Design of a Visualization Device for the Study of Sulfuric Acid Flow Boiling

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1. Introduction

Recently, the demands of hydrogen energy have increased as an alternative energy resource to solve problems such as energy security, global warming and depletion of fossil fuels. Hydrogen offers significant possibility as a future energy resource, particularly in economical and environmental views of society. Accordingly, many countries have actively researched development of the hydrogen production.

A nuclear hydrogen production system using a Very High Temperature gas cooled nuclear Reactor (VHTR) with sulfur-iodine (SI) thermo-chemical cycles, which is one of the various methods of hydrogen production, is being developed in Korea Atomic Energy Research Institute [1].

The SI thermo-chemical cycles are process of hydrogen production without CO_2 emission by decomposition of water using heat energy of high temperature. The SI process was split into three procedures; Bunsen reaction procedure, H_2SO_4 decomposition procedure, HI decomposition procedure.

In these processes, the sulfuric acid decomposition is critical issues for the material corrosion on high temperature and pressure condition. To simulate the sulfuric acid decomposition, Hong et al. designed a sulfuric acid loop with a small-scale gas loop which is simulated for the integrity and feasibility tests on a H_2SO_4 decomposition process [2].

In the sulfuric acid decomposition process, the boiling heat transfer phenomena of sulfuric acid with a mixture gas differ from those of single-phase gas [3]. In this study, we discussed the design for the visualization of the sulfuric acid boiling flow pattern and heat transfer phenomena in simple geometry of sulfuric acid loop under atmosphere pressure condition.

2. Loop Design

2.1 Small-scale Gas Loop

The small-scale gas loop is shown in Figure 1. The gas loop consists of the primary loop with nitrogen gas and secondary loop for the H_2SO_4 decomposition.

The primary loop is composed of a pre-heater, a main heater, gas circulator, process heat exchanger, water tank, nitrogen supply system. The outlet temperature of pre-heater and main heater is to 500°C and 1000°C, respectively. The boundary conditions of the primary loop are tabulated in Table 1.

Table 1. Boundary conditions

	Primary	Secondary
Working Fluid	Nitrogen	Sulfuric acid
Design Temperature	1000 °C	950°C
Design Pressure	4~6 MPa	1.0 MPa
Mass Flow	2.0 kg/min	1.0 kg/min

The secondary sulfuric acid (H_2SO_4) loop consists of a pre-heater (sulfuric acid evaporator), sulfuric acid decomposer, a process heat exchanger, a SO2 trap, a H_2SO_4 collector, a separator, a H_2SO_4 storage tank, a H_2SO_4 supply pump as shown in Figure 2 [4]. Cold liquid sulfuric acid is supplied from a H_2SO_4 storage tank via pump to pre-heater (sulfuric acid evaporator). Liquid sulfuric acid via pre-heater, sulfuric acid decomposer is heated to 500°C. The heated sulfuric acid decomposes into H_2O and SO_3 before it enters a process heat exchanger. As the acid passed over a process heat exchanger, SO_3, which is transferred heat from nitrogen gas of primary loop, is dissolved into SO_2 and O_2. The emitted gas from the process heat exchanger is a gas mixture with SO_3, SO_2, H_2O, O_2. Then, the mixed gas flow into the separator and sulfur trioxide in mixture gas combines with water vapor to form liquid sulfuric acid. Liquid sulfuric acid flows into the sulfuric acid collector. Sulfur dioxide in the gas mixture is trapped in the SO_2 trap system using NaOH solution. The oxygen, which occurs in the SO_2 trap system, is released to the atmosphere via filter system.

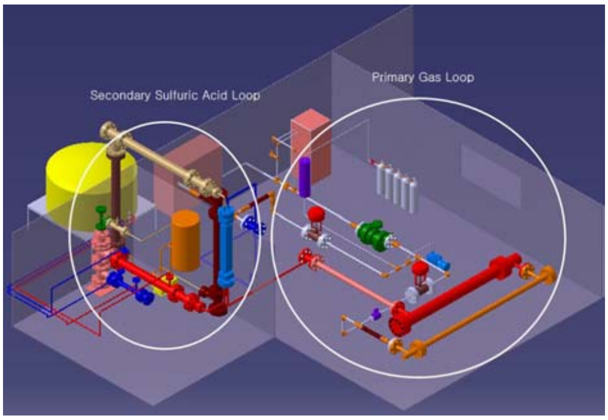

Fig. 1. Schematic diagram of the small-scale gas loop

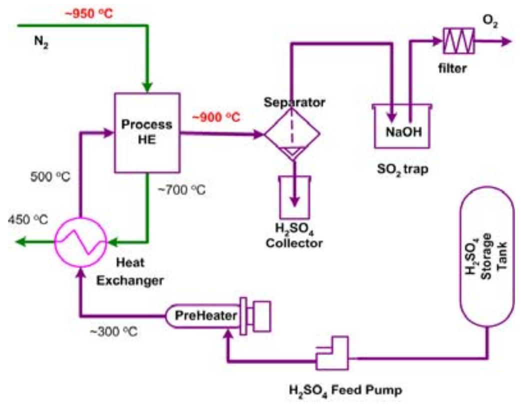

Fig. 2. Schematic of sulfuric acid loop

2.2 Visualization Test Loop

The visualization test devices of sulfuric acid flow boiling is shown in Figure 3. The test loop will be installed as the simulation system for the study of the characteristics and visualization of a sulfuric acid boiling heat transfer phenomena.

The test section for the simulation consists of four parts; three quartz tube, coil heater, inlet plenum, outlet plenum. The geometry data of sulfuric acid flow boiling test loop is shown in Table 2. The material of test section tube is used by quartz and the diameter and length is 1240 mm and 14 mm, respectively.

The quartz heater is heated by indirect heating system using coil heater. The coil heater is selected to be heated on the quartz surface as shown in Figure 3. The heated section of quartz tube is heated by 80 mm from inlet plenum and the rest of the quartz tube without a heater is unheated. The measurement of temperature distribution in test loop is used by K type thermocouple with gold coating.

Table 2. Geometry of test loop

Material	Quartz
Tube Length	1240 mm
Tube Diameter	14 mm
Number of Tube	3 EA

Fig. 3. Schematic of visualization test loop

3. Conclusions

We designed a visualization test loop for the flow boiling heat transfer phenomena of a sulfuric acid. The design of the test loop can simulate the various test conditions for the study of sulfuric acid boiling under atmosphere conditions.

In the future, the visualization test system for the measurement of heat transfer coefficient will require a facility for sulfuric acid loop under high temperature and high pressure.

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REFERENCES

[1] J. H. Chang et al., A study of a Nuclear Hydrogen Production Demonstration Plant, Nuclear Engineering and TECHNOLOGY, Vol.39, No.2, pp. 111-122, 2007

[2] S. D. Hong et al., A High Pressure and High Temperature Sulfuric Acid Experimental System, Proc. KNS Autumn Meeting, 2008.

[3] H. Noguchi et al., Experimental Results of Sulfuric-Acid Flow Boiling, Atomic Energy Society of Japan, Vol. 6, No.1, p.1-4, 2007, in Japanese.

[4] S. D. Hong et al., Development of a Compact Nuclear Hydrogen Coupled Components (CHNCC) Test Loop, ANS Embedded Topical Meeting: ST-NH2, Boston, MA, USA, p. 215, June 24-28, 2007.