# Core Pressure Drop Characteristics in a CANDU reactor

Jun Ho Bae*, Bo Wook Lee and Jong Yeob Jeong
*Korea Atomic Energy Research Institute (KAERI), Yuseong P.O. Box 105, Daejeon 305-600, Korea*
**Corresponding author:bjh@kaeri.re.kr*

## 1. Introduction

CANDU 6 consists of 2 loops and 4 quadrant passages, together with the purification and pressurizer systems. Two passages in each loop are connected by a balance line in order to have a pressure balance between two passages. And a pressurizer has a role to keep a pressure in the primary system to be a constant. 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 with a plant operation due to the unexpected reasons and it has a bad effect on the system stability in a normal operating condition [1]. Hence, this study aims to analyze the factors which cause to the unbalance of the flow and thermal characteristics between 4 passages.

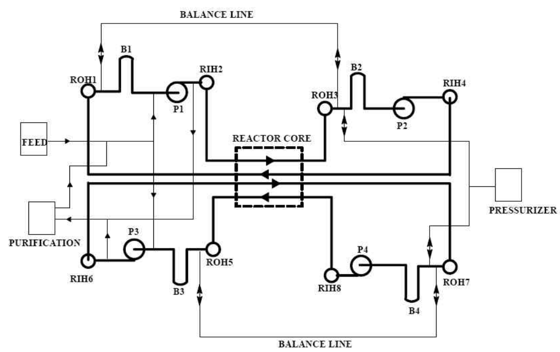



Fig. 1. Schematic diagram of CANDU 6.

## 2. The Effect of Purification System on a Core DP

As shown in Fig. 1, the purification system is connected only 2 passages among 4 passages, which are passages 23 & 67. The small amount of coolant is extracted from the primary system and it is purified by passing through the purification system. In the purification system, the extracted coolant is firstly cooled down to reach about 55°C before passing through the ion exchange resin. And the coolant purified by the ion exchange resin is heated up to reach about 165 °C before returning to the PHTS, while some of purification flow rate are transferred to the feed/bleed flow system with cold fluid temperature of 55 °C and it is utilized to control the pressurizer level. The bleed flow having cold temperature of 55°C is mixed with the purification flow of 165 °C before returning to PHTS. Hence, the bleed flow rate largely affects to the coolant temperature returning to PHTS. In this study, the effect of feed/bleed flow rate on the thermal-hydraulic characteristics of PHTS is examined by comparing the two cases which have the different feed/bleed flow rates. Considered feed flow rates are 4.5kg/s and 2.1 kg/s, which is the feed flow rate before and after the bleed valve orifice of Wolsung unit #3, 4 is replaced, respectively. Since the feed/bleed flow has a cold temperature of 55°C, this decrease of a feed/bleed flow rate results to increase the coolant temperature returning to PHTS about 20°C.

Before and after the bleed valve orifice is replaced, the flow and thermal conditions of coolant returning to PHTS are as follows:

Case 1 (Before the bleed valve orifice is replaced):
- Purification flow rate : 11.1 kg/s
- Bleed flow rate : 4.5kg/s
- Coolant temperature returning to PHTS : 157 °C

Case 2 (After the bleed valve orifice is replaced):
- Purification flow rate : 13.5 kg/s
- Bleed flow rate : 2.1kg/s
- Coolant temperature returning to PHTS : 175 °C

Although the purification flow rate is very small compared with that of PHTS, the temperature of purification flow can affect to the local thermal-hydraulic characteristics of a primary system, especially to the weldonet of purification system. In order to examine the local thermal characteristics in a primary system, the numerical computation has been conducted. A commercial CFD code of CFX version 12 has been used to evaluate the flow characteristics near the weldonet of purification system [2]. The simulation type is steady state and the turbulent flow is simulated numerically using the k-ε model. At the downstream exit, the usual Neumann-conditions are applied for the fully-developed flow. The tetra-prism mesh was generated by using ICEM code. Figure 2 shows the computational domain and the boundary condition for Case 1.

Figure 3 shows the temperature distribution near the weldonet of purification system before and after the bleed valve orifice is replaced. It is revealed that the local temperature near the weldonet is largely affected by the returning coolant temperature. The decrease of coolant temperature near the weldonet results to the increase of a magnetite deposition since a magnetite solubility is decreased with the decrease of coolant temperature. Hence, the replacement of a bleed valve orifice results to the decrease of magnetite deposition near the weldonet of purification system, which means the decrease of core pressure drop of pass 23 & pass 67, which are connected to the purification system. Hence, the replacement of bleed valve orifice finally results to decrease the difference of core pressure drop among 4 passages.

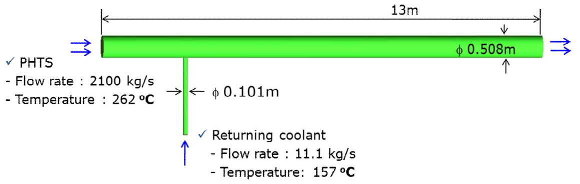
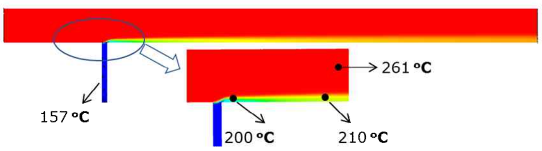
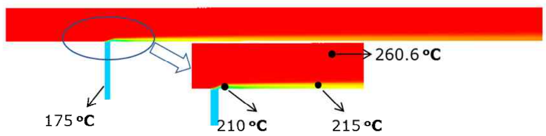



Fig. 2. Computational domain & boundary conditions.




(a) Case 1 (Feed flow rate : 4.5 kg/s)




(b) Case 2 (Feed flow rate : 2.1 kg/s)

Fig. 3. Temperature distribution near the weldonet of purification system.

### 3. The Effect of Pressurizer System on Core DP

A pressurizer, which is connected on ROH 3 and ROH 7, has a role to keep a pressure of a primary system at a constant value. Because of the difference of core pressure drop among 4 passages, the each outlet header pressure has a different value among 4 outlet headers. Hence, in a CANDU power plant, the pressurizer is controlled to keep the outlet header pressure having the maximum value among 4 outlet headers to be a constant. That is, a pressurizer is only concerned with the absolute pressure of outlet header having the maximum value among 4 outlet headers, while it is not related to the pressure difference among 4 outlet headers.

In a CANDU reactor, the core pressure drop of pass 23 & 67, which is connected to the purification system, is larger than that of pass 41 & 85 because of the difference of magnetite deposition. Hence, the ROH 3 & ROH 7 has the lower pressure compared with that of ROH 1 & ROH 5 due to the larger core pressure drop. And, the lower pressure at ROH 3 & ROH 7 causes to the larger void generation at the rear of channel, which reversely cause to increase a core pressure drop by the increase of two phase pressure drop. Therefore, if the difference of core pressure drop is generated in any way, the difference tends to be more intensified by these outlet header pressure characteristics.

### 4. The Effect of Balance Line on Core DP

The balance line flow is developed by the pressure difference of two outlet headers in a same loop. Hence, the pressure difference of two outlet headers can be decreased by increasing the flow rate of balance line. As shown in Fig. 4, the decrease of flow resistance of balance line increases the core flow rate of pass 41, while it decreases the core flow rate of pass 23, which has the relatively larger core pressure drop. Hence, the decrease of flow resistance of balance line results to the decrease of core pressure drop difference among 4 passages.

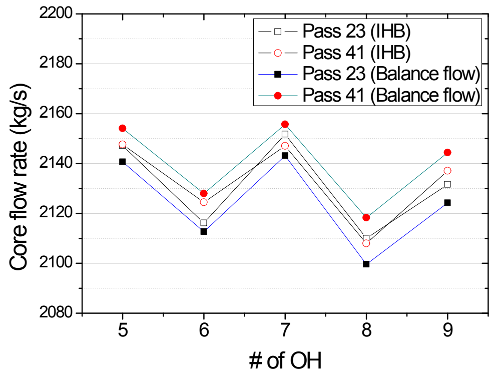



Fig. 4. Core flow rate comparison.

### 4. Conclusions

The increase of feed/bleed flow rate makes the coolant temperature returning from purification system to decrease and it results to the increase of magnetite deposition near the weldonet and the increase of core pressure drop. The core pressure drop difference among 4 passages tends to be more intensified by outlet header pressure characteristics, while it can be reduced by decreasing the flow resistance of balance line.

### Acknowledgement

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### REFERENCES

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