Current state of the construction of an integrated test facility for hydrogen risk

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1. Introduction

Experimental research on hydrogen as a combustible gas is important for an assessment of the integrity of a containment building under a severe accident. The Korea Atomic Energy Research Institute (KAERI) is preparing a large-scaled test facility, called SPARC (SPray-Aerosol-Recombiner-Combustion), to estimate the hydrogen behavior such as the distribution, combustion and mitigation [1 and 2]. This paper introduces the experimental research activity on hydrogen risk, which was presented at International Congress on Advances in Nuclear Power Plants (ICAPP) this year [2].

2. Methods and Results

A test facility was designed to simulate the expected situations in a severe accident described below:

(1) Thermal hydraulic conditions: There will be complex phenomena in the containment atmosphere because an amount of steam with high temperature will be released into a containment building.

(2) Hydrogen behavior: Hydrogen released into the containment atmosphere will mix with steam and air, and there will be the distribution of hydrogen concentration, which can cause hydrogen combustion. In addition, a hydrogen mitigation facility such as a Passive Autocatalytic Recombiner (PAR) can significantly affect the thermal hydraulic conditions as well as the hydrogen concentration.

2.1 Test matrix

Firstly, the thermal hydraulic tests will be conducted to measure the performance of SPARC, and then the hydrogen behavior such as the distribution and combustion will be observed to control the experimental conditions for validating the Korean PAR in the SPARC vessel for some years ahead.

2.2 SPARC test facility

SPARC consists of a pressure vessel and an operating system to control thermal hydraulic conditions in a pressure vessel as shown in Fig. 1 [1 and 2]. A cylindrical pressure vessel has a 9.5 m height and 3.4 m in diameter, and is scaled to observe the convection flow and gas distribution induced by the natural convection in a containment building. The total volume of a pressure vessel is 80 m^3 and design pressure is 1.5 MPa at 453 K. A pressure vessel of SPARC made by stainless steel 316L, which has good corrosion resistance for a large-sized pressure vessel with several flanges [1].

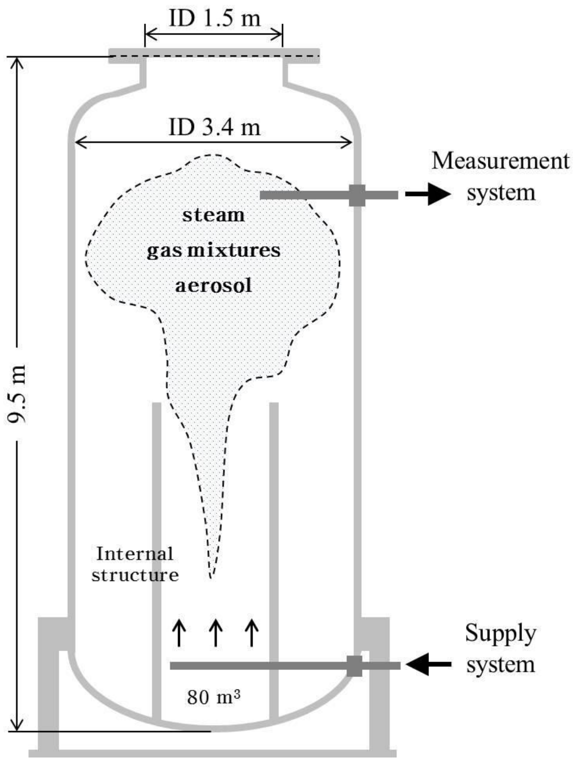

Fig. 1. Conceptual design of SPARC [1 and 2].

The outer wall of a vessel has guiding panes for the heat transfer oil flow to control the wall temperatures. Long flat bars with a 25 mm width and 12 mm thickness as guiding panes were welded on the outer surface of a vessel as shown in Fig. 2. A cylindrical jacket with 3.5 m in inner diameter was put on flat bars, and the top and bottom sides of a jacket were then welded with a vessel, i.e., the double walls for heat transfer fluid flow were constructed. The main cylindrical shell of a vessel was separated by three double walls and the top and bottom head of a vessel also has their own double wall. There is an inlet and outlet nozzle in each jacket and no flow path of heat transfer fluids between the five jackets.

Atmospheric temperature in a vessel can be handled by the temperature control systems. To increase the wall temperature of a pressure vessel, an inlet and outlet nozzle of each jacket is connected with the temperature control systems consisting of a heat exchanger and oil pump to make a closed loop for heat transfer oil flow.

Fig. 2. Guiding panes welded on a pressure vessel [2].

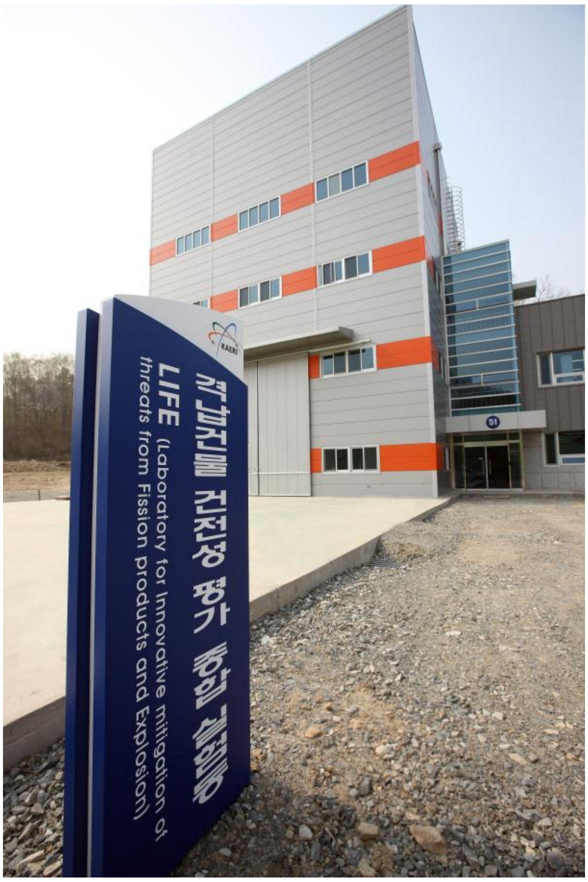

Fig. 3. Experimental building.

Oil having an increased temperature circulates through a jacket, and then returns to a heat exchanger. The wall temperature of a vessel is measured by a thermocouple at various positions. Atmospheric temperature in a pressure vessel is measured by a profile probe, which includes several thermocouple junctions in a sheath along an axis. The gas supply system injects air, nitrogen, helium, and hydrogen into a vessel, where a gas mixture in a vessel will be sampled by gas analyzers to measure the local volume concentration of hydrogen and oxygen. Pressure is measured by the pressure transmitters, and safety relief valves are installed on the top of a vessel. Pipe lines for the control, measurement, and supply system connects through 50 nozzles installed at various locations of the SPARC vessel wall.

2.3 Experimental building

The experimental building, called LIFE (Laboratory for Innovative mitigation of threats from Fission products and Explosion), was constructed for SPARC at the KAERI site, as shown in Fig. 3. The experimental area is 480 m^2 and the building height is 18.6 m, where a free volume above SPARC is 4320 m^3 and there is a natural ventilation system on a building roof for the safety from a hydrogen test. A crane to lift up to 5 tons was installed on the top of the building.

3. Conclusions

The KAERI is preparing a test facility, called SPARC (SPray-Aerosol-Recombiner-Combustion test facility), for an assessment of the hydrogen risk. In the SPARC, hydrogen behavior such as mixing with steam and air, distribution, and combustion in the containment atmosphere will be observed. The SPARC consists of a pressure vessel with a 9.5 m height and 3.4 m in diameter and the operating system to control the thermal hydraulic conditions up to 1.5 MPa at 453 K in a vessel. The temperature, pressure, and gas concentration at various locations will be measured to estimate the atmospheric behavior in a vessel. To install the SPARC, an experimental building, called LIFE (Laboratory for Innovative mitigation of threats from Fission products and Explosion), was constructed at the KAERI site. LIFE has an area of 480 m^2 and height of 18.6 m, and it was designed by considering the experimental safety and specification of a large-sized test facility.

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