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The qualitative risk assessment of an electrolytic hydrogen generation system

Naoya Kasai [a,*], Yuki Fujimoto [b,1], Ikuya Yamashita [c,2], Hisashi Nagaoka [c,2]

[a] Yokohama National University, 79-5 Tokiwadai, Hodogaya-ku, Yokohama, 240-8501, Japan
[b] Japan Industrial and Medical Gases Association, Success Shibadaimon Building, 2-8-13 Shibadaimon, Minato-Ku, Tokyo, 105-0012 Japan
[c] Honda R& D Co., Ltd., 4630, Oaza Shimo-Takanezawa, Haga-Machi, Haga-gun, Tochigi-ken, 321-3321 Japan

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ABSTRACT

A risk assessment for an electrolytic hydrogen generation system was carried out. The potential accident scenarios for the system were evaluated with a hazard and operability study (HAZOP) and failure mode effect analysis (FMEA). Brainstorming sessions were conducted to evaluate the possibility of each potential accident scenario. In the severity analysis for each potential accident scenario, the jet flame length was estimated based on an empirical formula using reference data. The blast pressure was mainly estimated by using the results of the reference. The risks of all potential hazards with and without the implementation of various safety measures were analyzed using risk matrices. It is clear that with the safety measures in place, the risk levels of all system hazards are acceptable.

Introduction

Global environmental issues such as global warming have led to an urgent need to transition to a "hydrogen society." By employing H_2 as an energy carrier, electricity can be generated in power stations or fuel cell vehicles without the emission of CO_2. However, H_2 is potentially hazardous due to its wide explosion limit range and low ignition energy. Moreover, because H_2 is the smallest molecule, it easily leaks from sealing parts such as valves and flanges. H_2 is generated from water or hydrocarbons using various processes such as water electrolysis. In water electrolysis method, H_2 is typically generated under high pressure conditions to improve the efficiency, so that risk assessment is required for safe use of the equipment.

Numerous studies on the various risks associated with H_2 use have been carried out, including those focused on hydrogen fueling stations [1–21], unintended release of H_2 [22–24] and H_2 jet flames [25,26] and the H_2 concentration layer adjacent to the celling [27–29].

Based on the configurations and specifications of the prototype system, the configurations and specifications of the system of electrolysis process of water for the analysis of the

* Corresponding author. Tel.: +81 45 339 3979; fax: +81 45 339 4011.
E-mail address: n-kasai@ynu.ac.jp (N. Kasai).
[1] Tel.: +81 3 5425 2255; fax: +81 3 5425 2256.
[2] Tel.: +81 28 677 3311.
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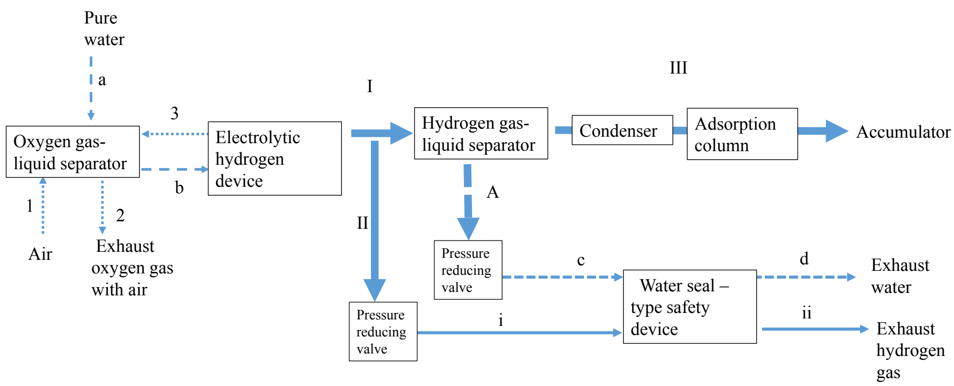

Fig. 1 – Configuration of the high pressure hydrogen gas generation system with electrolyzer. In Fig. 1, solid lines and Roman numerals are used for the H_2 piping, and thick dotted lines and small letters are used for the water piping. Thin dotted lines and Arabic numerals are used for the piping carrying O_2 or air. Bold lines and capital letters indicate piping in which the pressure is 82 MPa.

study was considered. To contribute to develop a regulation of electrolytic hydrogen generation systems, authors carefully built the system for the analysis based on the prototype system so that it can represent various electrolytic hydrogen generation systems. The H_2 inventory of the system for the analysis was intentionally made larger than that which would be used in the prototype system. A hazard and operability study (HAZOP) and failure mode effect analysis (FMEA) were carried out on an electrolytic hydrogen generation system arranged for the study. Potential accident scenarios were then analyzed. The risk level of each scenario with and without the implementation of various safety measures was evaluated.

Method and material

Electrolytic hydrogen generation system

The configuration of the electrolytic H_2 generation system considered in this study is shown in Fig. 1. Each piping line generally has a pressure indicator and a filter to remove impurities. The biggest advantage of this system is that, in contrast to conventional systems, the H_2 pressure can be increased to 82 MPa without the use of a compressor, while the O_2 is maintained at atmospheric pressure.

Table 1 shows the specifications of the various types of piping employed in the system. As shown in Fig. 1 and Table 1, the O_2 gas–liquid separator supplies pure water to an electrolytic H_2 generation device and exhausts the O_2 returned from the device. A H_2 gas–liquid separator, a condenser, and an absorption column enhance the purity of hydrogen by removing moisture from the H_2 gas. Then, H_2 gas flows to the accumulator at a pressure of 82 MPa. A water seal-type safety device is used to safely exhaust H_2 gas. The total H_2 inventory in piping I and II is 40 Nm^3 and that of piping III, including the devices, is 700 Nm^3. Under normal conditions, piping i and ii do not contain H_2. When an accident occurs, the 82 MPa H_2 gas is vented through the piping in the direction II → i → ii. Similarly, water with 82 MPa is vented through the piping in the direction A → c → d. Each piping line that handles high-pressure fluids is equipped with safety measures such as a safety valve and a pressure indicator. The entire system

Table 1 – Specifications of piping used in the system. Roman numerals, small letters, Arabic numerals and capital letters indicate the piping of Fig. 1, respectively.

Piping system	Contents of piping	Pressure [MPa]	Hydrogen inventory [Nm^3]	Configuration
1	Air	0.1	–	Check valve included
2	Oxygen gas		–	Vent line
3	Oxygen gas		–	Safety valve and shut-off valve included
a	Water		–	Check valve included
b	Water		–	Check valve and shut-off valve included
c	Water	0.9	–	Safety valve included
d	Water	0.1	–	Shut-off valve included
i	Hydrogen gas	0.5	Small amount	Shut-off valve included
ii	Hydrogen gas	0.1	Small amount	Vent line
I	Hydrogen gas	82	40	Check valve and safety valve included
II	Hydrogen gas			Vent line
III	Hydrogen gas		700	Back pressure valve, check valve, and safety valve included
A	Water			Back pressure valve included