

## Hydraulic Analysis of a Small Scale Intermediate Heat Exchanger Test Loop

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### 1. Introduction

The construction work of a small scale intermediate heat exchanger (IHE) test loop has been initiated in the beginning of this year as a series of the high temperature gas reactor 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 900 Celsius degree under the 6 MPa pressure condition. The high enthalpy of nitrogen transfers the energy to the sulfur trioxide flowing through the secondary loop at the decomposer 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 decomposer and the performance test of the material is also very challengeable thing. The schematic loop diagram with the conception of equipment has been developed during this year. The pressure loss of the loop is needed as a specification of equipment purchase. In this paper, the pressure loss of a primary loop has been evaluated and a decomposer, a heat exchanger, and an air cooler geometry have been designed prior to hydraulic evaluation.

### 2. Heat Equipment Sizing

The decomposer, the heat exchanger, and the air cooler needs the capacity more than 10 KW which can be evaluated from the rate of energy stored inside the control volume including equipment. The decomposer and the heat exchanger are designed with identical dimension due to similar thermal capacity and the merit of manufacturing cost and the maintenance. The material of a decomposer will be made by silicon carbide can be endure sulfur environment. The heat sink is calculated for one dimensional geometry problem with the three layers of a nitrogen channel, a silicon carbide wall, and a trioxide sulfur channel. The channel of 150 mm width, 0.6 mm height, and 650 mm depth with 10 layers is reviled as the proper geometric dimension from the calculation. The nitrogen in primary side flows through 5 layers and the trioxide sulfur paths through lest the 5 layers. The capacity of decomposer is little lower than that of the heat exchanger. The difference of capacity is only due to the inlet and outlet condition discrepancy. If we use the finned channel instead of the pure channel, the thermal capacity will be increased and more compact

decomposers are designed. On the other side the pressure loss will be slightly increased.

The air cooler is designed with finned tube to increase cooling efficiency and also can be reduced pressure loss in the tube by using relative short tube comparing to the bare cooling tube. The air cooler is designed to pass through the small diameter finned tube cooled by forced convection from outside the fin with  $200 \text{ W/m}^2 \text{ K}$  of the heat transfer coefficient. The 20 mm diameter tube with 2 m length is selected as the air cooler tube. The 50 mm fin diameter, 1 mm fin thickness, and 2 mm pin pitch is selected as the fin dimension. The cooling capacity of the air cooler is 16 KW.

### 3. Pressure Loss Evaluation

The primary loop pressure drop is needed as design input of the compressing recirculator.

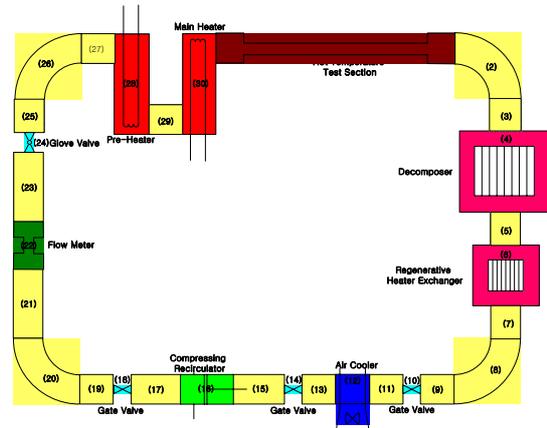


Figure 1. Schematic Diagram of Primary Loop

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. The models used for the calculation are shown in the Table 1. The friction factor is calculated by the Moody chart. The pressure loss of the flow meter is provided by the manufacturer [3].

The pressure loss of each component is shown in Table 2. The total pressure loss of a primary loop is 60 KPa. The pressure loss of a flow meter is more than half of the total pressure loss.

Table 1. Models Utilized for Pressure Loss Coefficient

Component	Form Loss Coefficient		Friction Loss Coefficient
Test Section	Dia.4-9	Dia.4-1	Fig. 2-2
Decomposer	Dia.4-1	Dia.4-9	Fig. 2-2
Heat Exchanger	Dia.4-1	Dia.4-9	Fig. 2-2
Cooler	Dia.4-9	Dia.4-1	Fig. 2-2
Flow Meter	---		Ref. 3
Pre-heater	Dia.4-4	Dia.4-9	Fig. 2-2
Main Heater	Dia.4-4	Dia.4-9	Fig. 2-2
Piping	---		Fig. 2-2
Elbow	Fig. 6-11		Fig. 2-2
Glove Valve	Dia.9-4		---
Gate Valve	Dia.9-6		---

Table 2. Pressure Loss for Each Component

Component	Form Loss [Pa]		Friction Loss [Pa]
Test Section	2444	3960	10380
Decomposer	84	45	3193
Heat Exchanger	84	45	2406
Cooler	35	31	322
Flow Meter	35000		0
Pre-heater	107	42	0.2
Main Heater	211	278	0.3
Piping	0		455
Elbow	623		10
Glove Valve	635		0
Gate Valve	394		0
Total	43889		16766.5

The friction loss of the test section is the highest number in frictional pressure loss. The frictional pressure loss of the decomposer and the heat exchanger also highly influence on the frictional pressure loss. The loop pressure loss of 100 KPa is recommended as a design value of the loop in consideration of the uncertainty and the design flexibility.

#### 4. Concluding Summary

The geometric parameters of the decomposer, the heat exchanger, and the air cooler with more than 10 KW thermal capacity have been proposed and pressure loss of the primary loop has been evaluated by utilizing the pressure loss models published in open literature. The results are summarized as follows;

1) The decomposer and the heat exchanger is plate type with 5 layers for each fluid. The finned channel instead of

the pure channel will allow more compact design. On the other side these pressure loss will be slightly increased.

2) The finned air cooler is designed to increase thermal capacity as well as to reduce pressure loss of the air cooler.

3) The total pressure loss of the primary loop is estimated as 60 KPa. The pressure loss of the flow meter is more than half of the total pressure loss. The loop pressure loss of 100 KPa is recommended as a design value of the loop in consideration of the uncertainty and the design flexibility.

4) The more detail analysis for design optimization with CFD code on thermal equipments including the non uniform flow distribution influence is needed.

#### REFERENCES

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- [2] I. E. Idelchik, Handbook of Hydraulic Resistance, 2<sup>nd</sup> Edition, Hemisphere Publishing
- [3] Rheonik, Rheonik Flowmeter Summary, 2005. 8.