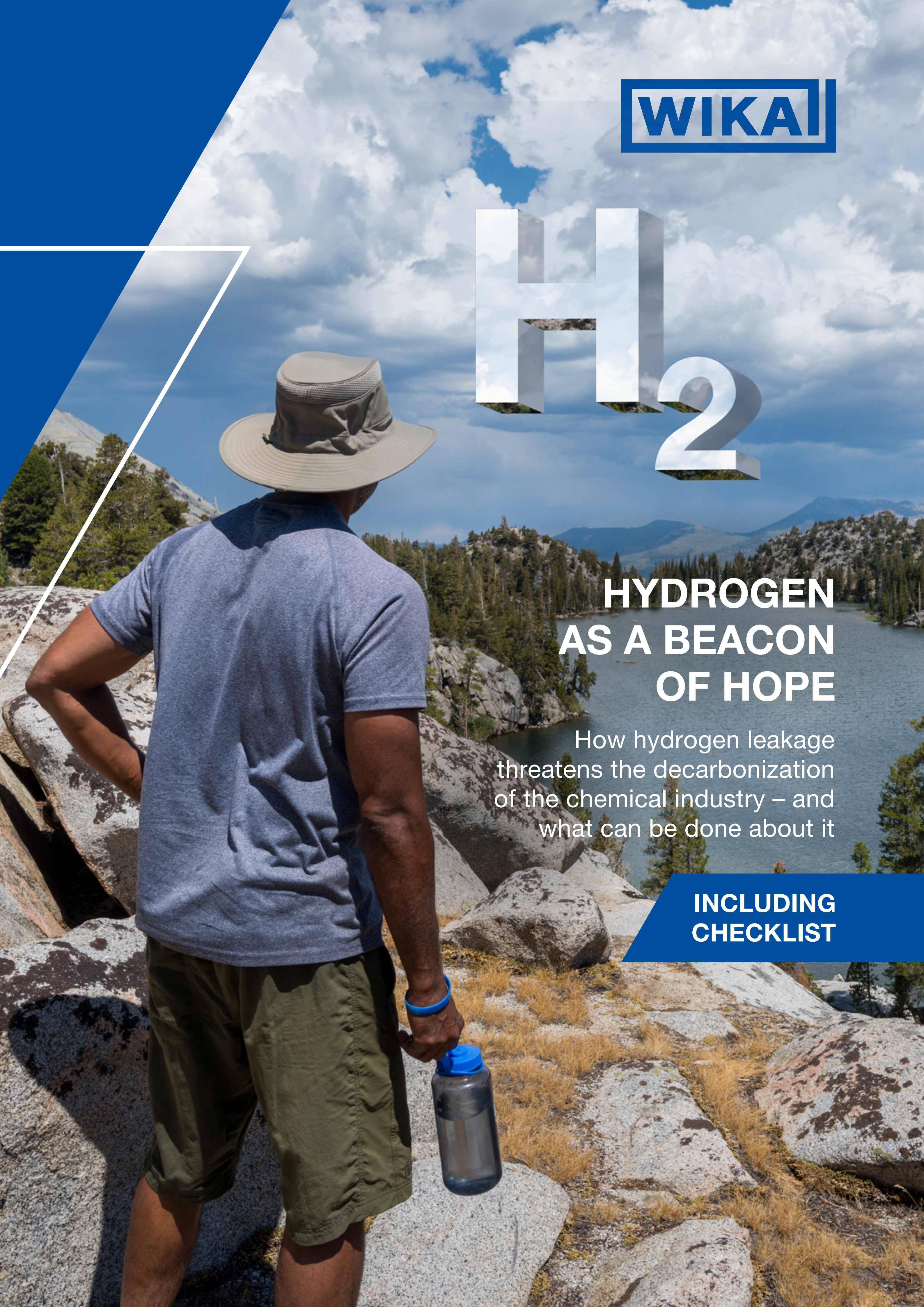

WIKA

H_2

HYDROGEN AS A BEACON OF HOPE

How hydrogen leakage threatens the decarbonization of the chemical industry – and what can be done about it

INCLUDING CHECKLIST

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The chemical industry needs hydrogen in order to reduce its dependence on fossil fuels, an important move for two reasons:

- To remain economically viable in the long term
- To move closer to the goal of carbon neutrality

Of all the alternative fuels, hydrogen is best positioned to take over hydrocarbons both as a source of energy and as a feedstock in the production of chemicals. When hydrogen is the fuel, the only byproduct is water (after all, hydrogen means “water-former”), unlike the carbon dioxide and other greenhouse gases that are emitted as the result of combusting oil or gas. Green hydrogen is an even more ecological solution, as it is produced via electrolysis using renewable energy sources like wind, sunlight, and tides. For these reasons, an increasing number of experts in chemical production see H_2 as a beacon of hope for decarbonizing an industry that many thought was forever dependent on petroleum.

Governments around the world are also taking note of this potential. As of June 2022, the United States, Germany, and other economic powerhouses have released more than 30 strategies to strengthen initiatives around the production, use, and distribution of hydrogen. These global developments point to a clear trend: the importance and, thus, consumption of hydrogen will increase significantly in the near future. Energy analysts at PwC, for example, expect the volume to increase seven-fold by 2050 *(PcW Study, 2021)*.

However, hydrogen is not without climate hazards. While H_2 is not a greenhouse gas per se, it does extend the lifetime of atmospheric methane, which is a GHG, by reacting with the hydroxyl radicals (OH) that destroy those organic molecules. Fewer hydroxyl radicals means methane remain longer in the atmosphere. Hydrogen also increases the concentration of water vapor, which stores energy and causes the planet to heat up even more. Thus, fugitive hydrogen emissions will erase or even reverse any advances toward carbon neutrality.

To prevent fugitive H_2 emissions, it is essential to have a comprehensive, needs-based infrastructure throughout the hydrogen value chain, as well as strict and continuous controls in the areas of chemical production, storage, and transport. Measurement technology can make an enormous difference in minimizing hydrogen leaks and helping the industry move toward greater sustainability, both environmentally and economically.

The chemical and hydrogen specialists at WIKA have created this white paper to shed light on the following topics:

- Hydrogen as a factor in achieving net zero targets in the chemical industry
- Overview of the requirements of an H_2 infrastructure with regard to politics, chemistry, and plant engineering
- Essential basic knowledge for avoiding hydrogen leakage
- Measuring instruments as a helpful tool for successfully minimizing leakage risks

1.1 Net Zero in the Chemical Industry: Goals and hurdles

As outlined by global policymakers and industry leaders, the purpose of increased hydrogen use is clear: net zero. The ultimate goal is complete climate neutrality in all areas and practices. As the world's largest economy and the second largest emitter (after China), the United States announced a goal of halving the country's emissions of greenhouse gases by 2030, and to reach net zero by 2050. The US private sector plays a major role in this bold move and have made their own pledges to meet these goals by or even before 2030 and 2050.

For this plan to succeed, the chemical sector will have to make a significant contribution. After all, chemical production is one of the main sources of industrial emissions, and even the production of much-needed hydrogen resulted in about 900 megatons of CO_2 worldwide in 2020. Three realities stand in the way of decarbonizing the chemical industry:

- Current dependence on petroleum-based feedstock
- The negative CO_2 balance of individual products
- The high energy demands of many chemical processes

These are not insurmountable obstacles, though. In fact, the industry is making steady progress toward overcoming them. For example, it is possible to switch to renewable energies for core processes in ammonia and methanol production. This includes the use of green hydrogen as a substitute for methane steam reforming.

In theory, the industry can solve the issues that line the road toward climate neutrality. In practice, implementing these solutions take resolve – and more than a few dollars. An Accenture report estimates that the global chemical sector will have to increase its investments by more than $12 billion per year over the next three decades. The upside is an increasingly smaller carbon footprint and more growth opportunities.

In short, the decarbonization of this industry is crucial and challenging – but doable. The effort will require significant public- and private-sector investment as the parties work together to build the necessary hydrogen infrastructure to move toward a net-zero future.

1.2 Requirements for the Hydrogen Infrastructure: Now and in the future

Energy analysts expect the consumption of hydrogen to increase seven-fold in the long term, but the current hydrogen infrastructure cannot meet this demand. To ensure that the chemical industry has reliable, safe, and climate-friendly hydrogen in the future, now is the time to create and expand the necessary infrastructure.

1.3 Governmental action, local and global

There is already movement on this front in the United States. The Infrastructure Investment and Jobs Act (IIJA), signed into law in November 2021, includes $8 billion to the Department of Energy (DOE) for clean hydrogen hubs (H_2Hubs) across the country. Applications for $7 billion of that funding opened in September 2022. The DOE National Clean Hydrogen Strategy and Roadmap outlines three strategies for using hydrogen as a decarbonization tool:

- Targeting strategic, high-impact uses for clean hydrogen
- Reducing the cost of clean hydrogen
- Focusing on regional networks

This plan, among other actions, provides a strategic framework for researching, developing, and promoting the transport and storage of hydrogen in various parts of the economy. The subsequent Inflation Reduction Act of August 2022 includes a tax credit for producers of clean hydrogen.

Of course, the US is not alone in promoting a clean hydrogen economy. The German government, for example, is funding 62 hydrogen initiatives under the EU's "Important Projects of Common European Interest" (IPCEI) program, which has hydrogen distribution as a focus. A total of €8 billion has been earmarked for selected major hydrogen projects in which the steel and chemical industries play a major role.

1.4 Infrastructure challenges for the chemical sector

Policymakers have acted – and will continue to do so – to enable the distribution and storage of hydrogen in the volumes that will be needed in the future. It is also important to create a reliable and future-oriented legal framework that makes infrastructure expansion economically attractive.

The chemical industry also has a task: to build a network of dedicated hydrogen pipelines to transport the gas. Existing natural gas pipelines are simply not durable enough to distribute hydrogen. When molecular hydrogen breaks down into atomic hydrogen, the ions enter the lattice structure of metals (hydrogen permeation), making them susceptible to embrittlement. Metals that absorb hydrogen are prone to cracking.

Furthermore, while H_2 mixed with CH_4 can be used as a fuel, the chemical industry requires high-purity hydrogen if the gas is to be used as feedstock.

As an alternative to the resource-intensive development of a nationwide H_2 infrastructure, some have proposed that chemical plants near rivers, lakes, and oceans produce hydrogen onsite using electrolysis. This, however, is not a true solution to the problem of leakage, as one of the advantages of hydrogen is that it can be stored much longer than electricity, which means those tanks and vessels are prone to hydrogen embrittlement as well. Consequently, preventing leakage is a top priority in any H_2 effort.

Leaks are a pernicious issue in natural gas pipelines. As hydrogen can escape even more easily than methane through the tiniest holes, cracks, and weld seams, the transport and eventual storage of this gas is one of the major barriers to wider adoption of this gas as a fuel and feedstock. Hydrogen permeation and embrittlement only exacerbate the problem.

The leakage rate for natural gas is already higher than what the Environmental Protection Agency estimates. Research published in *Science* found that leaks in the US methane supply chain in 2015 was 2.3% of gross production, about 60% higher than the EPA's inventory estimate (Alvarez et al., 2018). The white paper Atmospheric Implication of Increased Hydrogen Use (April 2022), commissioned by the UK government and authored by scientists at Cambridge University and Reading University, says the leakage rates for hydrogen are likely to be higher, as H_2 molecules are smaller than CH_4 molecules.

2.1 Indirect negative climate effects of hydrogen leaks

The implications of this finding for hydrogen infrastructure are alarming, and not just for the economic loss of the gas.

1. The combination of hydrogen and air forms an explosive atmosphere at levels as low as 4 mole %.
2. When hydrogen leaks and enters the atmosphere, it reacts with the hydroxyl radicals that would have "cleaned up" methane, a greenhouse gas.
3. Hydrogen increases the concentration of water vapor, **which is responsible for about half of the planet's greenhouse effect.**

The abovementioned UK study developed a new method for calculating global warming potential (GWP) "for species whose emissions result in indirect radiative forcings." Thus, the group estimates the GWP of hydrogen to be 11 ±5[1], as it amplifies water vapor and has a negative effect on the ozone layer. Thus, in order to realize the green benefits of a hydrogen economy, governments and the chemical industry must solve the problem of leakage during transport and storage.

2.2 What we need to know and do about hydrogen leakage

To minimize the risks of hydrogen leakage, we must first fully understand the problem and its extent. The chemical industry should take the following steps:

- Develop instruments that can measure hydrogen concentrations on a parts-per-billion scale to systematically quantify leakage.
- Use climate metrics to illustrate the extent to which hydrogen leakage impedes reaching climate goals in the near term.
- Consider probabilities of H_2 leakage in decisions about where and how to use hydrogen.
- Reduce transportation needs by locating production and deployment sites nearer each other.
- Develop best practices for minimizing hydrogen leakage by adapting the measures currently employed to reduce leakage of other gases, while keeping in mind the unique chemical properties of hydrogen.

[1] Compare that to GWP 1 for carbon dioxide and GWP 27-30 for methane (EPA.gov, 2022).

An important part of understanding the problem of hydrogen leakage is the meticulous measurement of storage and transport temperatures as well as line pressure. This can be done only with the use of highly specialized, reliable, and accurate measurement technology.

3 Energy Expenditure as Decisive Parameters for H_2 Transport and Storage

H has the least mass of all known elements, and H_2 is the lightest of all molecules. Thus, hydrogen has an extremely low density at atmospheric pressure. In order to store and transport it efficiently, it must first be condensed. Conventional methods include:

- High-pressure compression – for H_2 in a gaseous state, pressures of 5,000 to 10,000 psi (350 to 700 bar) or more
- Cryogenic liquefaction – for H_2 in a liquid state, cooling it below its boiling point of –423°F (–253°C, 20.28 K)
- Solid-state storage – adsorption for hydrogen storage on the surface of solids; absorption for hydrogen storage within the lattice framework of solids

All three approaches involve high operational and/or energy costs (Rao & Yoon, 2020):

- Tanks that can withstand such high pressure require the use of expensive composite materials.
- Liquefying hydrogen requires a multi-storage cooling process and expending the equivalent of ~40% of its energy content.
- The downsides of solid-stage storage:
  - low gravimetric capacity of <5.5 wt% (the DOE has 6 wt% as the target)
  - limited reversibility under optimal pressures and temperatures
  - instability of storage materials
  - requirement of low temperatures (–321°F / –196°C)

These costs, especially in terms of energy, have a negative impact on the net-zero potential of hydrogen use, especially if the required energy comes from nonrenewable sources. The energy costs of transporting hydrogen long distances and storing it for long periods add to this conundrum.

For these reasons, researchers are working on novel, less energy-intensive ways to store hydrogen. One process that shows promise is the use of liquid organic hydrogen carriers (LOHCs), which also opens up new possibilities for heat capture and catalyst regeneration.

3.1 LOHC systems: Many positive (and a few negatives)

As their name implies, liquid organic hydrogen carriers are carbon-hydrogen or carbon-carbon compounds that remain a liquid at ambient temperatures and pressures. To carry hydrogen, hydrogen-lean LOHCs react with hydrogen in an exothermic catalytic reaction at elevated pressure (435–725 psi / 30–50 bar) and high temperatures (302–392°F / 150–200°C). Once saturated, LOHC stores hydrogen relatively safely in ambient conditions. When the hydrogen is needed, the hydrogen-rich LOHC releases hydrogen in an endothermic catalytic reaction at higher temperatures (482–608°F / 250–320°C). This hydrogenate/dehydrogenate process is easier and more economical than compressing or liquefying hydrogen, and has a greater carrying capacity than solid-stage storage.

Researchers are currently experimenting with different hydrogen-rich and hydrogen-lean compounds to see which ones offer the most positives and fewest negatives. These pairs include methylcyclohexane (MCH)/toluene, and perhydro-dibenzyltoluene/dibenzyltoluene, decalin/naphthalene.

LOHC systems are receiving so much attention because they, in principle, allow the storage and transport of massive quantities of hydrogen for an almost unlimited time – and all without the risk of hydrogen leakage. In fact, the only limitations on quantity and duration depend on the tank size and technical characteristics of the LOHC compound. Moreover, unlike other Power-to-X concepts[2], LOHC systems allow energy storage without releasing CO_2 or N_2 into the atmosphere. Thus, this type of hydrogen storage is a positive step toward realizing the potential of H_2 as a climate-friendly fuel.

However, LOHC systems are not without some downsides. For example, while dibenzyltoluene is slow to combust, it should not be touched or ingested, and is a hazard if it enters the water supply. Working with LOHCs require taking the highest safety precautions, necessary for protecting the environment, human health, and companies. And this requires continuous control by means of accurate, reliable measurement technology.

[2] Power-to-X refers to pathways that convert, store, and reconvert the surplus electricity generated using solar, wind, and other renewable sources (power) into a wide range of products (X), such as transportation fuels, chemicals, and heat. Used mostly in northern Europe, this catch-all term is a shorthand for turning green energy to green fuel.

As mentioned in chapter 1.2.2, hydrogen permeation and embrittlement are major issues that must be overcome to realize a mature hydrogen infrastructure. Molecular hydrogen (H_2) can go through most non-metallic materials. And when dihydrogen comes into contact with metal surfaces, it takes relatively little energy – even in ambient conditions – to dissociate the gas into its atomic form, then into the H+ ions that can so easily penetrate most metals' lattice structure. The greater the energy in the environment, such as extreme process temperatures and pressures, the faster the permeation and embrittlement will occur in storage tanks and pipelines.

Measuring instruments also face the same issues, leading to signal drift and mechanical failure. Fortunately, there are ways to overcome these and other challenges.

4.1 Materials that resist permeation and embrittlement

Measuring instruments used in a hydrogen environment should be made with metals that have a closely packed cell arrangement. They include 316L (316 stainless steel with a low carbon content), 316Ti (titanium-stabilized version of 316), and other austenitic steels, which are ideal for highly corrosive and high-temperature environments. Special alloys such as Hastelloy C276, Inconel 718 or 2.4711 (Elgiloy®) are also well suited for hydrogen applications.

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4.2 Coatings that resist permeation

For extra resistance to hydrogen permeation, the austenitic steel or special alloy can be coated with a metallic barrier. Nickel, aluminum, and copper exhibit low hydrogen permeability, but gold is by far the metal that best resists permeability, even at high temperatures.

4.3 Instruments that minimize leakage

Seals in pressure gauges are common places for hydrogen to escape. For this reason, the gauges used in hydrogen applications should have a metallic seal rather than one made of an ordinary polymer. A fully welded design also prevents leaks. In addition, choose pressure instruments that have undergone a helium leak test as part of their quality assurance process.

4.4 Instruments that withstand extreme process conditions

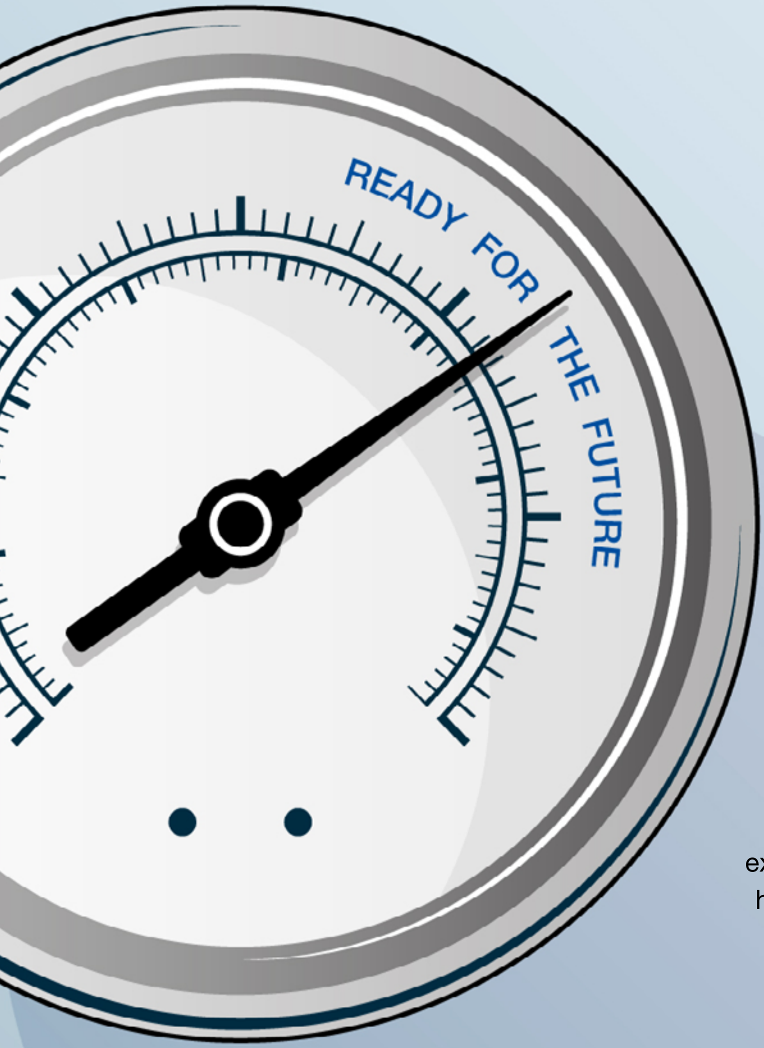
In hydrogen fueling stations, the gas is stored in pressures as high as 15,230 psi (1,050 bar). And for liquid hydrogen, temperature measurement solutions need to maintain their accuracy at or below –423°F (–253°C).

WIKA USA, a trusted partner for the chemical industry

For safety and performance, hydrogen applications require:

- Measuring instruments designed to meet extreme conditions
- Specialists with years of chemical expertise and industrial experience

A global leader in the field of high-performance measurement solutions, WIKA is a proven partner for companies that produce, transport, and use hydrogen. From hydrogen compression and filling stations to mobile and stationary fuel cells, WIKA USA offers quality instruments for the industry's entire value chain, whether the H_2 is produced conventionally or with renewable resources. Go to **www.wika.us** to see our entire portfolio of hydrogen-optimized measurement solutions. We also invite you to **contact** our chemical and product experts for more information and personalized advice.



5 HYDROGEN READINESS SELF-TEST

Despite the barriers that stand between the United States and a mature hydrogen economy, the path is slowly becoming clearer. The government is investing billions of dollars in making this vision a reality, and so is the global chemical industry. How ready is your company?

To help businesses, sites, and plant manufacturers answer this important question, the measurement experts at WIKA have compiled a 17-question self-test for hydrogen readiness. Circle the statement that best aligns with your company's situation, outlook, and plans.

1. Does your company have a fugitive emissions reduction plan, or has funding been allocated for process improvements aimed at reducing emissions?

- ☐ **No,** we do not currently have a fugitive emissions reduction plan. A
- ☐ **Yes,** the financial resources are available because senior management is aware of the strategic importance of fugitive emissions reduction. However, the plans have not yet been put into action. B
- ☐ **Yes,** we have such a plan and are following it to reduce fugitive emissions. C

2. Is your company aiming for specific hydrogen-related certifications for fugitive emissions?

- ☐ **No,** we are currently not planning such an activity. A
- ☐ **Yes,** we have a continuous improvement process and regularly evaluate new ideas. Potential certifications help us stay on track. B
- ☐ **Yes,** we are pursuing certifications. Our company has a continuous improvement process, and we regularly share new ideas in industry forums. C

3. Are there any special safety approvals that your company adheres to, such as IEC 61508, SIL, IFC, NFPA 2, and/or NFPA 55?

- ☐ **No,** we don’t currently adhere to any safety approvals. A
- ☐ **Yes,** we comply with all safety approvals required by local authorities. B
- ☐ **Yes,** we adhere to not only the necessary approvals, but go the extra mile when it comes to safety. Achieving the highest level of safety is of great importance to our company. C

4. Does your company currently have initiatives or working groups devoted specifically to dealing with the issue of hydrogen leakage?

- ☐ **No,** the topic is completely new to us, and we are taking a wait-and-see approach. — A
- ☐ We have touched on this topic internally but currently do not have any initiatives or a working group. — B
- ☐ Since the optimized use of hydrogen is one of the defining pillars of our future strategy, we have an interdepartmental working group that is planning concrete activities. — C

5. Has your company allocated funds specifically for measures to reduce hydrogen leakage?

- ☐ **No.** We currently do not have a hydrogen expansion plan and, thus, have not budgeted for measures in this area. Our current focus is business development. — A
- ☐ We are currently working on general aspects of the coming hydrogen infrastructure. While funds are available for that, they are not earmarked to address hydrogen leakage. — B
- ☐ **Yes.** hydrogen leakage is one of the risk areas we have already identified. A sub-group is currently working on it and has a dedicated budget. — C

6. To what extent is the current and targeted type(s) of H_2 managed in your company?

- ☐ We use hydrogen only selectively and have always done so. We do not make any distinction regarding the origin. — A
- ☐ We know exactly what type of hydrogen is used and in what quantities. However, there is currently no concrete plan to increase the share of green hydrogen. — B
- ☐ The targeted increase of green hydrogen is a central aspect of our company's carbon neutrality strategy, which is stringently followed. — C

7. What is your company's attitude regarding carbon neutrality and a hydrogen strategy?

☐	We don't currently have a separate hydrogen strategy as it relates to carbon neutrality, but there could be one in the future.	A
☐	We want to protect the environment but not slow down our productivity. That's why we are taking a wait-and-see attitude and hoping that the cost of blue/turquoise/green hydrogen will come down in the near future.	B
☐	We precisely calculate the use of each type of hydrogen, and the use of e-fuel is practical and even economical in situations like mobility. But while hydrogen is an important pillar of our green strategy, we don't want to become a hydrogen-only company.	C

8. In your company's conventional hydrogen production, is carbon capture integrated into the process?

☐	**No,** we have not established a carbon capture process.	A
☐	**Yes,** CO_2 is either integrated into other processes within the plant or is collected and sold. In this way, we regulate our emissions and also get an economic benefit.	B
☐	Carbon capture is not an issue for us because we produce only green hydrogen.	C

9. Where is your company in the process of transitioning to a cleaner form of hydrogen?

☐	We currently have no such plans.	A
☐	We are working on converting the plant from gray to blue.	B
☐	We are working on converting the plant from gray to green.	C

10. Since "gray plants" produce the bulk of hydrogen used in the chemical industry today, what steps are you taking to reduce CO_2 emissions?

☐	None. Our gray plants operate as they always have.	A
☐	We are working to optimize the efficiency of our gray plants while still relying on them.	B
☐	We have taken concrete steps to improve our gray plant's efficiency and are seeing gains in that area. The ultimate goal, of course, is to transition to a green plant.	C

11. Is hydrogen production part of your chemical plant's other processes, such as ammonia production?

☐	**No**, we purchase our hydrogen from another source.	A
☐	**Yes**, we produce the hydrogen that is used in other processes, but the integration could be smoother and more complete.	B
☐	**Yes**, our hydrogen production unit is fully integrated with our processes.	C

12. Are you tied to a technology license when making process improvements or MRO (maintenance, repair, operations) decisions?

☐	**Yes,** we are committed to a technology license, and our technology licensor has to approve all changes.	A
☐	**No,** but we consult with our technology licensor when making process changes or choosing a different MRO provider.	B
☐	**No.** We do our own engineering and can make process improvement decisions without breaking any license agreements.	C

13. Has your company made any process improvements with regard to the use, storage, or transportation of hydrogen?

☐	We have made minimal or no changes to our hydrogen processes since our inception.	A
☐	We have established a continuous improvement process that allows us to evaluate and test new ideas.	B
☐	We have a continuous improvement process and regularly share new ideas in industry forums and conferences.	C

14. Does your company have the technical means (e.g., pressure and temperature transmitters and switches) to continuously monitor and control the hydrogen in your processes?

☐	**No.** I simply assume that we meet all specifications.	A
☐	Somewhat. We currently take standard measurements but would like to optimize them for greater safety, especially as our H2 volume increases.	B
☐	**Yes.** We use both analog and digital technologies to continuously monitor and control our hydrogen processes, from high-precision sensors to a SCADA (supervisory control and data acquisition) system.	C

15. Is it difficult for your company to maintain process continuity due to repeated mechanical failure of instruments?

☐	**Yes,** mechanical failure of instruments is a major challenge for us, and we have not yet found a supplier that can meet all of our process requirements.	A
☐	**Yes,** it is somewhat difficult, but we are currently working with our suppliers to overcome the challenge.	B
☐	**No,** it is not difficult because our current suppliers are able to meet all of our metallurgical and instrument needs.	C

16. Can your company's current suppliers keep up with the technological requirements of working with hydrogen?

☐ **No.** We often have difficulty finding the right products for our complex chemical processes or a satisfactory supplier for a long-term business relationship. A

☐ **No,** but we are working with our suppliers on these challenges. To that end, we are in active conversation with experts and seek advice from them. B

☐ **Yes,** we have competent, future-oriented partners, and these business relationships enable us to significantly improve our processes. C

17. Since the production of green hydrogen is expected to become less expensive over time, do you have plans to qualify your personnel for the commissioning of your own electrolysis plant?

☐ **No.** Since there's no plan for us to produce our own green hydrogen, the topic of employee qualification is irrelevant. A

☐ **No.** Our human resources department will take the appropriate actions when management decides to commission a green plant. B

☐ **Yes.** Employee qualification is being planned or in progress, and will be completed before the new plants are commissioned. C

5.1 EVALUATING YOUR HYDROGEN READINESS

Give yourself 0 points for every "A" statement circled, 2 points for every "B" statement, and 4 points for every "C" statement. Then add them up. Note: This self-test is not a judgment of your company's ability to incorporate hydrogen into more of its chemical processes. Rather, the purpose of this evaluation is to identify areas where action is needed and to stimulate internal discussions on the subject.

NOT QUITE READY *0 to 24 points*

Your company has not put much effort into developing a strategy for harnessing hydrogen as a promising technology. While there is some awareness of the gas's role in achieving net-zero climate goals, internal hurdles get in the way of creating such a roadmap. Some of those hurdles include lack of financial resources, not enough buy-in from senior management, and dependence on business partners and suppliers ill-equipped to problem-solve the issue of hydrogen leakage. The majority of chemical companies in the US are at this stage.

Nonetheless, there is growing awareness that your organization needs to take action on this front, due to growing pressure politically, societally, and economically. To get started, contact the hydrogen and chemical experts at WIKA USA for personalized advice.

READY FOR THE MOMENT *24 to 52 points*

Your company is already aware of the potentials and challenges of hydrogen use. Despite these insights, there is not currently a comprehensive analysis or comprehensive long-term strategic plan. One issue is a conflict between the desire for safe, economical hydrogen processes and doubts that your plants can successfully overcome process-related hurdles. The way your plants are currently set up, they may be able to meet the high requirements for safe, low-emissions hydrogen processes – but are not quite optimized for greater hydrogen use in the future.

There are a few things that can strengthen your company's hydrogen strategy. For one, consider forming a working group to look into measurement technologies that minimize hydrogen leakage. The product specialists at WIKA USA would be happy to speak to this group and other decision makers regarding hydrogen-optimized instrumentation.

ON THE WAY TO A NET-ZERO FUTURE *52 to 68 points*

Your company is taking a long view of the requirements and opportunities of hydrogen-oriented operations, both to decarbonize the business and to ensure its future stability. There is planning, transparency, and vision at the top levels of the organization, as well as a company-wide willingness to invest financial and human resources along this journey. You use the experience you already have to continually optimize existing processes and to align them with the requirements of a hydrogen infrastructure, some of which include measuring instruments to minimize leakage during processing, transport, and storage.

Even though the company is well on its way to a carbon-neutral future, you likely could be taking greater advantage of connected technologies to network your hydrogen processes. With state-of-the-art sensors to enable this digital transformation, new opportunities open up in the areas of asset and condition monitoring, alerts and predictive maintenance, process optimization and automation, and more. WIKA USA offers a suite of IIoT (industrial internet of things) solutions. Ask how our technology specialists can get your facility ready for Industry 4.0.

6 Summary

Hydrogen is a beacon of hope in the effort to decarbonize the chemical industry and achieve a net-zero target; its use would reduce the share of fossil resources in the feedstock and give companies a clean, potentially green source of energy. In the next few decades, the global consumption of H_2 is expected to greatly increase as more countries move away from hydrocarbons and more private-sector entities embrace a hydrogen economy.

One cloud that dims this beacon is hydrogen leakage, and this issue – if the necessary precautions are not taken – threatens the decarbonization of the chemical industry. The best way to prevent the emissions of this indirect greenhouse gas is with the continuous monitoring and control of hydrogen vessels' pressure, temperature, and outlet points. Early detection is key – and is possible only with the aid of high-performance measuring instruments that meet the unique physical and chemical requirements of hydrogen production, storage, transport, and use.

With deep experience in the chemical industry and with hydrogen applications, WIKA USA understands the need to balance profitability with sustainability. We design and manufacture high-quality products for the most extreme process conditions, while our specialists offer consulting service that can help your company solve the problem of hydrogen leakage. Find solutions for the entire hydrogen value chain and other chemical applications at www.wika.us

For more information about hydrogen-optimized measuring solutions or other instruments for monitoring your processes, contact us. Our experts look forward to speaking with you.

hydrogen@wika.com

7 About WIKA: Experience meets performance

Founded in 1946, WIKA is an experienced and trusted partner in all areas of industrial measurement technologies, thanks to a broad portfolio of high-precision instruments and comprehensive services. This privately held company is a global leader in solutions for measuring pressure, temperature, level, force, and flow, as well as for calibration and SF_6 gas handling.

The WIKA Group is active in more than 75 countries, most with their own local subsidiaries, of which WIKA USA (WIKA Instrument, LP) is the largest. With production sites around the world, WIKA offers convenience, flexibility, and fast delivery for our business partners. We have more than 10,200 knowledgeable and committed employees who contribute to our customers' success, and they are the reason why 600 million of our measuring instruments are currently in use.

7.1 WIKA in the chemical industry: tailor-made solutions for your applications

For decades, we have supported our customers in the chemical and petrochemical industries with competence, partnership, and a pioneering spirit. Whether mechanical or electronic solutions, our products excel in the most demanding applications: explosion-prone areas; aggressive, volatile, viscous, or crystallizing media; high vibration and pulsation; extreme temperatures, pressures, and ambient conditions. Our customizable instruments for measuring pressure, temperature, level, force, and flow are found in every conceivable environment, from deep sea to outer space, and they offer maximum reliability and minimal interruptions. Our experienced professionals offer personalized advisory on your plant's development, integration, and operations with exceptional products, systems, and services. Our mission is to ensure the efficiency, profitability, reliability, and sustainability of your applications and processes.

7.2 Top performance in technology and services

WIKA is a trusted provider of both quality instruments and specialized services. In our portfolio are a wide selection of measuring instruments with field-proven functionality in all accuracy classes, ranges, units, outputs, and various degrees of automation. Our worldwide laboratories are accredited according to country-specific requirements. Whether in one of our certified facilities or at your location, WIKA offers a comprehensive suite of services, from maintenance and repairs to installation and calibration. In addition, we are able to work on most instruments and devices from other manufacturers. Maximum flexibility and convenience, minimum downtime and waiting.

7.3 Sustainability at WIKA

For more than 75 years, a core value of the company have been sustainable management. And as a family-owned and -operated business, we think in terms of generations rather than quarters. Our corporate guidelines set out our responsibilities to our employees, the communities in which we are located, and to the welfare of our planet.

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