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Current state of the construction of SPARC test facility for observing hydrogen's behavior

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1. Introduction

Under a severe accident, the behavior of the atmosphere in a closed containment building can significantly affect the integrity of a containment building as the last defense barrier. In particular, hydrogen released into a containment building can mix with air, i.e. a flammable mixture exists in the containment. Hydrogen combustion can make a dynamic load, which can cause severe damage to a structure or facility. Many studies on hydrogen behavior, such as distribution, combustion and mitigation, have been conducted since the TMI accident, and they were recently summarized in [1]. A large-scaled experimental facility is required for simulating the complex severe accident phenomena in a closed containment building. We are preparing the test facility, called the SPARC (Spray, Aerosol, Recombiner, Combustion), to resolve the international open issues regarding hydrogen risk as well as the validation of the Korean PAR (Passive Auto-catalytic Recombiner). This paper summarized the previous study submitted to the NUTHOS-11 [2], which introduced the SPARC test facility.

2. Methods and Results

2.1 Test Facility

The SPARC test facility was designed to simulate the various situations expected during a severe accident described below:

(1) Complex thermal hydraulic condition: An amount of steam and a gas mixture with high temperature will be released into the containment building.

(2) Potential for combustion: Hydrogen released into the containment atmosphere will mix with air and steam.

(3) Operation of the safety system: Spray, cooling fan, and hydrogen mitigation facilities, such as PAR and an igniter, can affect the atmosphere behavior, which depends on the thermal hydraulic conditions.

(4) Aerosol behavior: Vapor including the fission products can be generated from a pool at the saturation temperature in the containment.

We are preparing the SPARC test facility for an assessment of the containment integrity under a severe accident. Firstly, we have commissioned the SPARC test facility to estimate the performance of the control and measurement systems. Secondly, a gas mixing and stratification test will be conducted using helium as a substitute for hydrogen. We will observe the erosion of a stratification surface of helium owing to the vertical jet flow. The gas analysis system will measure the volume concentration of helium at various positions in time. In addition, the jet flow will be evaluated using a PIV (Particle Image Velocimetry). We will carry out a hydrogen combustion test, and then validate the performance of a PAR manufactured by Korea. The SPARC test facility consists of a pressure vessel and the control and measurement systems, as shown in Fig. 1. The following chapters, 2.2 through 2.4, introduce the main components in detail. Chapter 2.5 shows the commissioning test results of the SPARC.

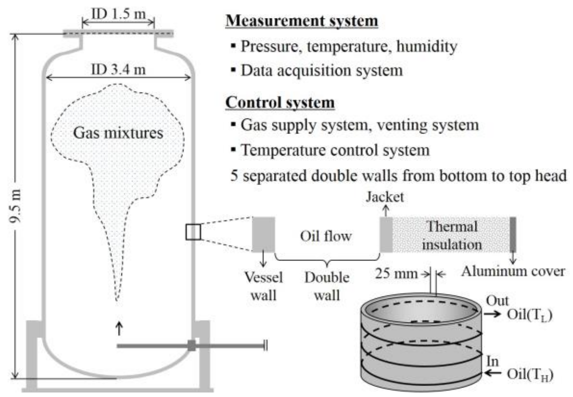

Fig. 1. Conceptual SPARC test facility [2].

2.2 SPARC vessel

A cylindrical pressure vessel has a 9.5 m height and 3.4 m diameter. It 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 the design pressure is 1.5 MPa at 180° C. Figure 2 shows a SPARC vessel made by stainless steel 316L.

The outer wall of a vessel has guiding panes for the circulation of the heat transfer oil to control the wall temperatures. 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, as shown in Fig. 2.

2.3 Control Systems

To increase the wall temperature of the SPARC, each of five jackets was connected with the temperature control system consisting of a heat exchanger and oil pump to circulate the heat transfer oil (Super Therm 300, SK). A heat exchanger includes an electric heater (50 kW) immersed in oil. The heat transfer oil having the desired temperature flows through a jacket, and then returns to a heat exchanger. The gas supply system can inject various gases such as air, nitrogen, helium, and hydrogen into a SPARC vessel.

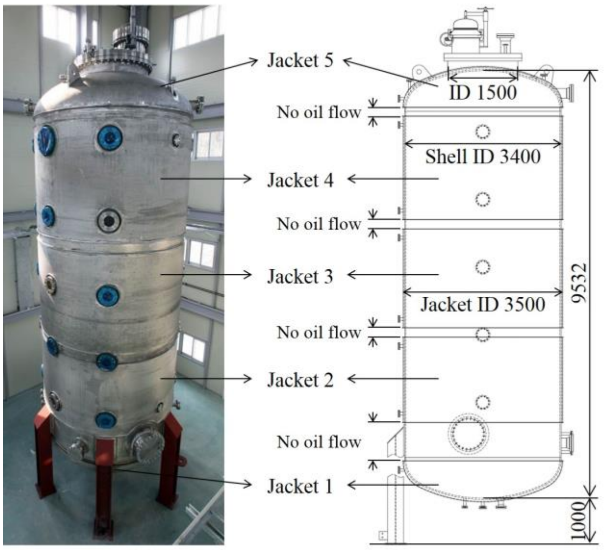

Fig. 2. SPARC vessel and jackets [2].

2.4 Measurement Systems

The inner wall temperature of a SPARC vessel will be measured by the forty-eight K-type thermocouples (CO3-K, OMEGA). The outer wall temperature was measured to estimate the heat loss from a vessel to the outside environment. The atmospheric temperature in a SPARC vessel was measured by a profile probe, which includes six thermocouple junctions in a sheath 1800 mm in length. The pressure of a SPARC vessel was measured using the two pressure transmitters (PA-33X, Keller) with the accuracy of 0.03 bar.

A gas mixture of air, steam, and hydrogen will be sampled by the hydrogen analysis device (FTC 300, Messkonzept) and the oxygen analysis device (PMA 1000, M&C). The volume concentration of hydrogen can be measured by the thermal conductivity method. The thermal conductivity of a gas mixture will increase with the increment of the hydrogen concentration. The hydrogen analysis device measures the heat transfer rate of a sampled gas, and then converts into the volume concentration of the hydrogen.

2.5 Commissioning Test

We controlled the pressure of a SPARC vessel using the air supply. It took about 8,400 seconds to increase up to about 5 bar. The compressed air at about 27° C was supplied as about 2.4 kg/m during the pressure rise. Figure 3 shows the atmosphere temperatures at the various locations of a SPARC vessel. The increment rate of the atmosphere temperature is about 34° C/h from room temperature to 100° C.

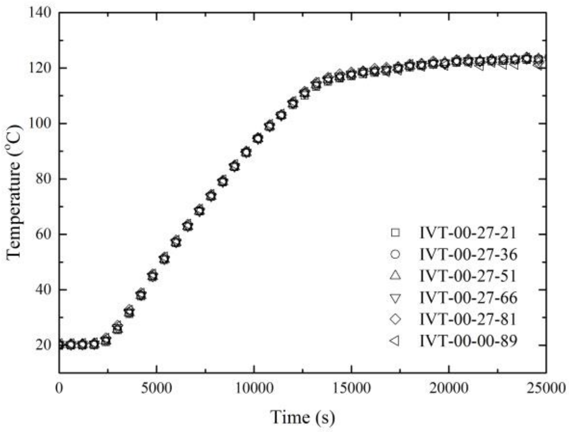

Fig. 3. Temperature control of the SPARC test facility [2].

3. Conclusions

KAERI (Korea Atomic Energy Research Institute) is preparing a test facility, called the SPARC for an assessment of the containment integrity under a severe accident. In the SPARC test facility, the hydrogen behavior such as mixing with steam and air, distribution, and combustion will be observed under various thermal-hydraulic conditions. We will carry out the performance tests of the safety systems such as the spray, cooling fan, PAR, and igniter. The SPARC test facility consists of a pressure vessel with a 9.5 m height and 3.4 m diameter, and an operating system to control and measure the thermal hydraulic conditions. The wall temperature of a SPARC vessel can be controlled by circulating heat transfer oil through jackets installed separately from the bottom to the top. In a commissioning test, we verified the controllable thermal conditions. It took about 8,400 seconds to increase up to 5 bar. The increment rate of the atmosphere temperature is about 34° C/h from room temperature to 100° C. The following test is the gas mixing and stratification using helium. We will observe the erosion of the stratification surface of helium owing to the vertical jet flow.

ACKNOWLEGMENTS

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