

Design of a Visualization System of Flow Boiling in a Vertical Tube with a Sulfuric Acid

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1. Introduction

The demands of hydrogen energy are growing interest in using alternative energy to fossil fuel. Hydrogen offers many opportunities as one of future clean energy in economical and environmental issues. Many researchers have actively studied development of the hydrogen production.

Very High Temperature gas cooled nuclear Reactor (VHTR), which was coupled with Sulfur-Iodine (SI) thermo-chemical cycle, has been selected for the Nuclear Hydrogen Development and Demonstration (NHDD) project in Korea Atomic Energy Research Institute [1].

Kim et al. [2] are developing a hybrid heat exchanger as a Process Heat Exchanger (PHE) for the sulfur trioxide decomposition. Hong et al. [3] constructed a small scale sulfuric acid loop for the performance tests.

In this study, we discussed the design for the visualization system of flow boiling in a vertical single tube under atmosphere pressure condition.

2. Methods and Results

2.1 Small Scale Sulfuric Acid Loop

A small scale sulfuric acid (H_2SO_4 96 %wt) loop consists of a H_2SO_4 storage tank, a H_2SO_4 feed pump, a sulfuric acid evaporator and decomposer, a process heat exchanger (PHE), a high temperature cooler, a separator, a SO_2 trap, a low temperature cooler, and a H_2SO_4 collector as shown in Figure 1 [3]. Liquid sulfuric acid of room temperature is supplied from a H_2SO_4 storage tank to the evaporator through the H_2SO_4 feed pump. Liquid sulfuric acid in the evaporator is raised from room temperature to 300 °C. The outlet temperature of superheater is reached up to 500°C. In the superheater, the evaporated sulfuric acid is dehydrolyzed into water vapor and sulfur trioxide (SO_3). In the PHE, the sulfur trioxide is decomposed into sulfur dioxide (SO_2) and O_2 . The mixed gas, such as SO_3 , SO_2 , H_2O , and O_2 , passes through the cooler and the separator. Sulfur dioxide

(SO_2) is trapped in the scrubber, and the oxygen is released to the atmosphere via filter system.

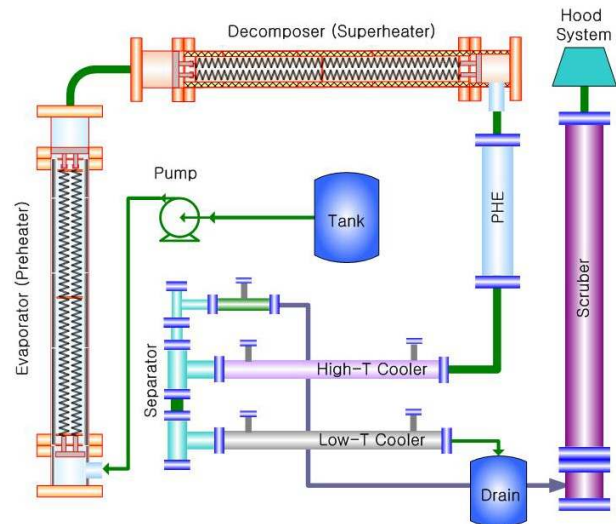


Fig. 1. Schematic Diagram of a Sulfuric Acid Loop

2.2 Design of a Visualization System

A visualization system of sulfuric acid flow boiling was designed [4] and modified design is shown in Figure 2. The modified visualization system was designed as the devices for study of a sulfuric acid flow boiling phenomena in a vertical single tube.

The devices consist of a quartz tube, mold heater set, test section, Hastelloy C-276 plate. The geometry is shown in Table 1. The single quartz tube used in a test section and the tube length and diameter is 2000 mm and 16 mm, respectively. High speed camera is used to visualize the flow boiling of sulfuric acid in the test section. The tube thickness is 2 mm. The heating system is used by fiber mold heater as shown in Figure 2. The length of fiber mold heater is 1500 mm and the test section is 200 mm. The material of inlet and outlet flange is selected to Teflon and Hastelloy C-276, respectively. The sealing method of flange is used by graphite grand packing. The maximum heater power is 7.5 kW.

The design condition is shown in Table 2. The design pressure is atmosphere and the design temperature is 500 °C. The working fluid is 96wt% liquid sulfuric acid. The mass flow of working fluid is 8cc/min.

Table 1. Geometry of test loop

Material	Quartz
Tube Length	2000 mm
Tube Diameter	16 mm
Tube Thickness	2 mm
Number of Tube	Single tube

Table 2. Design Condition

Design Pressure	Atmosphere
Working Fluid	96 wt% liquid sulfuric acid
Mass flow	8cc/min
Design Temperature	500 °C

3. Conclusions

We designed a visualization system for the flow boiling phenomena in a vertical single tube with sulfuric acid. We can figure out the following conclusions for the design of a visualization system of sulfuric acid flow boiling.

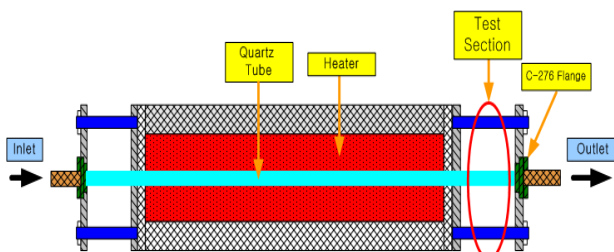
1. The visualization system can simulate the various test conditions for the study of sulfuric acid flow boiling in a vertical single tube.
2. The test section can visualize the scene through the high speed camera.

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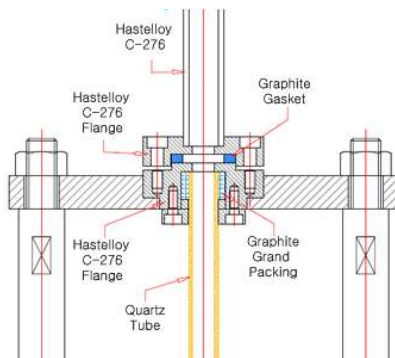
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(a) Layout



(b) Detail View of Hastelloy C-276 Flange

Fig. 2. Schematic Diagram of Visualization System