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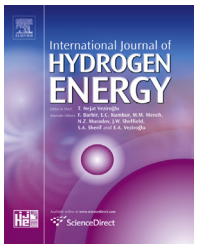

Effect of gasoline pool fire on liquid hydrogen storage tank in hybrid hydrogen–gasoline fueling station

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ABSTRACT

Multiple-energy-fueling stations, which can supply several types of energy such as gasoline, CNG, and hydrogen, could guarantee the efficient use of space. To guide the safety management of hybrid hydrogen–gasoline fueling stations, which utilize liquid hydrogen as an energy carrier, the scale of gasoline pool fires was estimated using the hazard assessment tool Toxic Release Analysis of Chemical Emissions (TRACE). Subsequently, the temperature and the stress due to temperature distribution were estimated using ANSYS. Based on the results, the safety of liquid hydrogen storage tanks was discussed. It was inferred that the emissivity of the outer material of the tank and the safety distance between liquid hydrogen storage tanks and gasoline dispensers should be less than 0.2 and more than 8.5 m, respectively, to protect the liquid hydrogen storage tank from the gasoline pool fire. To reduce the safety distance, several measures are required, e.g. additional thermal shields such as protective intumescent paint and water sprinkler systems and an increased slope to lead gasoline off to a safe domain away from the liquid hydrogen storage tank.

Abbreviations: FCV, fuel cell vehicle; HAZID, hazard identification study; CE, cold evaporator; FDMA, Japan Fire and Disaster Management Agency of the Ministry of Internal Affairs and Communications; TRACE, Toxic Release Analysis of Chemical Emissions; R.T., room temperature.

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Introduction

Hydrogen has been considered a promising energy carrier from the viewpoint of reduction in carbon dioxide emissions and efficient storage and transportation of energy. Moreover, hydrogen could be produced using renewable energy sources such as wind or solar energy, in which case it is referred to a renewable hydrogen or green hydrogen [1].

One of the rising technologies that utilize hydrogen is the fuel cell vehicle (FCV). A Japanese motor corporation has been selling commercial FCVs since December 2014, and other companies are poised to enter the FCV market as well. Therefore, it is necessary to establish hydrogen infrastructure, particularly hydrogen fueling stations. Specific safety measures and over-conservative approaches might increase the operational costs considerably. Thus, to make hydrogen fueling stations more economical, it is necessary to optimize these safety measures.

Many researchers have conducted risk assessments and analyses with respect to hydrogen fueling stations [2–20]. However, the characteristics of these stations differ depending on the country and location. Because each country has its own regulations regarding the construction and operation of hydrogen fueling stations, the availability of national spaces might determine the size of the stations. As Japan has limited space, multiple-energy-fueling stations, which can supply a few types of energy such as gasoline, CNG, and hydrogen, could ensure the efficient utilization of space.

Nakayama et al. identified three worst-case scenarios in a Japanese hybrid hydrogen–gasoline fueling station through hazard identification study (HAZID) [21]: (i) A massive gasoline pool fire forms at a gasoline dispenser, and the cold evaporator (CE) is damaged by thermal radiation. Large amounts of hydrogen then leak from the damaged CE area and ignite. Eventually, a catastrophic hydrogen explosion occurs. (ii) A massive kerosene pool fire forms at a kerosene dispenser, and the CE is damaged by thermal radiation. Large amounts of hydrogen then leak from the damaged CE area and ignite. Eventually, a catastrophic hydrogen explosion occurs. (iii) A liquid hydrogen trailer crashes into a gasoline tank truck while moving in the station. Large amounts of liquid hydrogen then leak from the trailer and ignite. Eventually, a fatal hydrogen explosion occurs. The present paper focuses on scenario (i); scenarios (ii) and (iii) will be discussed in a later paper.

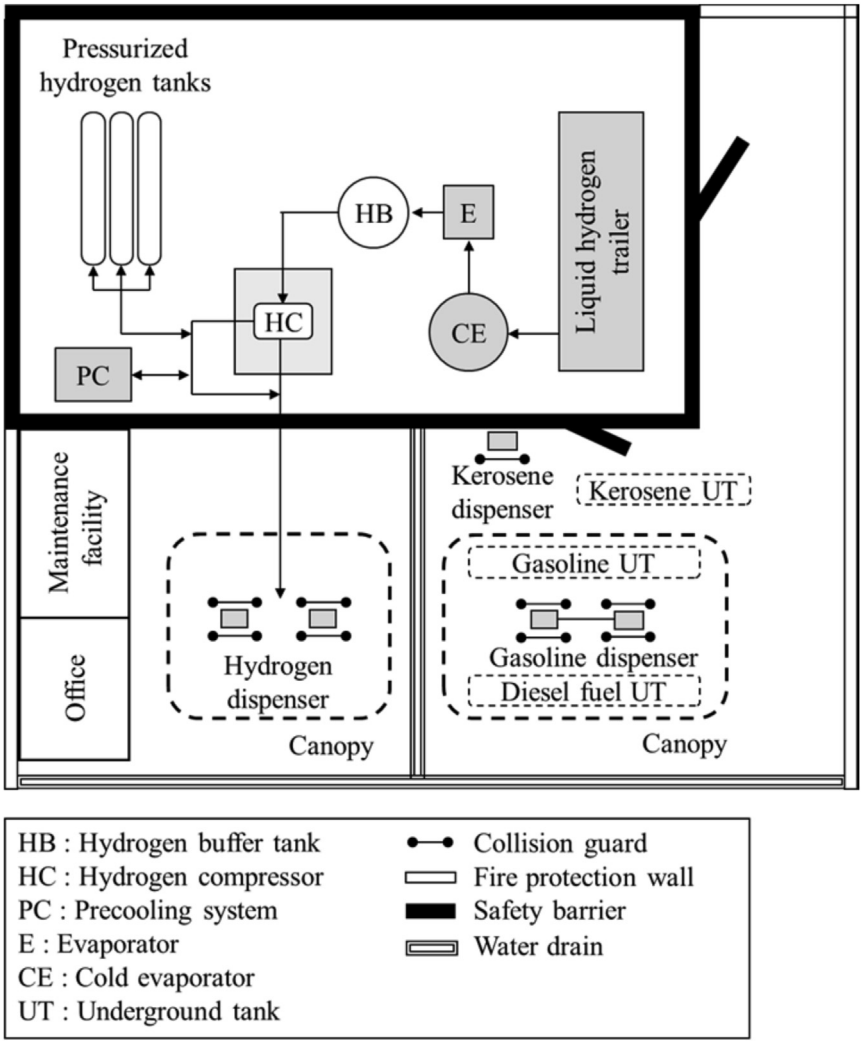

Fig. 1 – Layout of hybrid station with gasoline and liquid hydrogen supply systems [21].