

Advanced Hydrogen Storage Technology: A Bridge to the Future

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Infrastructure continues to be identified as a major challenge in developing the hydrogen energy economy across a number of end markets. Early technology demonstration programs sponsored by federal, state, and local agencies have provided hydrogen infrastructure developers with the opportunity to gain valuable experience regarding the supply chain associated with the production, distribution, and dispensing of hydrogen for the developing fuel cell electric vehicle market.

As the transition for the automotive market continues to move forward, fuel cell powered systems have already made their way into the material handling (fork-lift truck, automated guided vehicles), stationary power, cell tower, and other markets to build infrastructure experience and capacity. All these associated fuel cell markets present similar hydrogen infrastructure and supply chain challenges, but on a much smaller scale.

Hydrogen product supply and fueling station infrastructure at today's scale can be expensive, so costs must be economized to support and help accelerate market growth.

The purpose of developing high pressure high capacity hydrogen trailers is to provide customers in the transition with a means of fueling automobiles, cell towers, and small material handling sites at location, safely and economically.

For on-site hydrogen generation, equipment purchases at the low volume station specifications are skewed toward minimizing capacity to provide the lowest total costs, and to balance hydrogen fuel supply to fuel cell vehicle hydrogen demand. Usually, any appreciable growth beyond original fueling station capacity has required significant equipment for expansion. Many times these station adjustments also surround hydrogen storage issues.

Air Products has been a key player in many hydrogen energy developments across several market end uses. As the leading hydrogen supplier to refineries to assist in making cleaner burning transportation fuels, the company also has unique experience in the hydrogen fueling industry. Air Products has been involved in over 150 hydrogen fueling projects in the

United States and 19 countries worldwide. Use of the company's fueling technology is increasing with over 500,000 hydrogen fills per year, and several sites today for certain hydrogen fueling applications are fueling at rates of over 75,000 refills per year.

While it is generally accepted that a pipeline supply infrastructure similar to natural gas is the preferred lowest cost end game for hydrogen fuel cell vehicle fueling stations, it is unclear how the market will transition to that end game, or at what rate large production hydrogen plants would supply this initial demand. Undoubtedly, new sources of product supply will need to be secured and new types of hydrogen distribution will be deployed to enable market growth. In the meantime, the debate as to what comes first continues. Many infrastructure providers are reluctant to sink investment in hydrogen infrastructure to serve a pre-commercial vehicle market, and at the same time automotive manufacturers are not willing to invest in large scale fuel cell vehicle manufacturing without retail-like hydrogen fueling station availability.

However, the hydrogen storage question may have been answered already, and answered in a way that also removes the early market infrastructure challenge. Described as a low-cost game changing technology, this advancement in hydrogen storage technology is key in filling hydrogen fuel cell vehicles on the site of existing retail gasoline fueling stations. The storage technology is ready today and can provide an infrastructure bridge to the future. This new storage development allows hydrogen fueling to be placed on most existing gasoline forecourt spaces, thus potentially eliminating the infrastructure issue. Additionally, the



Air Products' hydrogen fuel dispensing technology placed at this retail gasoline station in California, part of a step change in infrastructure capabilities, is part of a "compression-less hydrogen fueling station."



The key to the cost effective “compression-less hydrogen fueling station” is a composite pressure vessel (CPV) trailer as pictured in this photo. The trailer containing the CPVs and associated equipment inside the fenced area are located in the corner of the forecourt space of an existing retail gasoline station in California. Underground piping directly supplies the hydrogen to the fuel dispensing equipment.

storage advancement for hydrogen delivery becomes more similar to traditional fuels and can mirror the gasoline model.

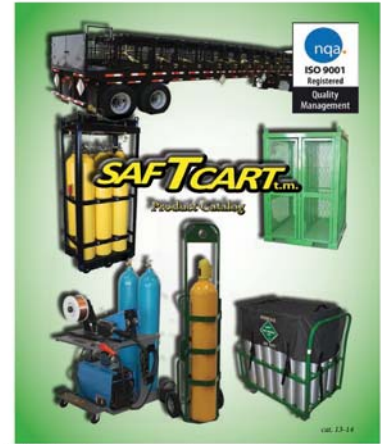
The new storage technology has already been installed and is on display today at a California location on the forecourt of an existing retail gasoline station (pictured above). Commercialization of this “compression-less hydrogen fueling station” is near. The storage technology features specialized composite cylinders for hydrogen storage. High pressure composite storage technology applied to hydrogen distribution can offer many advantages in serving the key hydrogen energy markets. The purpose of developing high pressure high capacity hydrogen trailers is to provide customers in the transition with a means of fueling automobiles, cell towers, and small material handling sites at location, safely and economically.

There are many benefits of the compression-less hydrogen fueling station. It offers an improved delivery technology to reduce the cost of transporting low-priced hydrogen from central facilities with high product availability. Its simple and modular design is expandable to full-sized station capacities, which reduce capital costs at the point of use. This type of fueling station offers reduced overall site maintenance costs and its minimized footprint enables it to be used at existing retail gasoline forecourt locations, which significantly lowers the initial cost of infrastructure. The station can minimize the lifecycle greenhouse gas emissions associated with the production, transportation, and use of hydrogen in fuel cell markets and its ability to utilize renewable resources most efficiently enables this technology to meet the requirements of CA SB 1505, a California bill that requires environ-

mental limits be achieved during the production of hydrogen for transportation use. Air Product’s compression-less hydrogen fueling station also meets the United States Department of Energy commercial hydrogen price targets that are competitive with gasoline today, as well as for hydrogen applications in other emerging fuel cell markets with smaller station capacity than other station configurations. It more closely matches the projected rollout of fuel cell vehicles to serve the automotive market as it grows, as opposed to the installation of large stations that may be underutilized for longer periods of time; and it provides a model for a national fueling infrastructure, which piggybacks on existing production capabilities, and would provide for energy independence as hydrogen can be produced from domestic sources.

This composite storage advancement was developed through Air Products’ research in hydrogen storage, and through joint work and an exclusive supply agreement with Structural Composites Industries, LLC. The key to the cost effective “compression-less hydrogen fueling station” is a composite pressure vessel (CPV) trailer.

The CPV trailer is connected directly to the on-site fueling system, making the delivery vehicle an integrated part of the fueling station. The proprietary and certified CPVs are an industry advancement and allow for gaseous hydrogen delivery in greater quantities depending on hydrogen demand. The CPV concept transports hydrogen for fueling at well over 350 bar/5,000 psi and, importantly, can be reliably bumped up or increased at the station for 700 bar/10,000 psi hydrogen vehicles with greater flexibility and at lesser cost through this advancement.



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The CPV technology is best positioned to take advantage of low cost gaseous hydrogen supply from large hydrogen production plants, pipelines, off-gas hydrogen and renewable sources, and existing liquid hydrogen supply networks serving industrial gas markets. CPV trailers could supplant the desire for hydrogen pipelines in certain areas, but not all pipeline locations. Beyond hydrogen powered transportation vehicles, this application has already offered significant advantages to the cell tower market through location accessibility and lower cost of hydrogen delivery, and also enabled other hydrogen fueling and fuel cell markets.

The composite storage and CPV trailer also can be paired to develop and support hydrogen ground storage at retail stations much like the current gasoline model. Beyond this station platform, Air Products has developed a third follow-on platform to expand station capacities to be commensurate with a typical corner gasoline station. This next station platform is already operating in more traditional markets globally,

proving its value proposition. Air Products has several station concepts incorporating modular and expandable CPV technology and has developed an entire portfolio of global patents with additional patents pending related to the trilogy of platforms for building a cost-effective hydrogen fueling infrastructure.

Air Products has plans to use this infrastructure model for eight hydrogen fueling stations to be onstream and operating in Southern California over the next year as part of a California Energy Commission initiative. This approach to the automotive market can be extended to other markets worldwide as a prudent method of proper and timely investment to roll out a new infrastructure. ■

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