Very High Temperature Helium Experimental Loop (HELP)

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1. Introduction

Korea Atomic Energy Research Institute (KAERI) has developed the gas loops to develop and verify the key components of the nuclear hydrogen production system. At the present, KAERI is operating a small-scale gas loop for feasibility tests of process heat exchanger [1] and has constructed a very high temperature Helium Experimental LooP (HELP) for verification tests of scale-down prototypes for high temperature key components in Very High Temperature gas-cooled Reactor (VHTR).

Figure 1 presents the HELP assembled with the key components. Design [1] and operation [2] experiences with a small-scale gas loop provide the basic information for design and construction of HELP. This paper introduces the design and specifications of HELP.

Figure 1 Whole View of HELP

2. Helium Experimental Loop (HELP)

The primary goal of HELP is to maintain the component-level operation condition for the verification tests of scale-down key components for nuclear hydrogen production system. The size was designed for the verification test of a 150kW-intermediate heat exchanger or the simulation test in a 1/6 scaled down fuel block. The loop consists of the primary loop and the secondary loop. The primary loop and the secondary loop simulate VHTR and intermediate loop in nuclear hydrogen production system, respectively. The loops were designed to withstand the maximum temperature of 1000°C, the maximum pressure of 9.0 MPa, and the normal mass velocity of 0.5 kg/sec. The working fluid is helium as the actual coolant of VHTR. The primary loop is composed of a preheater, a high-temperature heater, a hot gas duct, intermediate heat exchangers, a water-cooled U-tube heat exchanger, a gas-bearing circulator, a passive venting system and gas filters. The secondary loop has the same system configuration as the primary loop except a high temperature heater. Two loops share a helium supply system, a helium purification system and the water loop for a cooling tower as Figure 2.

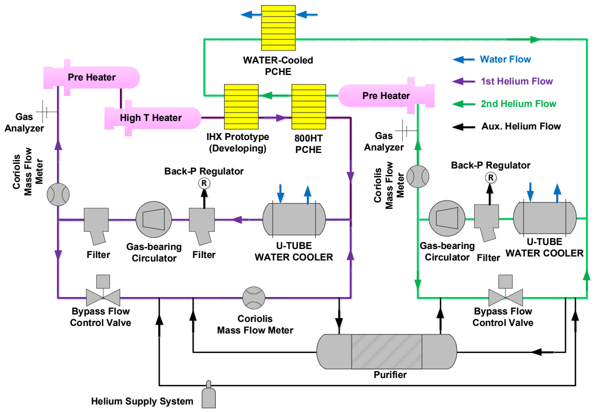

Figure 2 Schematic Diagram of HELP

The design outlet temperature of the preheater and the high temperature heater are 500°C and 1000°C, respectively. The maximum power of the heaters is 300 kW. The heated materials of the pre-heater and the high temperature heater are Inconel-600 and C/C composite whose design temperature is 850°C and 1600°C. The heated bodies are designed with a 3-phase Y-connection. The detail design was explained in Hong et al.[3] and Yoon et al.[4]. Figure 3 shows the schematic diagram of the high temperature heater in HELP. The heater power is controlled by SCR zero crossing control.

HELP has two water-cooled U-tube heat exchanger and two printed circuit heat exchanger (PCHE) for cooling the helium flow. Two U-tube heat exchangers are installed to maintain the inlet condition of the circulators in the primary and secondary systems, respectively. A 800HT PCHE is designed to make the operation condition for verification tests of a IHX prototype developed in the future. Especially, its circular and cubic channel [5] is designed to minimize the flow disturbance due to dust. A stainless steel PCHE is a water-cooler for cool the hot gas from the IHX prototype to temperature under 300°C. In the present, the printed circuit heat exchangers are installed for the high-temperature performance test of HELP.

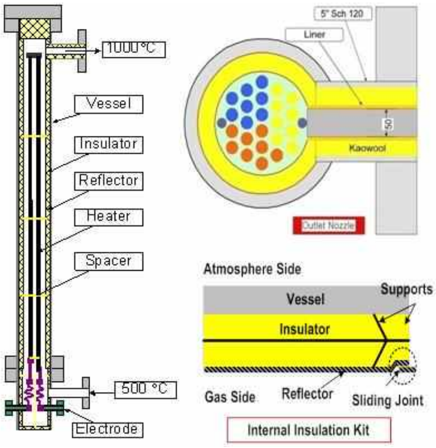

Figure 3 Schematic Diagram of High Temperature Heater

Gas-bearing type is selected as the circulator of HELP not to use the oil which is the source of C/C composite oxidation at the high temperature. Figure 4 shows the gas-bearing circulator. Its design pressure, design mass velocity, and compression ratio are 9.0 MPa, 0.5 kg/s (@4 MPa), and 1.04, respectively. The high speed squirrel-cage induction motor and internal water cooling jacket is selected for higher operation temperature than that of the circulator in the small-scale nitrogen loop [1]. A gas filter is installed at the inlet of the circulator to prevent solid particle ingress to the circulator internals. Especially, a gas filter is also installed at the outlet of the circulator to prevent metal particle from the circulator to the high temperature heater, because there is a probability that a eutectic alloy is formed by the metal particles from the gas bearing circulator and molybdenum liner in the high temperature heater.

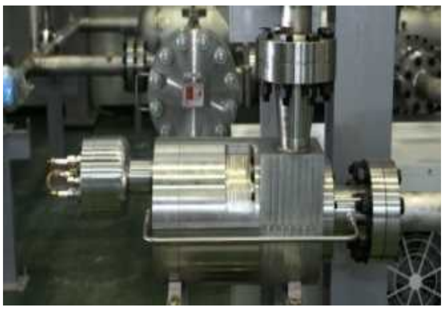

Figure 4 Gas Bearing Circulator

The control of gaseous impurities is necessary to prevent C/C composite heater and metal components from oxidizing at the high temperature condition. The important gaseous impurities are oxygen and steam. Oxygen and steam is Oxygen is removed through the Zr-Al 16 catalyst which commonly applies to helium or hydrogen gas purification in the level of ppb. Steam is adsorbed at the room temperature by GC-532 which is one of the molecular sieves GC-5A. Molecular sieves GC-5A are crystalline and highly porous aluminosilicate beads with pore openings of approximately 5. The purification system is installed at the bypass line to enable the operation temperature to be raised for the high temperature adsorption and catalyst. The design pressure and mass velocity are 6.0 MPa and 100g/m (@4 MPa), respectively. The target impurities are oxygen concentration under 1.0 ppm and absolute humidity under -110°C.

The scalable pressure transmitters produced by Rosemount Inc. were used to measure the pressure and differential pressure in HELP. The helium mass flow rate was measured through a U-tube coriolis mass flow meter produced by Micro Motion. There are many K-type thermocouples to measure the temperature at the various positions. Especially, two thermocouples with unequal diameters of 1/16 inch and 1/8 inch are used to correct the radiation bias error for hot gas temperature measurement [5].

3. Conclusion & Future Works

HELP was constructed to perform the verification tests for VHTR components. Its design specification was determined to give the component-level operation condition of VHTR components. Most of the key components in HELP were fabricated with domestic technology to advance the closed gas loop technologies in Korea.

In this year, the performance tests of HELP will be performed at high temperature and high pressure conditions. After HELP performance tests, IHX prototype tests will be carried out for the verification of IHX fabrication technologies.

ACKNOWLEDGMENTS

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