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Thermal-hydraulic Analysis of a Small Scale High Temperature and High Pressure Gas Loop

Dong Seok Oh, Sung Deok Hong, Jong Ho Kim, Chan Soo Kim, and Yong Wan Kim
Korea Atomic Energy Research Institute, 150 Duckjin Yusung Daejeon Korea, dsoh1@kaeri.re.kr

1. Introduction

The construction work of a small-scale high temperature and high-pressure gas loop has been initiated in the beginning of last year as a series of the nuclear hydrogen production project. The loop consists of a primary loop and a secondary loop. The detail description of a loop is shown in reference 1. A primary loop would provide high temperature nitrogen more than the 950 °C under the 4 MPa pressure environments. The high enthalpy of nitrogen transfers the energy to the sulfur trioxide flowing through the secondary loop at the process heat exchanger (PHE) and the trioxide sulfur is divided into dioxide sulfur and oxygen. The objective of the loop is to provide the high pressure and temperature environment to development of a high performance PHE and the performance test of the material. The primary loop will be constructed until the end of February 2007.

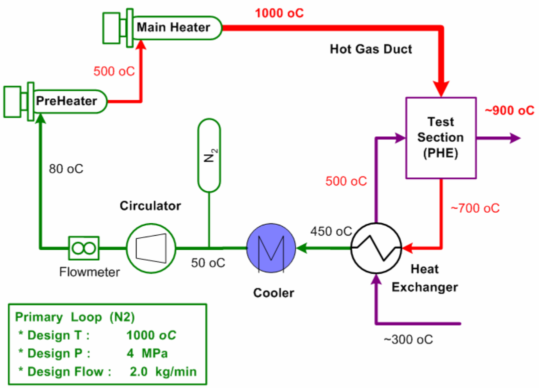

Figure 1. Schematic Diagram of Primary Loop

In this paper, we describe on the evaluation of the pressure loss in a primary loop and the basic design of the hot gas duct.

2. Pressure Loss Evaluation

The pressure drop data on the primary loop is needed as design input on the recirculator and as the basis data during detail design on the loop.

Table 1. Pressure Loss on Each Component

Component	Form Loss [Pa]	Friction Loss [Pa]	Componen t Loss (*) [Pa]	Fraction (**) [%]
HGD	178	181	359	1.3
Process HX	311	10200	10511	38.4
HX	246	7700	7946	29.0
Cooler	9	1470	1479	5.4
Flow Meter	4000	0	4000	14.6
Pre-heater	33	8	41	0.2
Main Heater	29	11	40	0.2
Piping	0	53	53	0.2
Elbow	90	2	92	0.3
Glove Valve	1316	0	1316	4.8
Gate Valve	1536	0	1536	5.6
Total	7748	19625	27373	100

(*); Form Loss + Friction Loss
(**); (Component Loss / Total Loss) * 100

The schematic diagram of primary loop is shown in Figure 1. The pressure loss coefficient is calculated by utilizing the models published in open literature of reference 2. Moody chart has been used to obtain the friction factor of the each component. The vendor provided us the pressure loss data on the flow meter [3]. The pressure loss of each component is shown in Table 1. The total pressure loss of a primary loop is 27 KPa. The pressure of PHE and heat exchanger, which is same geometry with the PHE, is more than half of the total pressure loss. The friction between fluid and the plate type heat transfer area produces the majority of the pressure loss in the PHE and the heat exchanger. The pressure loss of piping is negligible due to the low fluid velocity in a pipe. The loop pressure loss of 60 KPa is recommended as a design value of the loop in consideration of the uncertainty and the design flexibility.

3. Hot Gas Duct Design

Hot nitrogen gas is conveyed via the linear tube of the horizontal hot gas duct. Its one end connects to the main heater by a flange; the other end connects to the PHE by flange also. It consists of pressure vessel, thermal insulating fiber, a ceramic linear, flange, washer, and snap ring as shown in the Figure 2. The hot gas duct is a coaxial adiabatic duct with Kaowool fiver as insulating material between a pressure vessel and a ceramic linear. The inner diameter and wall thickness of ceramic linear are 27.6 mm and 3.5 mm, respectively. The outer diameter and the wall thickness of pressure vessel are 101.6 and 8.1 mm. The surface temperature of the pressure vessel is restricted to lower than 300 °C to maintain the integrity of pressure vessel at nominal operation. In order to compensate thermal expansion, one end of the ceramic liner is fixed by snap ring and the other end of the it is free end which can be freely move to adapt the thermal expansion. The ceramic liner is expanded to 8.5 mm at normal operating condition.

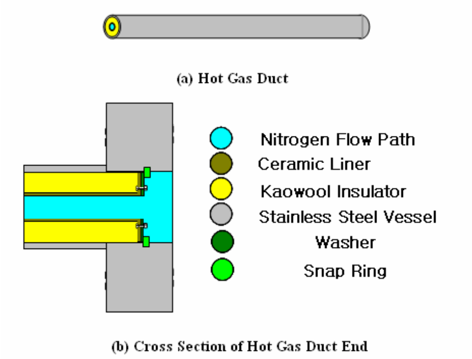

Figure 2. Configuration of a Hot Gas Duct

The hot gas directly contact with the inner wall of the flange. The heat of hot gas is conducted to the pressure vessel and outer surface of the flange. The conduction heat can increase the surface temperature of the pressure vessel. The k-type thermocouple is placed on the surface of the pressure vessel to monitor the surface temperature and a water jacket unit is placed outer surface of the pressure vessel contacting with the flange to accept the design requirement.

The thermal analyses is performed to obtain the heat loss and temperature distribution across the hot gas duct. We assume that the heat is not transferred through the axial direction but trough the radial direction. The pressure of the nitrogen gas system is close to be 4.0 MPa. The nominal nitrogen gas flow rate is 2 kg/min. The fluid temperature at inlet of the hot gas duct is 1000 °C. The thermal resistance of the nitrogen fluid flow, pressure vessel, insulator, ceramic liner, and convection and radiation in air is considered in the analysis. The thermal resistance of convection and radiation is parallel connected. The heat loss through the hot gas duct in 1 m length is 1.970 KW and the temperature of inner and outer surface of the pressure vessel is 285 and 282 °C, respectively. Therefore, the surface temperature of the pressure vessel can satisfy the design requirement.

4. Concluding Summary

The pressure loss of the primary loop has been evaluated by utilizing the pressure loss models published in open literature and the basic design of hot gas duct also has been performed. The results are summarized as follows;

1) The total pressure loss of the primary loop is estimated as 27 KPa. The pressure loss of the PHE and heat exchanger is more than half of the total pressure loss. The loop pressure loss of 60 KPa is recommended as a design value of the loop in consideration of the uncertainty and the design flexibility.
2) The surface temperature of the pressure vessel can satisfy the design requirement.

REFERENCES

[1] S. D. Hong, and D. S. Oh, W. J. Lee, J. H. Chang, Design of a Small Scale High Temperature Gas Loop for Process Heat Exchanger Design Tests, Proceedings of ICAPP' 06 Reno. NB USA, June 4-8, 2006

[2] I. E. Idelchik, Handbook of Hydraulic Resistance, 2nd Edition, Hemisphere Publishing

[3] Rheonik, Rheonik Flowmeter Summary, 2005. 8.