Program Record (Hydrogen and Fuel Cells Program)		
Record #: 19005	**Date:** October 7, 2019	
Title: 600 kg/day Hydrogen Fueling Station Footprint		
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Peer reviewed by: Members of U.S. DRIVE Hydrogen Codes & Standards (CSTT) Technical Team; Aaron Harris (Air Liquide)		
Approved by: Laura Hill & Sunita Satyapal	**Date:** October 7, 2019	

Description:

This record documents the basis for the baseline of 18,000 ft^2 as the footprint of a 600 kg/day hydrogen vehicle refueling station, as documented by the Hydrogen and Fuel Cells Program and peer-reviewed by industry stakeholders. A key assumption in this record is that a 600 kg/day station will utilize liquefied hydrogen delivery and bulk storage; the baseline footprint was estimated using liquid hydrogen requirements in the 2016 National Fire Protection Association Hydrogen Technologies Code, NFPA 2 [1]. It is important to note that hydrogen fueling station designs vary widely. Variations in key parameters, such as the capacity of liquid hydrogen storage onsite or the size of the liquid tanker expected for hydrogen delivery to the station, will influence the actual footprint of a fueling station.

Principles:

The fueling station footprint is a calculation of the minimum area required to install a fueling station and is driven by code requirements. Code requirements include minimum separation distances from bulk hydrogen storage, vent stack, and transfer points. This record estimates the footprint of fueling stations based on assumptions regarding station design and calculations of the setback distances required for compliance with these codes. This record aligns with the DOE priority to invest in "innovative technologies that show promise in harnessing American energy resources safely and efficiently" [2]. This analysis is based on the minimum separation distances for the various target exposures to credible hydrogen release scenarios.

Calculation Methodology and Results:

As of October 2018, the largest retail hydrogen fueling stations for light-duty vehicles in operation in the United States had a capacity of 350 kg/day [3]. Larger stations—up to 1,000 kg/day or more—are in the planning stages and will be required to meet the demand of the emerging fuel cell electric vehicle market, particularly as heavy-duty vehicles begin to enter regular operation. A minimum capacity of 600 kg/day is suggested by the California Air Resources Board as a near-term target in denser vehicle markets, such as urban centers [3].

Stations at and above 350 kg/day capacity today commonly use liquefied hydrogen (LH_2) delivery and bulk storage on-site. Delivering and storing large quantities of gaseous hydrogen is challenging. Common tube-trailers typically have a capacity of 300 kg H_2 (although this capacity can be higher) [4] and gaseous storage requires large tank arrays at the station. Stations designed for a capacity of 600 kg/day or more will almost certainly maintain LH_2 storage on site. Therefore, the estimated footprint of a 600 kg/day station is based on the bulk LH_2 separation distances in the 2016 National Fire Protection Association Hydrogen Technologies Code (NFPA 2) [1].

The most restrictive separation distances from NFPA 2 for tank sizes that could enable a 600 kg/day capacity are shown in Table 1 [1]. These distances include the provisions for credits given for insulation and fire barrier walls installed with the system. Note that these distances have not changed since their first publication over 40 years ago in NFPA standards covering hydrogen.

Table 1. Largest separation distances for LH_2 bulk storage (from Table 8.3.2.3.1.6(A) for a 3,501-15,000 gallon tank (900 to 4,000 kg H_2) in NFPA 2)

Exposure	Distance [ft (m)]
Air intakes, operable building openings, places of public assembly	75 (23)
Parked cars, combustible liquids, non-H_2 flammable gas	25 (7.6)
Lot lines	16.7 (5)

Using the constraints in Table 1 along with assumptions for a typical convenience store size, parking spaces, delivery truck routes, etc., Harris et al. estimated a LH_2-based fueling station footprint of 18,000 ft^2 [5]. This estimate assumed a vertical LH_2 storage tank with a capacity of 900–4,000 kg H_2, which is the capacity range expected for a 600 kg/day station [5]. A sketch of this station is shown in Figure 1.

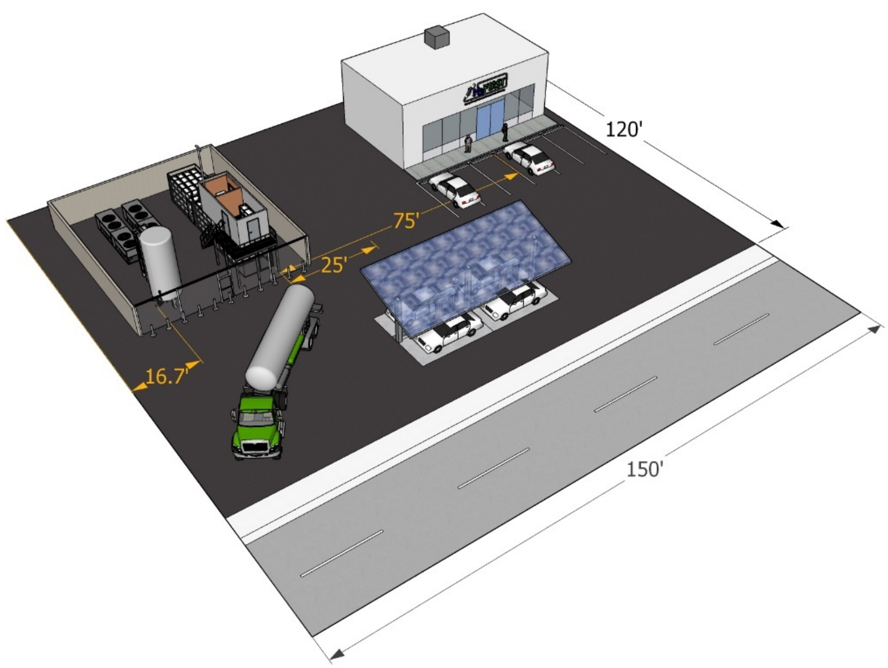

Figure 1. Sketch of a 600 kg/day, LH_2-based hydrogen fueling station, requiring 18,000 ft^2

Pratt et al. also provided a greenfield reference station layout for a LH_2 hydrogen fueling station with the same tank capacity and similar assumptions that meets the NFPA 2 requirements, on a lot that was 18,270 ft^2 [6]. It is also important to note that the footprint of the fueling station depends largely on the size of the liquid tanker used to conduct deliveries. Stations that are sized to accept larger tankers for hydrogen delivery may have a larger footprint.

The current retail fueling stations that utilize LH_2 bulk storage have had the flexibility for installation on relatively large lots, which range from approximately 30,000 ft^2 (Iwatani's Mountain View station) to just over 100,000 ft^2 (Iwatani's West Sacramento station) [3]. Achieving widespread penetration of the next generation of stations (≥600 kg/day) will require smaller lot sizes than current LH_2 stations. For example, a 400 kg/day station (albeit with gaseous storage and delivery) in San Francisco is being constructed on an 9,200 ft^2 lot [3, 7].

Research under the DOE program continues to work toward science-based separation distances for LH_2 bulk storage, thus reducing the required footprint for next generation, large scale hydrogen stations.

Review Process:

The Safety, Codes and Standards 600 kg per day footprint fueling station record was reviewed by Aaron Harris (Air Liquide), Carl Rivkin (National Renewable Energy Laboratory), and automobile industry stakeholders via the U.S. DRIVE Hydrogen Codes and Standards Technical Team.

References:

[1] National Fire Protection Association. NFPA 2: Hydrogen Technologies Code, 2016 Edition. Available at https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=2.

[2] https://www.whitehouse.gov/wp-content/uploads/2018/07/M-18-22.pdf.

[3] California Air Resources Board. 2018 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development. Available at https://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2018_print.pdf.

[4] Hydrogen Tube Trailers. Available at https://www.energy.gov/eere/fuelcells/hydrogen-tube-trailers

[5] Harris, A. P., Dedrick, D. E., LaFleur, C., San Marchi, C. Safety, Codes and Standards for Hydrogen Installations: Hydrogen Fueling System Footprint Metric Development. SAND2014-3416. 2014.

[6] Pratt, J.W., Terlip, D., Ainscough, C., Kurtz, J., Elgowainy, A. H2FIRST Reference Station Design Task Project. NREL/TP-5400-64107. 2015.

[7] California Fuel Cell Partnership. Station Map. Available at: https://cafcp.org/stationmap.