Optimising Small Bore Tubing Systems for Hydrogen Applications

Leveraging Parker's Expertise for Safe, Efficient, and Reliable Clean Energy Solutions

Parker

ENGINEERING YOUR SUCCESS.


1
H
Hydrogen
1.008

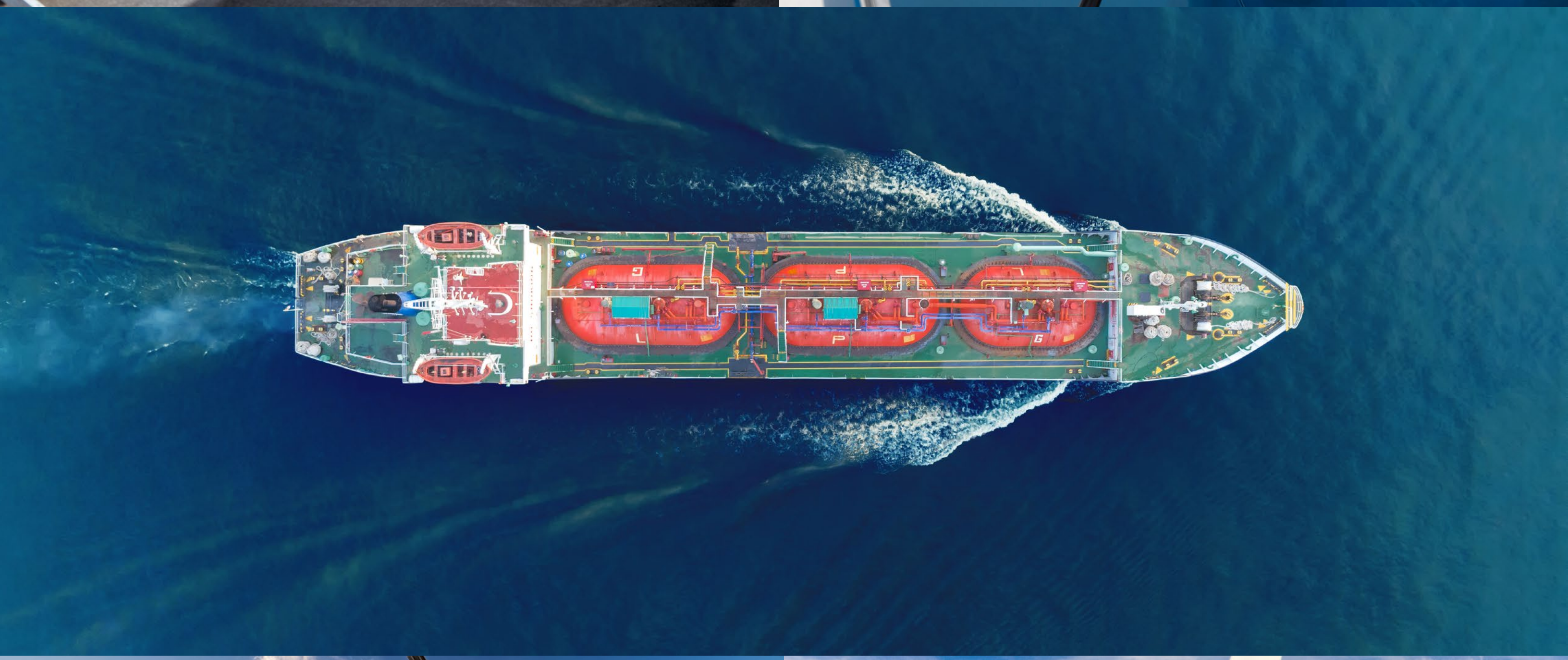
Nicolas Villemain
Global Capital Projects Manager
Parker Hannifin,
Fluid Connectors Group

As the demand for hydrogen continues to increase, the clean tech industry must address the challenges posed by the element's inherent properties. Hydrogen is the smallest element on the periodic table, forming highly flammable and volatile dihydrogen (H2) molecules that are difficult to contain. In fact, the industry currently utilises helium for the finest leak detection tests, highlighting the technical difficulties associated with designing, manufacturing, and installing small bore tubing systems. Due to hydrogen's high flammability, robust technical specifications are necessary to prevent potential leaks and accidental explosions.

Building hydrogen systems for production, transportation, storage, and dispensing necessitates the implementation of exceptional designs, high-quality components, and materials. Furthermore, these systems need the expertise of professionally trained installers. These elements are crucial to ensuring leak-free, reliable, and safe systems. Design safety is particularly important, given that hydrogen systems are used not only in industrial settings but also in public spaces, such as fueling stations.

This Guide encompasses many of the parameters to consider to ensure the safety of hydrogen systems, minimise unnecessary maintenance, and reduce the overall cost of ownership.





Contents

Introduction

For years, hydrogen has been utilised in various industries and laboratories. Over the past two decades, pioneers have begun to explore fuel cells and filling stations, with Parker Hannifin supporting these engineers and customers throughout this journey. This long-standing engagement has facilitated the development of a wealth of solutions to manage the complexities of hydrogen as a medium. As large-scale industrial interest in hydrogen has grown recently, we have drawn upon our vast experience to address and overcome any challenges that have arisen.

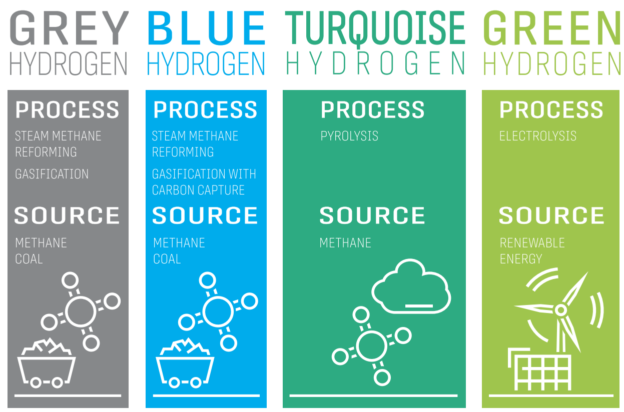
This Guide aims to provide engineers and end-users with an overview of the key factors to consider when specifying, building, and installing small bore tubing systems for hydrogen. Moreover, it proposes solutions to ensure the safe and reliable operation of hydrogen systems.

It examines small bore valves, tubing, and fittings utilised in hydrogen systems, focusing on pressure ranges from vacuum to over 1,000 bar (14,500 psi). It encompasses hydrogen applications such as generation, compression, storage, fuelling stations, and transportation.

The Guide is tailored to address the needs of various stakeholders, including infrastructure owners (hydrogen plants and fuelling stations), system builders, design engineers, small bore tubing installers/fitters, health and safety personnel, and maintenance technicians.

The Hydrogen Journey: From Generation to Vehicle Fuel Tanks

Hydrogen production methods are diverse and can be categorised based on their carbon footprint and primary energy source. Grey hydrogen is derived from steam methane reforming, while brown hydrogen comes from coal gasification. Carbon capture can be applied to these processes to produce blue hydrogen. Turquoise hydrogen is obtained through methane pyrolysis, and green hydrogen is produced via electrolysis of water (H2O) using renewable energy sources. Pink or purple hydrogen is generated using nuclear energy, and yellow hydrogen is sourced from the grid, which utilises mixed electricity sources.



Pressure ratings for small-bore tubing systems depend on the specific processes and range from a few bar to a maximum of 30 bar (435 psi) for electrolysers (such as PEM or Alkaline). Higher pressures are observed within the transportation sector, including forklifts, industrial vehicles, cars, and trucks, as well as refueling stations and storage applications. These systems can reach pressures of 350 bar (5,075 psi), 550 bar (7,975 psi), or even 700 bar (10,150 psi). Filling stations can even reach pressures of 1000 bar (14,500 psi).

Presently, hydrogen (H2) predominantly exists in its gaseous state. However, the industry also necessitates the use of hydrogen in its liquid form, which occurs at extremely low temperatures of −252.87 °C (−423.17 °F) under atmospheric pressure. To facilitate the transportation of substantial quantities of hydrogen, it is converted into its liquid state and transported in cryogenic tanks. These tanks are super-insulated to maintain the ultra-cold temperatures necessary to keep hydrogen in liquid form. This mode of transportation is employed both on land, using cryogenic tanker trucks, and at sea, using specially designed hydrogen tanker vessels, which operate on principles similar to those of Liquefied Natural Gas (LNG) ships.

Upon production, hydrogen in a gaseous form is often transported through pipelines at low pressure (up to 30 bar/435 psi) over short distances to supply local industries. However, transporting hydrogen in pipelines presents challenges due to corrosion issues. The industry is actively working on solutions to address these concerns.

For long-distance transportation to filling stations or industrial sites, hydrogen must be compressed to make the transport economically viable. Uncompressed hydrogen occupies a substantial volume with minimal energy per cubic metre. Typically, hydrogen is transported in high-pressure containers at 550 bar (7,977 psi) and subsequently delivered to filling stations by trucks.

At the filling station, a system composed of tubing, fittings, valves, check valves, filters, coolers, and temperature sensors is utilised to fill car or truck tanks. Due to the Joule-Thompson effect, the temperature of hydrogen increases when it is decompressed or released. This phenomenon must be considered when designing small bore tubing systems, and temperature derating might be necessary. Hydrogen is used as a fuel for vehicles, such as cars and trucks, which are equipped with fuel cells that generate electricity and release clean water (H_2O) without emitting harmful pollutants or CO_2 into the atmosphere. The true benefit of hydrogen lies in its ability to store energy from intermittent electricity generators like wind turbines, which cannot produce on-demand.

Addressing Risks Associated with Hydrogen Systems

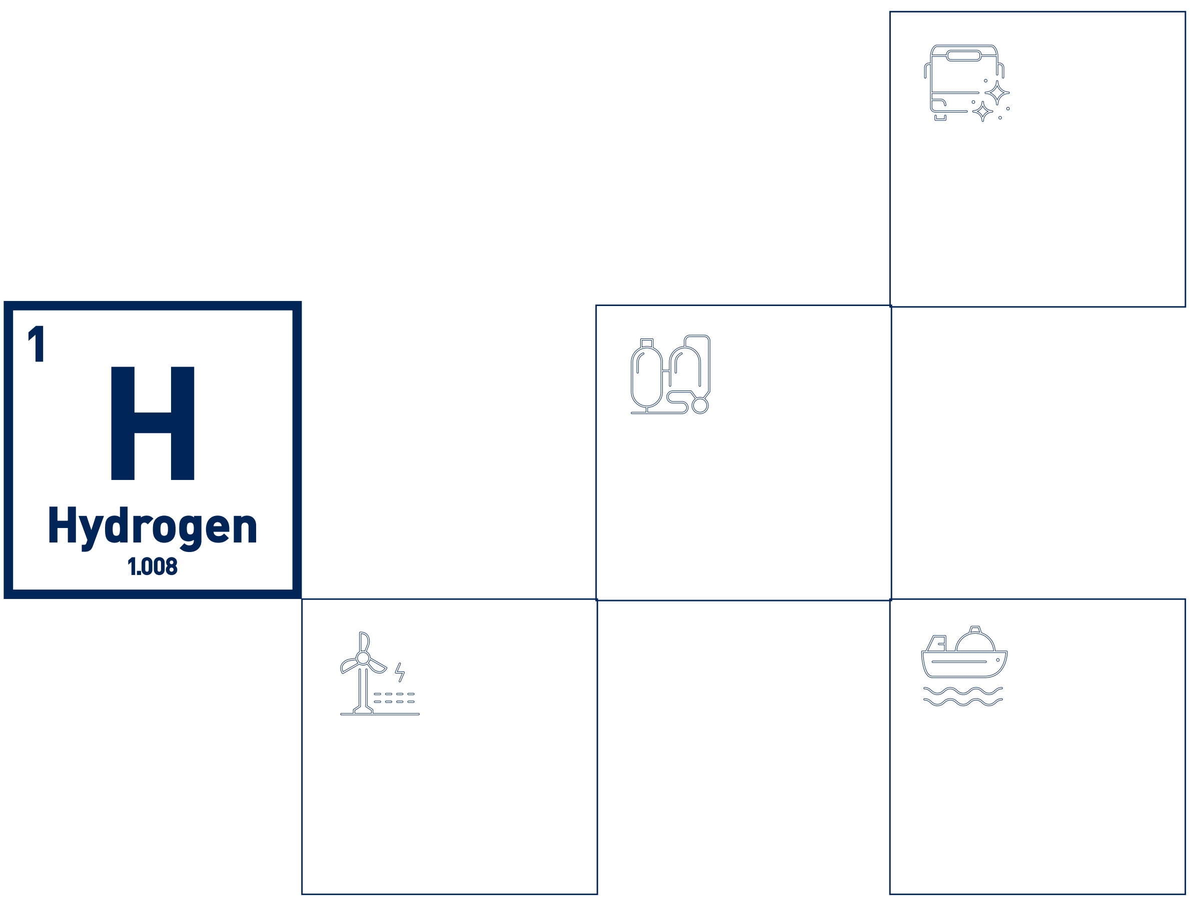
Hydrogen is a promising energy vector, but its unique properties can present certain risks. The small size of dihydrogen molecules makes them prone to escaping through minute holes, with the risk of leaks increasing in applications that require high pressure.

Furthermore, hydrogen is highly flammable, and with many hydrogen systems situated in public spaces like filling stations or transported on roads, the potential for harm to the public is a significant concern.

One of the key challenges associated with hydrogen is hydrogen embrittlement, which can cause an initially leak-free installation to develop leaks over time if the hydrogen interacts with unsuitable tubing or fittings.

In the event of a leak, hydrogen can ignite or even cause explosions in enclosed spaces. Financial efficiency is another crucial aspect to consider, as hydrogen leaks can lead to direct economic losses as well as environmental concerns. Some studies have highlighted that hydrogen, when released into the atmosphere, can contribute to greenhouse gas emissions.

To mitigate these risks, it is vital to adopt a robust approach to the design and maintenance of hydrogen systems. This guide will address various aspects of hydrogen system design, including reducing the number of potential leak paths, appropriate valve technologies, metallurgy, and maintaining high standards of workmanship.



The Key Considerations for Specification, Design, and Installation of Hydrogen Systems

In light of the aforementioned context, we will now examine the crucial factors to consider when specifying, designing, and installing safe and reliable hydrogen systems utilising small bore tubing fittings and valves.

1

Establishing an Acceptable Leak Rate

Initially, it is essential to determine the acceptable leak rate for your system. Constructing a leak-free hydrogen system entails striking a balance between over-engineered design and cost-effective solutions. Designers can commence by establishing an acceptable leak rate, which will dictate the selection of suitable products and technologies. Each application possesses its own definition of 'acceptability', contingent upon the risk of hydrogen entrapment, potential explosion hazards, lost production time, and the loss of economically valuable hydrogen.

Leaks and other unintended releases of gas or vapors from pressurized containment systems, such as appliances, storage tanks, pipelines, wells, or other equipment, are defined as fugitive emissions.

One standard that tackles the fugitive emission of valves is ISO 15848-1:2015. It categorises valves into distinct 'tightness classes'—A, B, and C—with Class A being the most stringent. This categorisation is based on the valves' performance in a series of tests (endurance classes) conducted at varying temperatures and pressures (temperature classes). The selection of valves involves balancing leak reduction and cost. To assist in this decision, Parker provides valves for all three classes. For instance, we offer Class A Fugitive Emission valves with a tightness class exceeding 1 x 10-6 mg.s-1.m-1, accompanied by full materials traceability. Alternatively, should Class A not be justifiable, we supply ball valves (Image 1) and needle valves (Image 2) Class B and Class C options with different leak rates.

Upon defining the acceptable leak rate, it is advisable to establish an appropriate leak detection procedure and medium. Options range from simple pressure decay and soap to a more relevant helium sniffer gun. It is worth noting that a soap bubble test may not reveal H2 leaks.

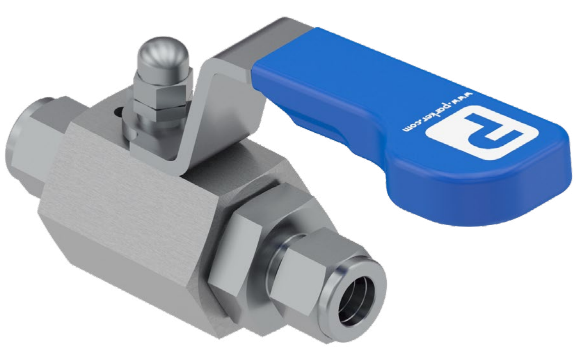


Image 1. Parker's Hi-Pro Series Ball Valves are available in fugitive emission Class A, B, and C options. The valves feature fully integrated tubing connections with reduced leak paths.

Image 2. Parker's H Series Needle Valves are available in fugitive emission Class A, B, and C options. The valves feature fully integrated tubing connections with reduced leak paths.

2 Optimising Tubing Selection for Pressure and Safety

The system's operating pressure is a crucial factor in determining the type and, more importantly, the size of tubing to be employed. Parker has published a series of tubing charts (Fig. 1) for different materials that illustrate the maximum suggested working pressure for various tubing sizes when used with Parker tube fittings. For instance, it is recommended to use 316/316L stainless steel tubing with a 0.028" wall thickness and ¼" outer diameter for up to 4000 psi for all services employing a standard assembly. All calculations are based on maximum outside diameter and minimum wall thickness and have been proven as accurate by extensive product testing.

Studying the tubing charts provided by fitting manufacturers is crucial. These charts should document various specifications, such as the tubing standard referenced, the material grade (for instance, ASTM or UNS numbers), whether the tube has been cold drawn, annealed, and so forth.

Parker's tubing charts are based on industry standards, including **ASME B31.1 Power Piping and ASME B31.3-1993 Chapter II Process Piping.** These standards have a 4:1 safety factor, meaning that the tube and fitting assembly can withstand four times the suggested design maximum pressure before failure. They are used for Parker's compression fittings, such as A-LOK®, CPI™, and MPI™.

Another standard used by Parker is **ASME B31.3 Chapter IX High Pressure Piping**, which employs a 2:1 yield pressure safety factor. This standard is used for Parker Autoclave Engineers cone and thread fittings, which is a common and agreed-upon practice in the industry. While less common, engineers may also use this standard for Parker's MPI™ fittings if used with MPI™ grade tube. It's important to note that this standard adopts a different definition of Allowable Stress and utilises a unique pressure calculation formula, leading to higher working pressure ratings.

It is the responsibility of the design engineer to understand these standards and select the one that best suits the application's requirements. It's critical to review what pressure will be used for the factory acceptance test, to ensure safety.

Table 1							316/316L Stainless Steel									Imperial
Tube O.D. Size	Wall Thickness, inches															
	0.010	0.012	0.014	0.016	0.020	0.028	0.035	0.049	0.065	0.083	0.095	0.109	0.120	0.134	0.156	0.188
1/16	5600	6900	8200	9500	12100	16800										
1/8						8600	10900									
3/16						5500	7000	10300								
1/4						4000	5100	7500	10300							
5/16							4100	5900	8100							
3/8							3300	4800	6600							
1/2							2600	3700	5100	6700						
5/8								3000	4000	5200	6100					
3/4								2400	3300	4300	5000	5800				
7/8								2100	2800	3600	4200	4900				
1									2400	3200	3700	4200	4700			
1 1/4										2500	2900	3300	3700	4100	4900	
1 1/2											2400	2700	3000	3400	4000	4500
2												2000	2200	2500	2900	3200

Fig. 1. Parker tubing chart with maximum working pressures per ASME B31.3 Chapter II,ensuring a 4:1 safety factor.

Another significant aspect to consider is that hydrogen heats as it expands, unlike other gases. Consequently, designers must account for this by derating the pressure if temperatures become excessive. For example, Parker's temperature derating chart (Fig. 2) indicates that at 260°C, the working pressure for stainless steel 316/316L tubing should be derated by 10%.

Table 15		Elevated Temperature Rating Factors						
Temperature		Tubing Material						
°F	°C	Stainless 316/316L*	6Mo	Alloy 400	Alloy 625	Alloy 825	Alloy C276	Titanium Gr. 2
100	38	1	1	1	1	1	1	1
200	93	1	1	0.88	0.93	0.92	0.91	0.87
300	149	1	0.95	0.81	0.88	0.87	0.84	0.72
400	204	0.97	0.9	0.79	0.85	0.83	0.78	0.62
500	260	0.9	0.87	0.79	0.82	0.79	0.73	0.53
600	315	0.85	0.86	0.79	0.79	0.76	0.69	0.45
700	371	0.82	0.84	0.78	0.77	0.74	0.65	--
800	426	0.8	--	0.76	0.75	0.73	0.63	--
900	482	0.78	--	0.43	0.74	--	0.61	--
1000	537	0.77	--	--	0.73	--	0.6	--
1100	593	0.62	--	--	0.73	--	--	--

Fig. 2. Parker table with pressure de-rating factors for elevated temperature conditions.

In many hydrogen systems, such as compressors and skids, different sections often operate under different pressure ranges. For instance, some small bore tubing circuits may operate at 300 bar, whilst others may function at 700 bar. This variation can pose safety hazards and challenges for those working on these systems. To avert these issues, there are two primary options.

The first option is to standardise all valves, tubes, and fitting components to match the highest pressure rating within the system. For example, if the system's pressure ranges between 300 and 700 bar, all components should be standardised to accommodate 700 bar. Despite potentially higher upfront costs, this option simplifies tasks for fitters, saves money on tools and training, and reduces stock levels.
The second option involves using distinct fitting technologies for different sections to optimise costs. However, it's critical to write the specification carefully to avoid errors. Different tube diameters should be utilised for each pressure range, and fittings that are visibly different should be selected to prevent mistakes.

3 Addressing Hydrogen Embrittlement

Hydrogen can cause significant damage to many materials, leading to an effect known as hydrogen damage or hydrogen attack. This often results in embrittlement, a phenomenon that weakens the material without any visible signs of damage, potentially causing catastrophic failure without warning. For further information on the nature and consequences of hydrogen embrittlement, please download our white paper.

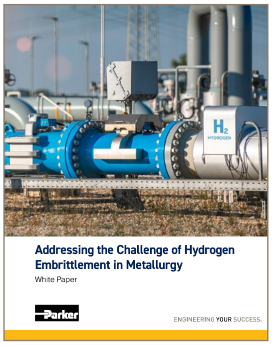
When specifying components for hydrogen systems, it is crucial to consider not only the material grade but also the processing and treatment methods and the component's usage within the system. Original Equipment Manufacturers (OEMs) can safeguard their operations by collaborating with suppliers that provide valid material certificates with reliable traceability information, ensuring the material's quality.

Parker, renowned for its exceptional performance in hydrogen applications, maintains rigorous control over material specifications and traceability. We supply 3.1 certificates ensuring comprehensive material traceability back to the original melt. This level of certification surpasses that offered by other manufacturers, who may not fully comply with the stringent requirements of a 3.1 certification.

In addressing the high-pressure requirements of hydrogen applications, some manufacturers may propose non-standard materials. For instance, while super duplex stainless steel may be suitable for high-pressure applications in the oil and gas sector, it is not an optimal choice for hydrogen applications due to its high susceptibility to hydrogen embrittlement, which is even higher than that of 316 stainless steel. The proposition of using a special grade of 316 stainless steel with increased nickel or chromium content might seem appealing but it can be a misguided and costly solution and often entail extended lead times. It's crucial to understand that simply altering the material's composition will not avoid the problem of hydrogen embrittlement. Such an approach, when considered in isolation, adds minimal value, especially when other processing requirements or high stress risers in the design aren't taken into account.

On the contrary, 316 stainless steel from reputable steel makers with controlled processes is broadly acknowledged as the appropriate choice for hydrogen applications. The critical factor is ensuring full traceability, which validates that the material exhibits the required chemical composition, as well as the appropriate metallurgical grain and structure. For guaranteed assurance, one should seek comprehensive 3.1 certificates from these reliable mills. Lastly, it is important to acknowledge that 316 stainless steel is not only an effective but also an economically competitive option with a vast array of products readily available in the market.

Welding, when necessary, can compromise the material's structure and increase its susceptibility to embrittlement. Parker's Phastite® (Image 3), an alternative tube connection solution without welding, may prove to be significantly more effective. Furthermore, using Phastite® connectors is considerably faster and simpler compared to welding processes.



Discover the Primary Causes of Hydrogen Embrittlement and Strategies for Prevention >

Image 3. Phastite® non-weld push-fit connectors are suitable for pressures up to 1,550 bar (22,500 psi).

4 Reducing Leak Paths

To effectively minimise leakage, it is crucial to reduce the number of leak paths.

The first step for design engineers is to collaborate with a reliable partner like Parker to optimise their hook-up design. This process involves replacing NPT and threaded connections with valves featuring fully integrated tube fittings, also known as tube-ended connections. By incorporating the fittings directly into the valve, the number of leak paths can be reduced, with one fewer leak path per connection. This approach not only cuts down the number of components but also decreases the assembly time compared to threaded connections.

Parker's instrumentation valves can be specified with fully integrated tubing connections using two-ferrule (Image 4) or single-ferrule compression fitting technologies, which improve system safety and integrity. Another recommended practice for reducing leak paths is the use of a manifold block (Image 5) to consolidate various valves and connections, rather than employing independent valves and connections.

Working closely with an experienced partner like Parker allows design engineers to evaluate their designs and determine the most effective methods of minimising the number of connections, ensuring optimal system performance and safety. Parker has a wealth of experience working with clients on their hook-up optimisation, providing valuable insights and tailored solutions to meet their specific needs.

Image 4. Parker's H Series Needle Valve, featuring fully integrated two-ferrule tubing connections (A-LOK®), reduces leak paths for a safer and more efficient system.

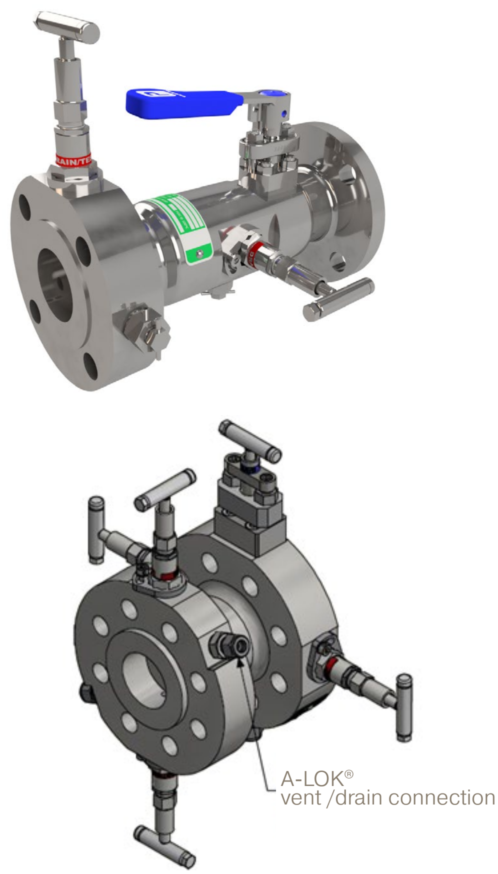


Image 5. Examples of Parker's manifold blocks consolidating multiple valves and connections, effectively reducing leak paths for a more reliable and efficient system.

5 Mitigating Vibration Hazards

Vibration in hydrogen systems is a critical concern, as it can significantly affect safety, performance, and component longevity. In cone and thread technology, vibration can lead to the loosening of cone and thread fittings over time. Vibration primarily stems from fluid dynamics, mechanical components such as compressors and pumps, pressure relief devices, external influences, pulsations and resonance, as well as thermal expansion and contraction. To mitigate these hazards, it is crucial to address and manage vibration effectively by utilising vibration-resistant components, implementing proper design practices, and performing regular inspections and maintenance of the hydrogen system.

Image 6. Parker Autoclave Engineers cone and thread fitting with anti-vibration collet gland assembly - the collet enhances structural strength and prevents rotation.

Parker Instrumentation Products Division offers an extensive range of solutions to establish vibration-resistant systems for hydrogen applications. The key solutions include:

- **A-LOK® and CPI™ tube fittings:** These fittings are specifically engineered to mitigate the effects of vibration and ensure reliable and robust connections in hydrogen systems, even under challenging conditions. A-LOK® fittings have been EC79 approved for on-board hydrogen-powered vehicles.
- **Phastite® tube connectors:** These connectors provide a permanent, weld-like solution that is easy to install and requires minimal maintenance. Their unique design guarantees a secure and leak-proof connection, even when subjected to continuous vibration and temperature fluctuations.
- **Parker Autoclave Engineers cone and thread fittings with anti-vibration collet gland (Image 6):** By incorporating an anti-vibration collet gland, Parker Autoclave Engineers' cone and thread technology offers an effective solution for addressing vibration issues. This technology preserves the benefits of cone and thread fittings while ensuring a secure connection in high-vibration environments.
- **MPI™ double ferrule inverted tube fittings:** MPI™ is a widely-used medium-pressure fitting that employs a two-ferrule compression design to handle pressures up to 1034 bar (15,000 psi) . These fittings are advantageous due to their inherent vibration protection, which helps maintain a stable connection in hydrogen systems exposed to continuous vibration.
- **Integral End Connection Valves:** Parker provides a comprehensive selection of low and medium-pressure valves that come with integral end connections, also referred to as OD connections. The connection technologies include: A-LOK®, CPI™, Phastite®, cone and thread, and MPI™. These integral end connections enhance the stability and reliability of hydrogen systems under vibration, ensuring a safe and efficient performance.

6 Selecting the Right Products

Selecting appropriate products for hydrogen systems is essential in ensuring safety, reliability, and efficiency. Factors such as application, relevant industry standards, regulations, and component longevity must be considered. Enhanced longevity in hydrogen systems is crucial for cost-effectiveness, reduced environmental impact, and successful implementation of hydrogen as a clean energy source.

Parker offers a comprehensive range of components and solutions suitable for various hydrogen applications. Through experience and continuous innovation, some products have been redesigned or developed specifically for hydrogen compatibility, aiming to improve the lifetime and performance of hydrogen systems.

For example, the Parker CXO series check valves (Image 7) for medium pressure feature a hydrogen-compatible spring, providing four times the cycle life of a non-hydrogen version of the same valve. Similarly, the 20SM Series Autoclave Engineers needle valve (Image 8) with the “HYG” option, has a modified seat to handle hydrogen. Parker Autoclave Engineers needle and check valves are tested and approved to meet the ISO 19880-3 standard for filling stations.

A unique offering from Parker, aimed at improving refuelling system design, is the medium-pressure air actuators designed for Parker Autoclave Engineers needle valves. These actuators boast a closing time of under one minute, outperforming competitors in speed. This notable advantage is crucial for refuelling station operators striving to provide faster filling times to their customers.

Parker also offers a range of products approved for use in hydrogen-powered vehicles as per EC-79, covering pressures from 30 to 700 bar (435 to 10,153 psi). This range includes A-LOK® series double ferrule tube fittings, cone and thread fittings, medium pressure needle valves and tubing.

Additionally, Parker offers a range of ball and needle valves that meet the ISO 15848 Class A, B, and C fugitive emission standard. To prevent the loss of valuable H2 gas into the atmosphere, consider selecting the Class A option (Fugitive Emission valves with tightness class above 1 x 10-6 mg·s-1·m-1).

Parker Hannifin provides numerous other products for hydrogen applications, such as the high-pressure hoses produced by its Polyflex division. These hoses are specifically designed to handle hydrogen, providing a distinct solution in today’s market.

Image 7. Parker Autoclave Engineers check valve CXO Series (HYG option), featuring a hydrogen-compatible spring and ISO 19880-3 approval for fuelling stations.

Image 8. Parker Autoclave Engineers needle valve featuring a modified seat, ISO 19880-3 approval for fuelling stations and EC-79 approval for hydrogen-powered vehicles.

7 Optimising Installation with Comprehensive Training

Proper training is crucial, particularly when dealing with high-pressure hydrogen applications. The majority of issues that arise with small bore tubing and valves can be attributed to inadequate installation or substandard workmanship. Furthermore, insufficient training exposes both installers and users to potential hazards. A hydrogen leak at 700 bar (10,153 psi) or a sudden break in a high-pressure line can have disastrous consequences, not only in controlled industrial environments- but also in public spaces, such as filling stations.

To address these training deficiencies, Parker offers the Small Bore Expert (SBEx) training course. This comprehensive course equips fitters, technicians, and maintenance staff with the requisite expertise to safely and effectively install and maintain small bore tubing systems, ensuring their efficiency and leak-free operation. SBEx courses are delivered by highly skilled and well-equipped Parker Sales Companies and authorised distributors. Upon successful completion of the training, participants receive certification, verifying their proficiency in the installation and maintenance of small bore tubing systems. By investing in such training, organisations can ensure the safety and efficiency of their hydrogen systems, minimising the risk of accidents and maintaining the integrity of their operations.

8 Standardising on a Single Supplier

It is crucial to avoid intermixing components and different suppliers within a single unit or site, as this can substantially increase the risk of leaks and catastrophic failures. To mitigate these risks, it is recommended to standardise on one manufacturer and a select range of technologies. This approach will simplify maintenance, prevent workmanship problems, and enhance overall safety.

Various suppliers maintain distinct machining tolerances, material grades, specifications, and even designs. Consequently, contractors may inadvertently combine components, leading to severe leaks and disastrous failures.

Parker valves and fittings maintain consistent, rigorously controlled quality standards, utilising fully traceable material grades. These components are easily accessible worldwide through our distributor network, which also offers training for fitters to prevent issues related to workmanship.

Conclusion

In conclusion, the successful implementation of hydrogen systems relies on meticulous design, appropriate component selection, and expert installation to ensure safety, efficiency, and longevity. Parker Hannifin, a global leader in the field, and its authorised distributors around the world offer global support and a comprehensive range of high-quality, hydrogen-compatible components to help you safely meet the stringent requirements of hydrogen.

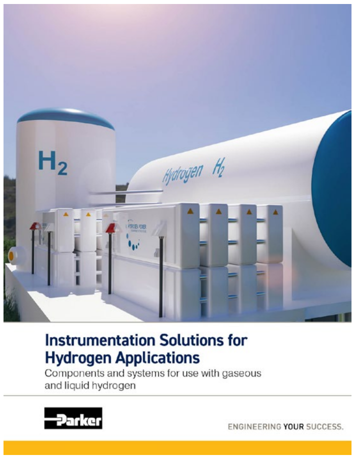
By partnering with Parker, design engineers can access valuable expertise and support, enabling them to optimise system performance and mitigate potential risks.

Parker's stringent material traceability, innovative components, and practical solutions for addressing issues such as vibration and leak reduction all contribute to the success of hydrogen systems across industries.

Furthermore, Parker's Small Bore Expert (SBEx) training course empowers fitters, technicians, and maintenance staff with the knowledge and skills needed to ensure the safe and efficient operation of hydrogen systems. Investing in comprehensive training is crucial for minimising risks and maintaining operational integrity.

By closely engaging with end users and system proprietors, Parker Hannifin can assist in developing bespoke specifications, resulting in hydrogen systems that not only fulfil but exceed expectations in terms of safety, reliability, ease of maintenance, and economic feasibility. Our dedication to innovation and excellence positions us as the ideal partner for organisations seeking to capitalise on the potential of hydrogen as a clean energy source.

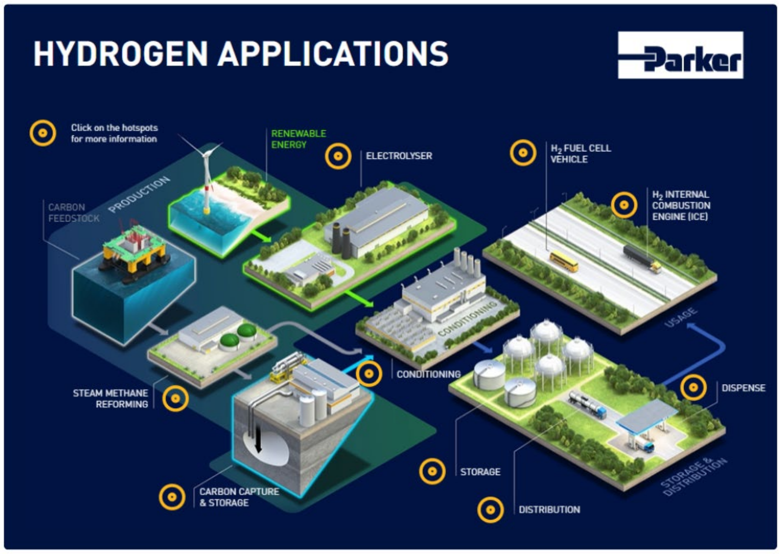
With Parker Hannifin's unparalleled expertise, pioneering solutions, and commitment to quality, the clean tech industry can confidently embrace the adoption of hydrogen as an energy vector, secure in the knowledge that they are in safe and capable hands.



Download Our Comprehensive Instrumentation Solutions Catalogue >


H2

Check out Parker's hydrogen value chain interactive map!



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.

Parker Hannifin Manufacturing Ltd.
Instrumentation Products Division Europe
Riverside Road
Barnstaple, EX31 1NP
United Kingdom
Tel.: +44 (0) 1271 313131
www.parker.com/ipd