Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Purification System Configuration for a Small-Scale High Temperature Gas Loop

ChanSoo Kim[1]*, J. H. Kim[1], J. W. Oh[2], S. D. Hong[1], Y. W. Kim[1], W. J. Lee[1], Y. J. Shin[1], J. H. Chang[1]
[1]*Nuclear Hydrogen Project, Korea Atomic Energy Research Institute*
P.O. Box 105, Yuseong-gu, Daejeon, Korea, 305-353
*kcs1230@kaeri.re.kr
[2]*World Gas Tech, 535-9, Hakha-dong, Yuseong-gu, Daejeon, Korea*

1. Introduction

The principal function of a purification system is to bypass a working fluid from the primary loop, remove its chemical impurities and radioactivity, and return it to the primary system [1]. Especially, the chemical impurities in a working fluid are the main factor not only to decrease system ability but also to shorten the lifetime of the components and structures in the primary system.

Hong et al. [2] designed a small scale gas loop for simulating a VHTR (Very High Temperature Gas Cooled Reactor) and IS (Iodine-Sulfur) cycle for nuclear hydrogen generation. Especially, a high temperature gas heater is made with C&C composite vulnerable to oxidation with oxygen or steam at a high temperature condition. Purification system must be installed to maintain the C&C composite heaters. This paper introduces the design of purification system for the small scale gas loop to prevent high temperature heaters from oxidation.

2. Methods and Results

2.1 General System Configurations

Figure 1 is the schematic diagram of a general helium purification system. At first, the impurity particles are filtrated through the coal trap near the inlet of a purification system. In the oxidizer, hydrogen and carbon monoxide are oxidized into steam and carbon dioxide. The steam is condensed through a cooler. Carbon dioxide, methane, nitrogen oxide and condensed steam are adsorbed at the low temperature in a molecular sieve. Finally, nitrogen, oxygen, noble gas and others are adsorbed in a cryogenic activated carbon. Most helium purification systems [3-5] have similar designs to the configuration in Figure 1.

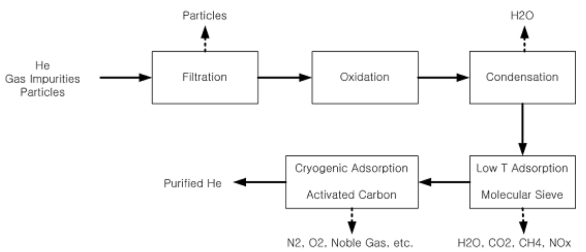

Figure 1 General Configuration of Helium Purification System

2.2 Nitrogen Purification System for the small-scale loop

A nitrogen purification system as shown in Figure 2 must be installed as the auxiliary system of the primary nitrogen system to maintain nitrogen's purity. Because this small scale loop doesn't have impurities as various as helium cooled reactor, the purification system design is simplified to remove only steam and oxide to prevent the C&C composite heaters from oxidation. Therefore, the following outlet requirements for this purification system are determined, based on those of the previous helium purification system [3-5].

- Oxygen concentration < 1.0 ppm
- Steam concentration < 1.0 ppm
- Design pressure during operation < 30 bar
- Design pressure during regeneration = 1 bar
- Design temperature during operation < 40℃
- Design temperature during regeneration < 400℃
- Pressure loss < 0.5 bar

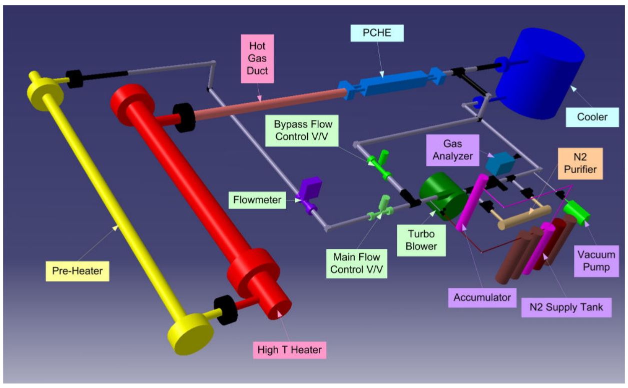

Figure 2 Small-scale Gas Loop

The nitrogen purification system is composed of molecular sieve for steam and getter metal for oxygen as shown in Figure 3. They can be regenerated during a few hours at a high temperature above 300℃, passing the argon gas including 4 % hydrogen.

Molecular sieve is a metallic alumina-silica crystalline of a three dimensional bonding between silica and alumina tetrahedrons. Adsorbed water can be removed during a high temperature heating, the uniform internals are constructed to selectively adsorb the molecules of a special size. In this system, the 13X molecular sieve is selected as the remover of steam.

This molecular sieve has usually been applied for gas drying and carbon dioxide removal.

Getter has a high chemical activity of a clean metallic surface which results in the chemical adsorption at the surface, forming stable compounds with the most gas molecules. In this loop, copper is used as oxygen getter. Copper is one of getters which can not adsorb nitrogen but can adsorb oxygen. Because general getters such as barium and zirconium can adsorb the most of gas molecules, they are not suitable in this nitrogen gas loop. In general, copper is the getter for no-steam and oxygen condition of a glove box.

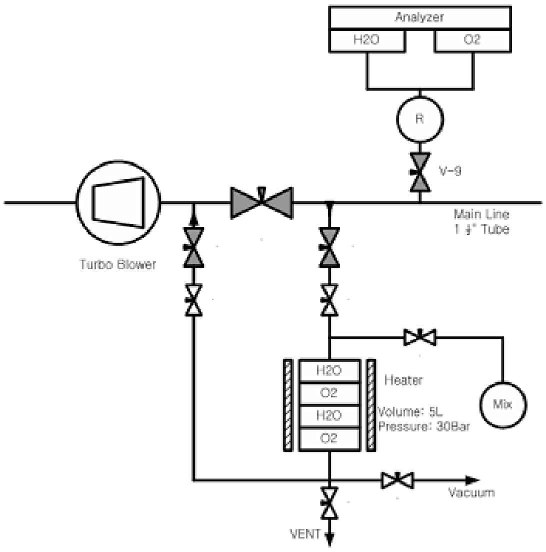

Figure 3 Configuration of Nitrogen Purification System

2.3 Operation Process and Adsorptive Capacity

The purification system is operated by the following processes to maintain the purity of nitrogen flow as:

1) Ensure that the nitrogen pressure in the primary loop is above 5 bar. When the pressure is lower than 5 bar, depress the primary loop by 1 torr through a vacuum system.
2) Pressurize the primary loop by 12 bar with high pure nitrogen (>99.999%)
3) Heat the main loop over 300℃ by operating heaters and circulator.
4) Detect the oxygen and steam concentration in the primary loop through a gas analyzer.
5) Operate the purification system with the suitable concentrations for the purification system. When impurity concentration is too large to operate the purification system, repeat 2)~4) after the heater off, cool-down and vacuum vent.
6) Close the valve between the main loop and purification system after the concentration is below 1.0 ppm. Maintain experimental conditions to the start tests.

Adsorptive mass of steam and oxygen per one operation of the purification system are evaluated from the conservative assumption where the humidity is 100% in the gas loop and kaowool insulator in the high temperature heater and a hot gas duct. All the mass values of nitrogen and oxygen are calculated from the ideal gas state equation. There is no special source for oxygen in the primary loop. Therefore, the purification system has the main objective of a gas drying. If the volume of this primary loop is 100 L, the removal steam and oxygen mass in the primary loop is 1.425 g and 0.034 g, respectively. Steam mass removed in the purification system is equal to the sum of the steam mass of the kaowool thermal insulator and the saturation condition at 1.0 torr. In this design, the capacity limit of the molecular sieve is 0.031 g H_2O/g molecular sieve at the room temperature (300 K). Installation mass of the molecular sieve is 2 kg which is large enough so as not to be anxious about its capacity limit.

3. Conclusion

The main impurities to adsorb in this loop are steam and oxygen to prevent the C&C heaters from oxidation. The results show that the design of this purification system is suitable to maintain the purity of nitrogen in the small scale gas loop. For a detailed design, the purification velocity must be evaluated from the isothermal adsorption curves

In the future, the purification system for a mid-scale helium loop will require a cooler, cryogenic activated coal, and a compressor for returning the helium gas to the primary loop.

ACKNOWLEDGMENTS

This study has been carried out under the Nuclear Research and Development Program supported by the Ministry of Science and Technology of Korea.

REFERENCES

[1] S. Strausberg, Helium Purification Subsystem Design Description, DOE-HTGR-86-103, GAT, 1987.
[2] S. D. Hong et al., Design of a Small Scale High Temperature Gas Loop for Process Heat Exchanger Design Tests, International Congress on Advanced Nuclear Power Plants, Reno, NV, USA, June 4-8, 2006.
[3] Y. Inagaki, et al., Cooling Performance of Helium Gas/Water Coolers in HENDEL, Nuclear Engineering and Design, Vol. 146, pp. 301-309, 1994.
[4] M. S. Yao, et al., The Helium Purification System of the HTR-10, Nuclear Engineering and Design, Vol. 233, pp. 163-167, 2002.
[5] N. Sakaba, et al., Short Design Descriptions of Other Systems of the HTTR, Nuclear Engineering and Design, Vol. 233, pp. 147-154, 2004.