Magnetite Transport Characteristics in a CANDU reactor

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1. Introduction

For a CANDU reactor, one of the important aging phenomena is the flow accelerated corrosion (FAC), together with the pressure tube creep [1]. The magnetite transport in the primary system, specifically the magnetite dissolution at the outlet feeder pipe and the magnetite deposition at the inlet feeder pipe, has an effect on a pressure drop in the primary system. Hence, the difference of the magnetite deposition on an inlet feeder pipe results to the difference of core pressure drop among 4 passages. Although CANDU 6 has the similarity characteristic between two passages and has the pressure equalizing system, the flow and thermal characteristics between 4 passages happen to be diverged as a plant operation due to an unexpected reason and it has a bad effect on the system stability in a normal operating condition [2]. In this study, among many reasons which bring to the flow unbalance among 4 passages, the effect of the magnetite transport on the thermal-hydraulic characteristics of the system has been analyzed.

2. Design Characteristics of CANDU 6

Figure 1 shows the schematic diagram of CANDU 6, which consists of 2 loops and 4 quadrant passages, which are named as pass 23, 41, 67 and 85. Two passages in each loop are connected by the balance line in order to have the pressure balance between two passages. And a pressurizer has a role to keep a pressure at a constant value in the primary system, which is connected on ROH 3 & ROH 7.

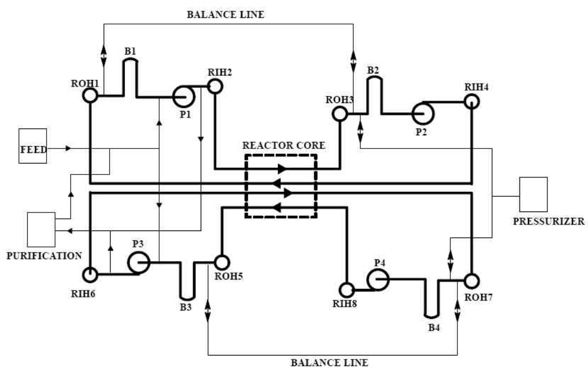

Fig. 1. Schematic diagram of CANDU 6.

The purification system is connected only 2 passages among 4 passages, which are pass 23 & 67. The small amount of coolant in the primary system is extracted from PHTS and purified in a purification system. In a purification system, the extracted coolant is firstly cooled down before passing through the ion exchange resin. And the coolant which is purified by the ion exchange resin is heated up before returning to the PHTS, while the coolant temperature returning to PHTS is lower than that of PHTS. The flow and thermal conditions at the purification system and PHTS are as follows:

1. Flow and thermal conditions in PHTS
   - Flow rate : 2100 kg/s
   - Temperature : 262 °C
2. Flow and thermal conditions of the coolant returning from a purification system
   - Flow rate : 11.1 kg/s
   - Temperature : 157 °C

Hence, the inlet header temperatures of RIH 2 & RIH 6, which are connected to the purification system, are affected by the cold fluid returning from purification system. The inlet header temperatures of RIH 2 & RIH 6 have been anticipated by estimating the mass weighted average temperature. The temperatures of RIH 2 & RIH 6 are estimated to have 261.4°C, which is lower about 0.6°C compared with that of RIH 4 & RIH 8. Actually, the inlet header temperatures measured from Wolsung unit show that the temperatures of RIH 2 & RIH 6 have the lower value about 0.5 ~ 1.2°C compared with that of RIH 4 & RIH 8. Although the temperature difference between 4 inlet headers may be affected by other factors, such as the steam generator fouling and divider plate gap, it is apparent that the cold fluid returning from purification system affects to the inlet header temperatures of RIH 2 & RIH 6, which are connected to the purification system

3. Magnetite Corrosion and Deposition in a loop

Figure 2 shows the magnetite transport mechanism in a loop. As shown in Fig. 2, the magnetite corrosion occurs on an outlet feeder pipe by the flow accelerated corrosion. The dissolved magnetite is deposited on the cold side of steam generator & inlet feeder pipe having a low temperature in a loop because the magnetite solubility at this cold temperature is lower than the amount of magnetite dissolved in a coolant.

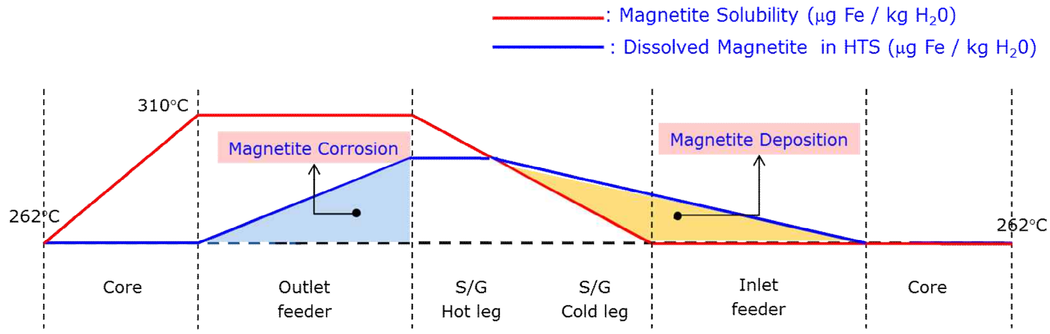

Fig. 2. Magnetite corrosion and deposition in a loop.

Figure 3 shows the magnetite solubility with a coolant temperature. The magnetite solubility tends to decrease as the coolant temperature decrease. And, the magnetite solubility is more dependent on a coolant temperature as the value of pH increases. In a CANDU reactor, the value of pH is controlled to have the value of 10.2 ~ 10.4. As shown in Fig. 3, the difference of the magnetite solubility between an outlet header temperature and an inlet header temperature determines the magnitude of magnetite deposition on an inlet feeder pipe. Hence, the difference of inlet header temperatures between RIH 2 and RIH 4 results to the difference of the amount of magnetite deposition on an inlet feeder pipe. That is, the decreased inlet temperature at RIH 2 & RIH 6, which is connected to the purification system, means the decreased magnetite solubility at the inlet feeder pipe, which results to the increased magnetite deposition on the inlet feeder pipe. As a result, it increases the core pressure drop of pass 23 & pass 67 compared with that of pass 41 & pass 85. Actually, the core pressure drop measured from CANDU power plant shows the core pressure drop of pass 23 & pass 67 have the relatively larger value than that of pass 41 & pass 85.

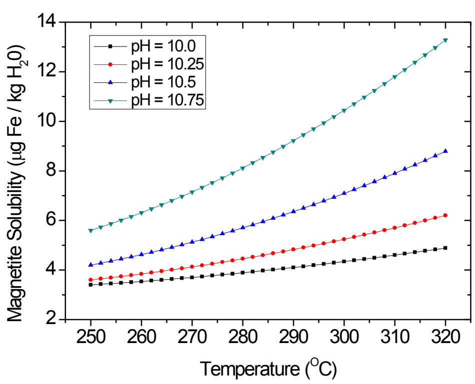

Fig. 3. The magnetite solubility with a coolant temperature.

The quantitative comparison of magnetite deposition has been analyzed between pass 23 & 67, which are connected to purification, and pass 41 & 85. If we assume that the coolant at the exit of an outlet feeder pipe is fully saturated with the magnetite, the difference of solubility between an outlet header and an inlet header temperature is the quantity of magnetite deposited on an inlet feeder pipe. However, the coolant at the exit of outlet feeder pipe is not saturated with magnetite although the saturation rate is not known. Table 1 shows the relative increase rate of magnetite deposition for pass 23 & 67 compared with that of pass 41 & 85.

Table I: The comparison of magnetite deposition between pass 23 & 67 and pass 41 & 85

Magnetite saturation rate at the outlet feeder	The relative increase rate of magnetite deposition
100%	1.2%
50%	2.4%
25%	4.8%

4. Conclusions

The temperature of RIH 2 & RIH 6 is lower than that of RIH 4 & RIH 8 due to the cold fluid returning from a purification system. It results to the relative increase of magnetite deposition of pass 23 & pass 67. As a result, the core pressure drop of pass 23 & pass 67 is larger than that of pass 41 & pass 85 for a CANDU reactor.

Acknowledgement

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