Designing Safety Into Hydrogen Systems

Overcoming Challenges in the Designing of Hydrogen Systems
White paper

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Designing Safety Into Hydrogen Systems

As a source of clean energy, hydrogen is making a great contribution to a more sustainable future. However, building systems to handle it safely and reliably is challenging, especially for inexperienced OEMs within an under-regulated industry.

This article looks at the challenges, and at practical ways in which OEMs and systems builders can overcome them.

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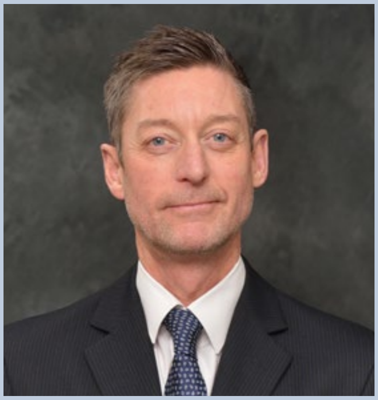

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Although not found on its own, hydrogen is the most abundant element in the universe – and hydrogen-based alternative energy systems are contributing critically to a sustainable, carbon-free future. This has created a hydrogen industry covering everything from production, through distribution and transportation, to end uses such as fuel cell systems, typically in heavy trucks.

However, along with its capacity to provide an abundant source of clean energy, hydrogen also presents handling challenges to its producers, distributors and users. As H2 hydrogen molecules are the smallest in existence, they penetrate other materials easily. For example, hydrogen gas cannot be kept in plastic because it will pass right through the container's walls. And, while different materials such as steel can be used for tanks, valves, tubes and other fittings that successfully contain the gas, hydrogen is extremely adept at finding flaws and establishing leaks. Leaks may not occur immediately after installation, but become more likely as time passes; hydrogen can attack the metallic materials containing it.

The problem is exacerbated because hydrogen is typically stored, in either liquid or gas form, at low temperature and high pressure. Low temperature enhances hydrogen's ability to attack the material it is contained in, while high pressure makes leakage more likely.

Leaks are to be avoided at all costs for two reasons; the first concerns a safety threat to personnel and equipment. If the leak occurs in an enclosed space, the leaked gas cannot escape, so builds up to become an explosion risk.

The second reason relates to cost. The least worst leak scenario is when the escaping gas can safely vent to atmosphere and disperse. However, while this reduces danger, a leak means lost gas and unwelcome costs to the system's operator. A serious leak may also mean that hydrogen is denied to the application that is calling for it.

Buyer and Supplier Problems

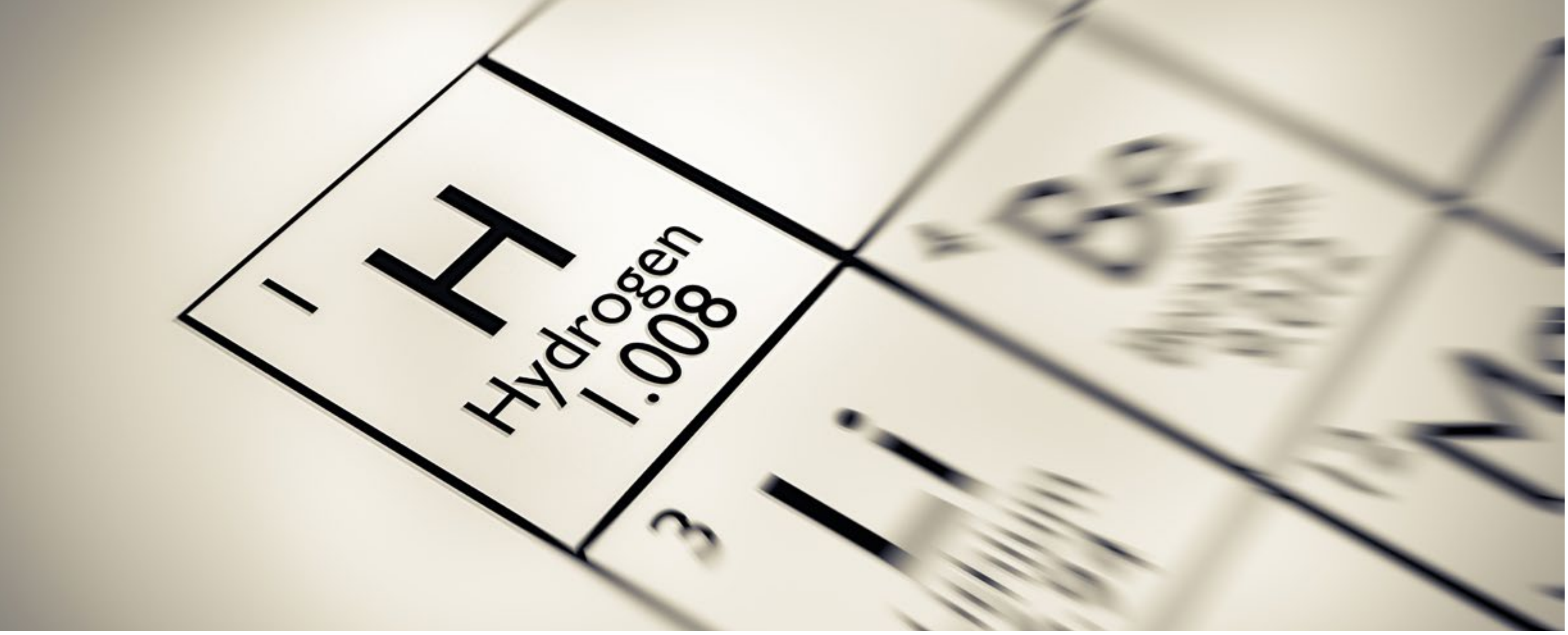
Despite these risks, there are many OEMs within the hydrogen industry that will not invest in suitable, certified components or assembly and installation training. Some buy in lower-cost components because they feel overwhelming pressure to be competitive. Others, though, may simply not be aware of the problems that hydrogen can cause, or the need to pre-empt these.

These situations arise because the industry is rapidly evolving, and has many startup and spinoff companies. They have limited staff sizes, and have not yet had the time to develop the depth of expertise that they really need. This 'buyer-side problem' is exacerbated by a 'supplier-side problem'; in this industry, certification is not mandatory, and there is nothing to stop suppliers offering components at an attractive price, but of poor quality. The difference between a poor component and a good one is not apparent without expert analysis.

By contrast, OEMs in the Oil & Gas industry are not so exposed to the risks of lower cost, poor quality components. The industry has a mature, safety conscious and experienced environment which has developed a set of rigid and mandatory standards to mitigate liabilities - and suppliers and users must follow these. Without appropriate certification, components cannot be designed into systems, and systems cannot be installed into end user applications.

So, the issue in the hydrogen industry becomes one of awareness and understanding. Although not yet mandatory, applicable standards do exist. If OEM system builders are informed of these standards, and the critical need to be guided by them, they can be kept safe from the consequences of building systems with poor components or inexpert assembly.

Accordingly, we offer below the information that we believe OEMs need. We start by explaining the technical reasons why hydrogen attacks the metallic vessels, pipes and fittings containing it. Then, we introduce the materials certificate as a vital tool for both suppliers and customers in identifying materials of genuinely good quality – from manufacturers who understand the embrittlement issues and how to minimise them. Finally, we discuss the other factors to look for in a good hydrogen component supplier. We show how Parker has embodied these factors in successfully supplying the industry for over 40 years.



Hydrogen Embrittlement

Along with its compelling advantages as an accessible, sustainable, and efficient alternative source of energy, hydrogen can be very damaging for most metallic materials; it causes what is known as hydrogen damage or hydrogen attack. With its extremely small molecules, hydrogen's degradation property is directly connected to its easy absorption by metals, coupled with its high mobility at the microstructural level.

Nearly every metallic material can be susceptible to hydrogen damage and there are several forms of hydrogen degradation. Hydrogen embrittlement cracking is the most common and affects the three main areas of industries that use hydrogen: production, transportation, and storage.

The hydrogen atoms find preferential places in the material's structure, modifying its physical properties and mechanical behaviour. Hydrogen diffusing into the material causes a loss of ductility, making it more brittle and more susceptible to cracking. This process weakens the material slowly and without any clear signs of damage, often leading to critical failure.

The factors that can affect the quality of a material's microstructure are numerous and have been widely documented within the materials world. Due to the subject's complexity, the effect of microstructure (as a major contributing factor to hydrogen behaviour) cannot be evaluated in simplistic terms. Taking one variable in isolation is not enough to guarantee the quality or performance of a given component and can be misleading.

For example, a material grade with a 'perfect chemistry' or with high levels of a particular ingredient can still result in a very low-quality product. The common consequences of improper and non-controlled material processing, heat treatment and / or manufacturing operations are high densities of undesirable phases and inclusions in the raw material. These will inevitably lead to premature hydrogen-assisted cracking during service, particularly in demanding H2 environments. Material processing is therefore key.

The mechanics of the application also play a major role. Stress states in components can be caused by the presence of residual stresses associated with certain fabrication techniques as well as stresses applied during service. These can arise, for example, through pressure cycling, or shock and vibration. Improper product design and improper installation can also cause overloading of stress onto the material.

All of these factors can cause premature failure of components in hydrogen service. And this failure can occur suddenly, without prior warning. When it comes to handling hydrogen, therefore, material and equipment selection becomes, more than ever, an essential ingredient for success.

Download our White Paper to learn how to prevent hydrogen embrittlement.

Materials Certificates

Clearly, it would be impossible for a systems builder or OEM (unless they also happen to be metallurgists) to have meaningful discussions with their component suppliers about the complexities of microstructure and mechanics. But they do not have to: a quality assurance document called a materials certificate does the job for them. Also known as a mill test report (MTR) or mill test certificate (MTC), a materials certificate is used in the metals industry to certify a material's technical parameters such as chemistry, mechanical or other physical properties, manufacturing routes, heat treatment details, testing results or compliance to a set of international or local standards.

A materials certificate allows a component manufacturer to satisfy their customers as to the provenance and quality of the materials used in their products – and offer an insight into material performance under real life service conditions.

Several industry standards establish harmonised material certificate formats, ISO/EN 10204 being the most widely used and the 3.1 type certificate the most common one.

Not all commercially available materials have a material certificate. Additionally, not all certificates offer the same level of information, and the traceability can greatly differ. A vague level of detail in a material certificate can often be associated with lack of control and poor quality procedures. Another consideration is that the language used in the certificate may not be understandable to its readers.

Uncontrolled mills or low quality steel makers often provide certificates with minimal information. They typically only contain details of the sample's composition and mechanical properties, but no mention of the manufacturing procedure, heat treatment condition, or provenance.

Conversely, certificates supplied by Parker include full provenance with good material traceability, giving insights into how the material was melted, processed, heat treated, at what temperature, and how long for. They also cover which methods were used for testing, which industry codes were met, whether the material is contaminated, and other factors.

Our certificates are also rich in information about test results and associated data. We include full details of tensile testing, with an in depth chemical analysis and an equally detailed description of mechanical characteristics.

There will also be declarations about the material's corrosion resistance, freedom from welds, weld repairs, and mercury and radioactive contamination. Further details will relate to the country of melt source, test methods used and associated parameters, and standards complied with.

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Clara Moyano,
Parker Hannifin

For the user, materials certificates comprise an extensive compilation of data that tells them everything they need to know about a material production batch, and allows them to have a fully controlled quality system.

Choosing the Right Supplier

While a well-written materials certificate is critical to establishing a hydrogen system equipment supplier's credibility, it does not tell the whole story. Buyers must also be confident in the breadth and depth of their supplier's product range, their experience with handling hydrogen and other challenging gases and liquids, and their training and support services.

Parker is one company that offers everything necessary to assure safe, reliable hydrogen system installations.

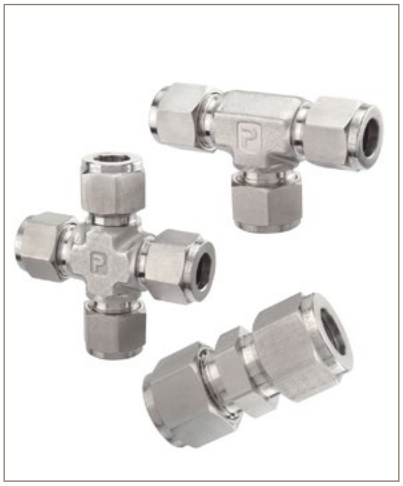
We have a history of supplying fittings and valves into the compressed natural gas (CNG), transport, liquified natural gas (LNG) and oil & gas industries and have been handling hydrogen media for about 40 years.

We have in-depth hydrogen industry information relating to the Health and Safety Commission (HSC) and safety cases. This is essential to us and our customers who must make a case for safety when proposing solutions for manufacturing, storing, transporting or using hydrogen.

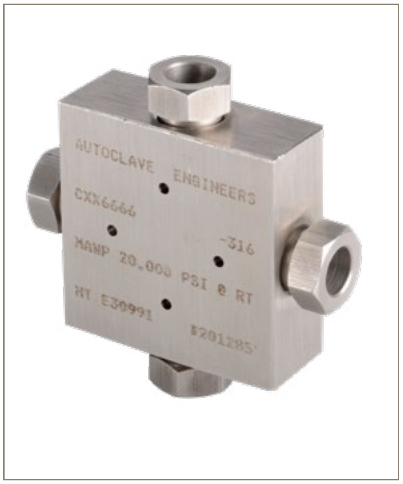
We have full forwards and backwards traceability, so we know exactly which products we have shipped. Each of our products has a trace code and a fully documented history, allowing us to trace it right back to the mill where it was manufactured. In the worst case – which has never actually happened at Parker – we can identify all customers who have received products using material from a mill batch which has been compromised, and replace them accordingly.

We put much effort into verifying and testing the materials we use and ensuring that they are correct and fit for purpose; we want our customers to benefit fully from the work we have done. In addition to robust materials certification, Parker has invested in obtaining industry-specific qualifications, such as EC-79 for transportation, ISO 15848 Fugitive Emissions, and ISO 19880-3 for refuelling stations.

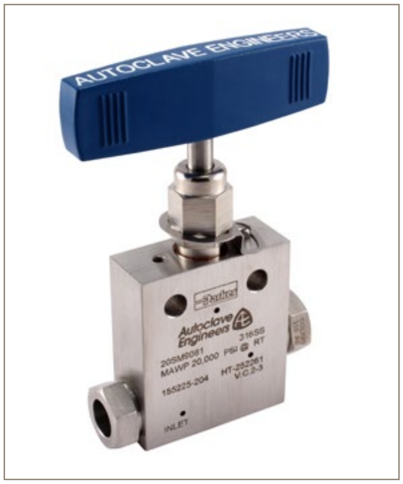
We offer fittings, valves, tubing, regulators and other products for use on board vehicles, in refuelling stations, and general hydrogen applications such as power generation, petrochemical, agricultural, and research & development. Our hydrogen-compatible components



Parker two ferrule fittings (A-LOK® Series) EC-79 approved for on-board hydrogen-powered vehicles. Temperature range: -40°C to +120°C (40°F to +248°F) MW Pressure: up to 350 bar (5,076 psi).



Parker Autoclave Engineers cone and thread fittings EC-79 approved for on-board hydrogen-powered vehicles. Temperature range: -40°C to +120°C (40°F to +248°F) MW Pressure: up to 700 bar (10,152 psi).



Parker Autoclave Engineers needle valve (20SM Series) ISO 19880-3 certified for hydrogen refuelling stations. Temperature range: -73°C to 316°C (-99°F to +601°F) MW Pressure: up to 700 bar (10,152 psi).

and systems enable safe and efficient operation from vacuum to 1,380 bar (20,000 psi) and temperatures from -253°C to +538°C (-423°F to +1000°F).

Learn more about Parker hydrogen-compatible instrumentation components and systems:

www.parker.com/hydrogen-service

Parker also recognises that customers must understand how to install the fittings to ensure reliable and safe operation in hydrogen systems. Accordingly, we offer our **Small Bore Expert (SBEx)** safety training courses, which teach instrument engineers, fitters, technicians, and maintenance personnel how to specify and install efficient, safe and leak-free small bore tubing systems. The SBEx training programme is generally in accordance with the UK Oil & Gas Operators Association (UKOOA) Guide for the management, design, installation of small bore tubing systems – EN directive number 0852932758.

We have SBEx trainers both in house and within our distributors.

Conclusion

If working on hydrogen systems is a relatively new development for you or your organisation, it may not be immediately apparent why choosing the right materials and assembling them correctly is so critical for safe and reliable operation. A system with poor components may work well when initially commissioned; the problems will only come later, as the hydrogen degrades the fittings.

However, you can avoid these problems by discussing your requirements with a reputable, experienced supplier like Parker. We offer the certified products, training courses and worldwide support that you need to install systems that will operate safely and reliably throughout their operational life. You can use our expertise to mitigate the risk to your projects.

PARKER HANNIFIN IS A MEMBER OF THE

Hydrogen Council

a global CEO-led initiative of leading companies with a united vision and long-term ambition: for hydrogen to foster the clean energy transition for a better, more resilient future.

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