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Short Communication

Low-cost, transportable hydrogen fueling station for early market adoption of fuel cell electric vehicles

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ABSTRACT

Thousands of public hydrogen fueling stations are needed to support the early Fuel Cell Electric Vehicle (FCEV) market in the U.S.; as of July 2014 there were 12. Government agencies are the largest investors in the U.S. hydrogen fueling infrastructure and are developing stations that cost anywhere from $1.8–$5.9 million each. To attract private investors and decrease dependence on government funding, a low-cost, mobile hydrogen dispensing system must be developed. This paper describes a transportable 700 bar hydrogen fueling station that has been designed with an off-the-shelf component cost of $423,000; less than 23% of the capital cost of current stations. The design utilizes liquid hydrogen storage and a novel cryogenic compression system which can be factory built for high volume, rapid production. These stations are contained in a standard 40 foot ISO shipping container to adapt to varying locational demand. The demand adjusted cost to sell hydrogen is estimated to be $9.62/kg. This paper presents the mechanical design and operation of the fueling station. This design won the grand prize for the 2014 Hydrogen Student Design competition and a complete report including an economic analysis and safety features is available elsewhere.

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Introduction

Hydrogen stations currently operating or in development in the U.S. for fueling Fuel Cell Electric Vehicles (FCEV) range from $1.8–$5.9 million to construct [1]. The cost is a result of each station demonstrating a unique design with little standardization. These stations are permanent installations with fixed capacities (60–350 kg/day) that cannot easily adapt to the changing demand for hydrogen (H_2). The high cost and lack of flexibility of these stations creates high risk for private investors placing the financial burden to support the H_2 fueling infrastructure on government agencies. Hundreds of hydrogen fueling stations are needed for near term adoption in targeted metropolitan areas. As of July 2014, only 12 public H_2 fueling stations exist for FCEVs [2]. H_2 station cost reductions must be realized to attract private investors and reduce the dependence on government subsidies to successfully support the imminent commercialization of FCEVs.

Lowering the cost of distributing, storing, and dispensing H_2 that is produced at a central plant is difficult given the physical properties of H_2 and strict safety regulations. H_2 is compressed several times between production and end-use to improve its low storage density and increase the flow rate during transfers which contributes to station capital and operating costs. Typical H_2 compressors for 35 MPa and 70 MPa fueling cost $50,000–$140,000 each, are the most maintenance intensive component of stations, and consume 2–4 kWh/kg of electricity (compressing 20–350 bar) [3]. The low Joule-Thompson inversion temperature of H_2 causes the gas to heat when expanded close to room temperature, requiring high pressure H_2 chillers to precool before filling FCEV fuel tanks which cannot exceed 85 °C [4]. Modern tube trailers for gaseous H_2 delivery rated for 35 MPa are carbon fiber wrapped, cost $633,750 each, and hold enough H_2 to fill approximately 160 FCEVs [5]; that is almost five times fewer vehicles than a common gasoline tanker costing less than $100,000 [6]. The H_2 combustibility range of 4–75% in air requires additional safety equipment that also contributes to station cost.

At present, industry experts are focused on supply chains, H_2 compression, high pressure storage components, and standardizing station designs as the primary approach to reducing station costs. Consensus is that early commercial stations deployed in 2014–2016 will output 333 kg/day on average and cost approximately $2.8 million each [1]. That is a 62% decrease in capital cost per capacity from current stations benefitting mostly from economies of scale. Advances in carbon fiber cylinders hope to raise the storage capacity of gaseous H_2 delivery tube trailers to 1155 kg at 54 MPa by 2020 to meet anticipated demands [5]. Another approach is using cryogenic tanker trucks for liquid hydrogen (LH_2) delivery. These tankers have a 4000 kg H_2 capacity, cost $600,000, and have been established for decades [7]. This superior capacity is the reason that 80–90% of small merchant H_2 distribution occurs via cryogenic liquid tanker trucks [8]. LH_2 is therefore the primary distribution path to meet the near-term early-market needs [9].

The mass deployment of H_2 fueling stations for early support of the FCEV market depends on a low-cost, modular design. In this paper the design for a transportable H_2 fueling station is presented that would use readily available components at a cost of $423,000. The station utilizes LH_2 storage and a unique two step dispensing process to minimize operating and equipment costs. Each station could be setup in less than a week, operate autonomously, and require only LH_2 delivery, 208 V power, and municipal water. These fuel stations can dispense at least 100 kg/day of 70 MPa H_2 at a cost comparable to gasoline. A conceptual rendering of the H_2 fuel station is shown in Fig. 1.

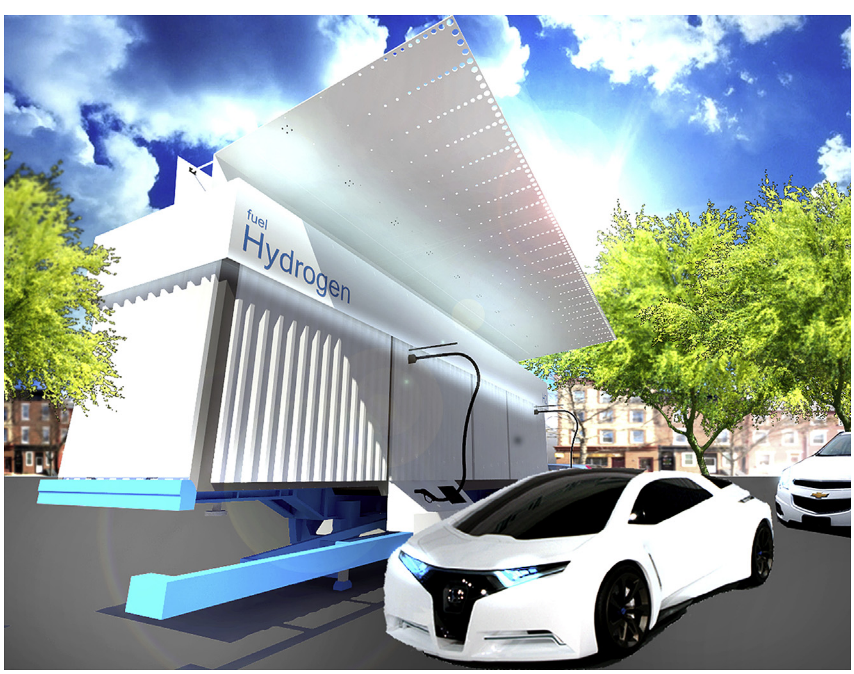

Fig. 1 – Conceptual rendering of the transportable hydrogen fueling station.