Review of the Decrease in the COLSS Reactor Coolant Flow caused by an Increase of the RCP Differential Pressure (DP)

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1. Introduction

The staff of the core management section discovered a decrease in the COLSS Reactor Coolant flow of less about 2% compared to the usual flow at a OPR1000 unit, Cycle 4, during daily surveillance of the core on November 8, 2001. An analysis of the COLSS detailed report made it clear the decrease in the COLSS reactor coolant flow was caused by an increase of the RCP DP used in the COLSS RCS flow calculation.

2. Methods and Result

2.1 Data Analysis of the COLSS RCS Flow Calculation

When the decrease in the COLSS RCS flow occurred, the data related to the flow calculation were as follows.

2.1.1 RCP Differential Pressure(RCP DP)

RCP DP as a local signal used to calculate the RCS flow in COLSS. The COLSS RCS flow is in inverse proportion to the RCP DP. As shown below in Fig.1, the RCP DP increased by approximately 200cmH_2O from 7000 cmH_2O to 7200 cmH_2O during approximately one day (19 hours). At the same time, the COLSS RCS flow decreased by about 1.6% from 107.2% to 105.6%.

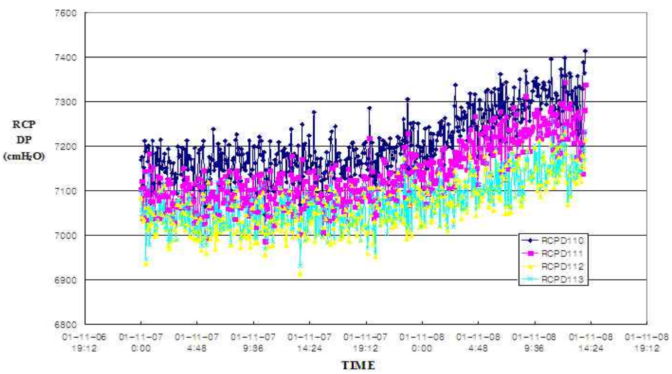

Fig. 1 RCP-DP curve

2.1.2 CORE DP

The data of the CORE DP is to verify the reliability of the RCP DP. The behavior of the CORE DP shown in Fig. 2 is similar to that of the RCP DP.

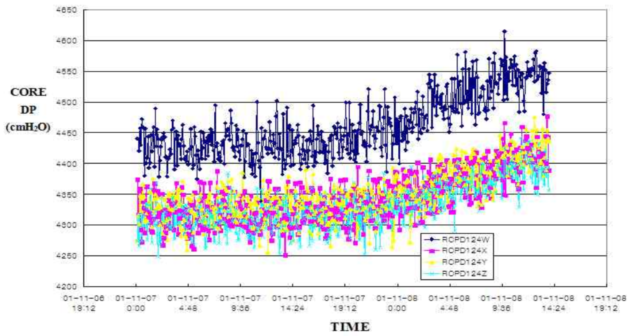

Fig. 2 CORE DP

2.1.3 RCS Temperature

The RCS temperature is one of the main variables used to calculate the RCS flow by a calorimetric method. The RCS Temperature was stable without changes while the RCP DP increased (Fig. 3).

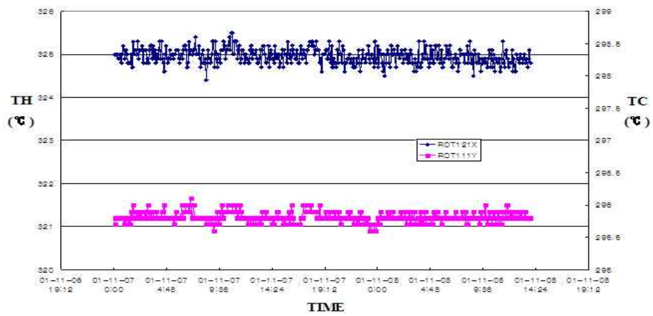

Fig. 3 RCS Temperature

2.2 The Method of RCS Flow Measurement & Results

There are a number of methods to calculate the RCS flow at the reference plant including a monthly measurement by using a calorimetric method (or when the RCP DP is below 60% of the reactor power), the COLSS flow, and the CPC flow as an online program.

2.2.1 Monthly RCS Flow Measurement

The monthly RCS Measurement proceeds as follows.

- The cold and hot leg temperatures are obtained from CPC.

- The RCS flow is calculated by measuring the rise in enthalpy in the core from the temperature difference between the cold legs and the hot legs.

$$Q(BSCAL) = \Delta h * m$$

Here, Δh denotes the rise in the enthalpy. " m" is the RCS Flow, and Q(BSCAL) is the reactor power from COLSS

3 COLSS Flow

COLSS calculates the RCS flow using the RCP pump head vs .the flow curve as provided by the vendor.

$$Head_i = 144 * PDP_i * RCSV_i \quad (i=1\sim4)$$

In this equation, Headi refers to the head of Pump I (ft), PDPi is the differential pressure of Pump i(psid), RCSVi is the specific volume(ft^3/lbm), and 144 refers to conversion of ft^2 to in^2.

The differential pressure of RCP is in inverse proportion to the RCS flow. Consequently the higher the RCP DP becomes, the smaller the RCS flow becomes. In addition, the COLSS flow is corrected as regards the result of the monthly RCS flow measurement, as stated above.

4 CPC Flow

The CPC flow is calculated by in consideration of the state and speed of the RCPs. The calculation process is as follows :

$$Funct(Th) = F_{T1} + F_{T2} * (Thref - Thavg)$$

$$Mi = (Ni/Vck) * Funct(Th)$$

In this equation, F_{T1} and F_{T2} are Flow Adjustment Constants, Thref is the reference hot leg temperature, Thavg is the average hot leg temperature, Mi is the normalized pump speed, Ni is the normalized pump speed, and Vck is the normalized specific volume

The results of the RCS flow measurement by each method at that time are shown in Table 1.

Table 1. Flow measurement result

Method	Before RCP DP ↑	After RCP DP ↑	Remarks
RCP DP	109.3%	107.6%	1.7% ↓
Heat Bal.	107.2%	107.4%	Not Change
COLSS	107.1%	105.5%	1.6% ↓
CPC	106.9%	106.4%	Not Change

2.3 The Cause of the decrease in COLSS RCS Flow

The cause of the decrease in COLSS RCS flow was an increase of the RCP DP. After the examination, it was found that the change of the RCS chemistry at UCN Unit 4 led to the increase the RCP DP. A CVCS gas stripper started to lower the Iodine concentration in the RCS. After starting the gas stripper, Li was additionally removed when it passed through the pre-holdup ion exchanger.

Table 2. The values of the Li concentration and the pH

Date	11/6	11/7	11/8	11/9	11/10	11/11	11/12
Li	2.26	**2.08**	**2.12**	2.20	2.24	2.28	2.28
pH	7.11	**7.07**	**7.08**	7.10	7.11	7.12	7.12

As shown in Table 2, the Li concentration is proportional to the RCS pH. The low pH in the RCS promoted to the movement of corrosion products in the core and this was the cause of the increase of the RCP DP and the core DP. To correct this problem, the operator injected LiOH into the RCS and bypassed the pre-holdup ion exchanger in the front of the gas stripper. As a result, the Li concentration, pH and COLSS RCS flow were restored to normal conditions.(referred to Fig. 4)

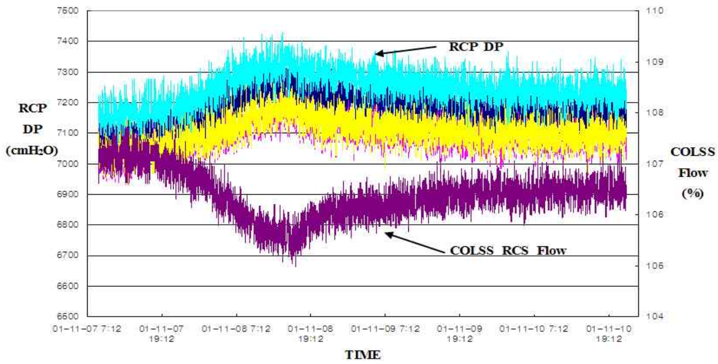

Fig. 4 RCP DP vs. COLSS RCS Flow

5 Conclusions

The decrease in the Li concentration and pH promoted a move of corrosion products into the RCS. The consequence was that the RCP DP became lower and the COLSS RCS flow decreased. The COLSS RCS flow has a direct effect on the COLSS operational margins, including the DNBRPOL and BDELT(core power). In addition, the CPC margins are affected by the COLSS RCS flow as the CPC flow is corrected by this measure on a daily basis. As a guaranteed means of preventing the recurrence of a similar problem, the related procedure was revised to include the content, "The core flow should bypass the pre-holdup ion exchanger when the gas stripper is operating."

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