North American
CleanEnergy

VOLUME 18 | ISSUE 6

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Creating a New Standard in LH2-Refueling Performance and Safety

by Felipe Machado

It's a fact of life in industrial processing that, in order to accomplish "good" things, you must sometimes have to work with potentially "bad" things. Such is the case with liquid hydrogen, or LH2. As the industrial world continues to look for new ways to move away from the use of traditional fossil fuels to power vehicles and industrial processes, a number of alternatives have begun to rise to the fore.

For the most part, this quest to expand the energy pool via "green" clean energy alternatives is being driven by Environmental, Social, and Governance (ESG) initiatives aimed at reducing the high carbon footprint, greenhouse gas emissions, and ozone depletion potential that are implicit in fossil-fuel usage, which many argue are at the forefront of global climate change.

While propane and liquid natural gas have traditionally been the most popular amongst the new wave of clean energy fuels (with Europe, China and India leading the way), hydrogen has begun to gain additional attention and momentum as another promising alternative. In fact, in 2021 the U.S. Department of Energy announced the creation of the Regional Clean Hydrogen Hubs program offering $7 billion in grants to companies that would like to develop more hydrogen liquefaction plants, with many traditional oil-and-gas producers showing interest in expanding their horizons into the LH2 universe.

In late 2023, seven hub-projects were selected for funding through the program, shaping a network of new liquefaction facilities that will eventually span the country from the Mid-Atlantic to Pacific Northwest, and the Gulf Coast to Upper Midwest. But the challenges that are inherent in the dispensing of LH2 must be overcome before the fuel can assume a prominent place in the world's motor-fuel pool.

To that end, enterprising companies are looking for ways to optimize the dispensing of LH2 in terms of efficiency, reliability – and safety – through the development of innovative dispensing technologies, all while making the refueling process for the consumer as similar and familiar to that of the traditional service station as possible.

The Challenge

While LH2 can theoretically be used to power all motor vehicles, its capabilities make it a top choice as a reliable and efficient fuel for use in long-haul vehicles such as transport trucks, planes, barges, and ships. However, getting the fuel from Point A to Point B in the supply chain, and in the massive amounts in which it is needed, can be problematic.

While LH2 possesses great potential for growth as an energy source (buoyed by its carbon-neutral status and environmentally sensitive emissions of water and air), the volatile nature of LH2 can make it challenging to harvest, refine, transport, dispense, and consume. This makes ensuring safety for the handler and environment Job No. 1 along its production and supply chain.

With a working temperature of -423ºF (-253ºC) that is close to absolute zero, or -460ºF (-273ºC), LH2 is one of the most challenging cryogenic gases. This means that the equipment used to dispense LH2 must contain massive amounts of thermal insulation in the dispensing nozzle to prevent huge ambient losses in volume from evaporation as the fuel is being dispensed.

Another phenomenon with LH2 nozzles is the occurrence of hydrogen embrittlement. It's a physical fact that all metals will be detrimentally affected at some level by hydrogen, with the level of exposure helping to determine if any embrittlement will occur. If a metal does experience hydrogen embrittlement, it can result in noteworthy losses in tensile strength, ductility, and fracture toughness, along with accelerated fatigue-crack growth. When the level of embrittlement reaches a critical point, the result can be catastrophic failure of LH2-containing components.

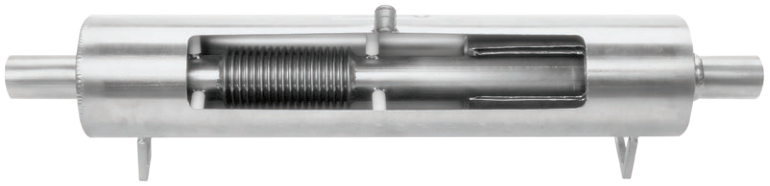
To lessen the risk that hydrogen embrittlement will take place in an LH2-dispensing nozzle, metals that are more resistant to hydrogen embrittlement should be used, such as high-quality stainless-steel grades. Sealing on moving parts is another area where precision in material selection and engineering must be optimized in order to ensure a safe refueling solution.

Many common elastomers are not suitable for use with cryogenic substances. The recommended seal type is one constructed from polychlorotrifluoroethylene, or PCTFE. PCTFE stands out in cryogenic service because of its high tensile strength and good thermal characteristics. This combination of exceptional physical characteristics and stability at ultra-low temperatures make PCTFE an ideal choice for equipment used in LH2 dispensing.

Additionally, the nozzle must be constructed so that there is no chance that leakage will occur. If a leak does happen, the nozzle's operation must be able to be instantly halted in order to prevent a potentially dangerous scenario from developing. On top of that, the nozzle must possess automated flow-control capabilities that

enable the operator to be physically situated at a safe distance as the refueling process takes place.

One final operational concern with LH2 is the potential for the buildup of condensed liquid air on the nozzle during a refueling activity. This condensed liquid air is extremely combustible liquid oxygen. Therefore, the LH2-dispensing system must be jacketed and have an extremely high vacuum in order to keep the outer surfaces at ambient temperature so there can be no buildup of liquid air.



The Solution

Recognizing the challenges that are the hallmark of LH2 handling – ensuring safety in every instance – companies that specialize in the development of systems and components for use with clean energy alternative fuels, such as LH2, have put on their thinking caps to find solutions to these challenges.

One notable development has been the creation of a fueling nozzle that is designed to be a robust LH2 transfer and dispensing solution that can replicate a safe and reliable traditional diesel-like handling and dispensing experience for the consumer.

This next-generation nozzle offers the following features and benefits:

- Unique design that diminishes complexity in LH2 dispensing
- Built-in leak-detection capability
- Automated fuel control that enables the operator to remain in a remote location during the refueling process
- Three-stage thermal-isolated method of operation that optimizes efficiency and performance
- Jacketing that meets the low-temperature handling requirements of LH2 and resists the dangerous buildup of liquid air
- Lighter weight for easier handling

These features and benefits, along with the safety-inducing operational capabilities, make the nozzle very intuitive to use. The removal of any ambiguity in its handling or operation also allows the sellers of LH2 to create a dispensing process that mimics the "culture" of traditional vehicle fueling, which can help ease any concerns the consumer may have when dispensing an unfamiliar fuel.

Conclusion

There's no getting around it, the clean energy future is coming. In order to optimize its potential from a production, supply, financial, and safety aspect, it must be outfitted with equipment and systems that are able to meet the unique handling characteristics of the growing roster of clean energy fuels. In that vein, LH2 stands poised to assume an elevated role in the nation's motor-fuel pool, especially as it relates to the fueling of large vehicles.

Producers and suppliers of LH2 must be fully aware of the "bad" characteristics that are fundamental to its handling and dispensing, so they can realize the "good" that can come from its use. Suppliers to the clean energy market have taken a positive step forward in that quest with the development of new technologies for an optimized, mainstream and inherently safe LH2-refueling operation.

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OPW Clean Energy Solutions // opwces.com

Valves for the hydrogen economy

CIRCOR International, Inc.'s high pressure primary isolation valves and pressure control technologies have been used to enable the supply of hydrogen to hydrogen fueling stations. When a supplier of Hydrogen Trailers required valves qualified in accordance with the latest European Transportable Pressure Equipment Directive, a requirement for all valves used to isolate transportable hydrogen storage modules, CIRCOR's engineers provided a solution in the ASV Series Pneumatically Actuated Stop Valve. This valve is based on CIRCOR's reliable balanced valve concept but includes sealing technologies capable of performing across the range of pressures temperatures and leak rates required. Standard and custom engineered fluid- and gas-handling solutions from CIRCOR support a wide range of mission critical applications and are essential for the reliable and safe operation of all types of industrial hydrogen systems.

CIRCOR International, Inc.
// www.circor.com

Hydrogen market analysis tool

Key Hydrogen's H2 Advantage incorporates proprietary mapping datasets with a powerful visual mapping software to create global geospatial maps that will give a clear competitive advantage to energy companies and investors seeking guidance on feedstock availability, off-taker opportunities, and the best hydrogen location analytics to maximize project profitability. The H2 Advantage Platform allows users to analyze asset portfolios for optimal hydrogen transition, and highlights the best financial return locations and nearby offtake opportunities. Hydrogen developers can get a global view of the hydrogen landscape, pinpointing ideal development locations and infrastructure insights. It also emphasizes renewable power options for projects with additionality requirements. Financial advisors can navigate the hydrogen market, assess potential offtake opportunities, and estimate derivative cash flows. From site selection for demos and pilots to asset management for system monitoring and growth, The H2 Advantage scales with users' growth trajectory.

Key Hydrogen // www.keyhydrogen.com

High-pressure tube trailers for hydrogen delivery

North Carolina-based OneH2, Inc.'s new cylinder technology for 931 bar high-pressure hydrogen tube trailers is a culmination of several years of development and investment, and operates under a unique special permit issued by the U.S. Department of Transport for use on roads. The new 931 bar design allows for direct fills of higher-pressure, 700 bar automotive and heavy vehicle applications, making hydrogen-fueled transport much more economical. By transporting hydrogen gas at higher pressures, OneH2 bypasses the extra processing normally required by other delivery methods. 931 bar trailers consist of various combinations of high-pressure cylinders packaged together. Each cylinder can hold up to 60lb gross (27kg) of gaseous hydrogen at 931 bar pressure, which is close to three times that of the cylinder technology OneH2 previously used. Trailers can be configured with various capacities. With a maximum configuration of up to 18 cylinders, a single trailer can hold up to 1071lb (486kg) of automotive, fuel-cell grade, hydrogen. If on-site space is an issue, OneH2 offers smaller trailer configurations, down to 6 cylinders, 353lb (160kg) promoting better maneuverability in tighter environments. To ensure maximum utilization of onboard hydrogen, OneH2 uses a cascading function, allowing each cylinder to act as its own cascading bank. The trailer also includes key features that optimize performance and safety, such as onboard hydrogen gas sensors, on-tank actuator valves for isolation, telemetry to report the status of the trailer on-road, safety interlocks, and a temperature and pressure relief device (TPRD) for each tank. The trailer's cylinders are designed and tested in accordance with international standards that provide specifications for the design, construction, and testing of type IV composite cylinders. OneH2 also offers 931 bar Mobile Fuelers using the same cylinder technology. The refueler includes an onboarded dispensing system for both 350 bar and 700 bar pressure, turning the trailer into a portable fueling station. This mobile and portable refueling station allows customers to receive hydrogen at any location and immediately refuel vehicles, with minimal to no investment in on-site equipment and reducing permitting and construction headaches.

OneH2 // www.oneh2.com