Sensitivity Evaluation on the ROH Quality for the DBA Safety Analysis of Wolsong NPP Unit 1

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1. Introduction

As one design characteristic of the CANDU-6 NPP (PHWR Type), boiling of the primary coolant is allowed a little bit. However, the Quality (Ratio of mass of vapor to that of vapor and liquid mixture) of primary coolant is restricted to a certain value, that is, 4.0% for the Wolsong NPP.

In the safety analysis of Wolsong NPP Unit #1, the ROH (Reactor Outlet Header) quality was assumed to be 2.82% as an initial condition, which was predicted at 11 EFPY(Effective Full Power Year) after the grand refurbishment. The initial condition for the safety analysis of 2.82% was adopted as a LCO (Limiting Condition for Operation) in the ITS (Improved Technical Specifications) of Wolsong NPP Unit #1[1].

For this sensitivity study on the ROH Quality, three representative events - LBLOCA, SBLOCA and Loss of Flow (LOCL4) - were selected and the effects of quality on the thermal hydraulic behaviors of coolant system and trip coverage effectiveness of shutdown systems (SDS1/2) were evaluated.

2. Method and Code Modelling for Sensitivity Study

This sensitivity study was performed using the CATHENA Code[2]. In the CATHENA model, the ROH coolant quality was varied by modifying the Steam Generator (SG) tube heat transfer correction factor (‘CORRECTION FACTOR:(*.*)’).

Additional three CATHENA models were developed beside the reference model (#1) (2.82%) as shown in the Table 1.

Table 1. CATHENA Model Development

Model #	**#1 (Ref.)**	#2	#3	#4
SG Correct. Factor	**1.14**	1.00	0.90	0.80
ROH Quality (%)	**2.82**	3.26	3.65	4.12
RIH Temp. (℃)	**267**	267.9	268.6	269.5

As shown in the Table 1, as the SG correction factor is getting smaller, the ROH quality is getting larger and the coolant temperature of RIH (Reactor Inlet Header) is also getting higher due to the less heat transfer rate between primary side and secondary side between SG tubes.

3. Results

3.1 Large Break LOCA

RIH 35% Break (the most limiting break size in the viewpoint of fuel failure) was evaluated for the 4 CATHENA sensitivity models. For this thermal hydraulic analysis, the power pulse (resulted from coupling calculation with TH code & Physics code) of this event is assumed to be same for 4 sensitivity cases.

Table 2 shows the occurrence time difference of LBLOCA related SDS1/2 Trip parameters with various ROH qualities. This result demonstrates that the trip time difference is very marginal, even ignorable, with various ROH qualities up to 4.12%.

Fig. 1 shows the differences in the thermal hydraulic behaviors of coolant system and the containment (Reactor Building). Only small noticeable differences are shown in the coolant temperature and discharged energy with various initial ROH qualities and RIH temperatures, but the pressure and temperature increase inside the containment due to the discharged mass and energy through the break (calculated by GOTHIC code) is not noticeable at all.

Therefore, the various ROH qualities do not bring noticeable effects on the LBLOCA safety analysis results, which is partially due to the LBLOCA characteristics of very fast proceeding event.

Table 2. SDS1/2 Trip Signal Occurrence Time with Various ROH Qualities for LBLOCA

Model #		**#1 (Ref.)**	#2	#3	#4
ROH Quality (%)		**2.82**	3.26	3.65	4.12
RIH Temp (℃)		**267**	267.9	268.6	269.5
SDS1	Low Flow	**0.25**	0.24	0.25	0.24
	HNP	**0.42**	0.43	0.45	0.44
	RAT	**0.76**	0.76	0.76	0.75
	Low Press	**1.61**	1.59	1.58	1.57
SDS2	Low DP	**0.26**	0.25	0.25	0.25
	HNP	**0.42**	0.43	0.45	0.44
	RAT	**0.77**	0.78	0.78	0.77
	Low Press	**1.65**	1.63	1.62	1.61

HNP: High Neutron Power
RAT: High Rate Log Neutron Power

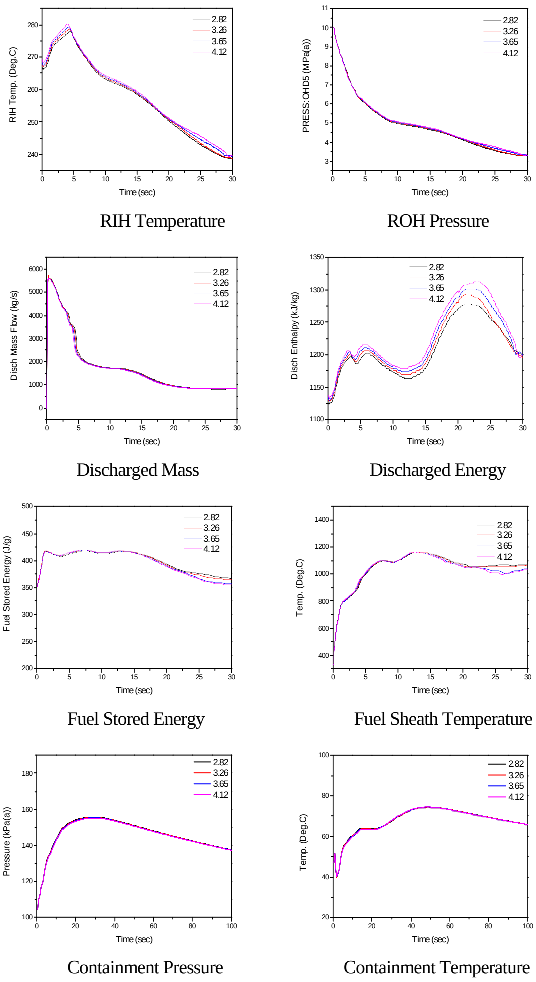


Fig. 1. Comparison of TH Analysis Results with Various ROH Qualities for LBLOCA (Tripped by SDS2 3rd Trip parameter - SDS2 RAT)

3.2 Small Break LOCA

RIH 2.5% Break (largest break size in the SBLOCA) was evaluated for the 4 CATHENA sensitivity models. Similar to LBLOCA, Table 3 shows the trip time differences with various qualities and Fig. 2 shows the comparison in the results of thermal hydraulics, reactor power and fuel sheath temperature. In the event of SBLOCA, the effects of various ROH qualities are a little more noticeable than that of LBLOCA. That is, as the quality is getting higher, the increase rate in the reactor power and coolant pressure is getting larger. However, fast increase in the reactor power and coolant pressure leads to the faster reactor shutdown with trip parameters related to the reactor power and coolant pressure. Therefore, coolant pressure is maintained below the acceptance criteria (13.0 MPa) [4] so the integrity of coolant system boundary is assured for all qualities. And the peak fuel sheath temperatures are similar each other and was assessed to keep the fuel integrity. However, the peak temperature for the quality of 4.12% exceeded the acceptance criteria of 800℃ [4] by 4℃, so the detailed fuel analysis is necessary for this quality for the case of adoption this high quality as a LCO.

Table 3. SDS1/2 Trip Signal Occurrence Time with Various ROH Qualities for SBLOCA

Model #		**#1 (Ref.)**	#2	#3	#4
ROH Quality (%)		**2.82**	3.26	3.65	4.12
RIH Temp (℃)		**267**	267.9	268.6	269.5
SDS1	HNP	10.10	8.18	7.11	6.45
	High Press	19.70	16.79	15.36	14.42
	RAT	27.38	21.52	15.16	17.88
SDS2	HNP	10.10	8.18	7.11	6.45
	High Press	21.71	18.80	17.36	16.42
	RAT	29.19	23.45	21.41	19.54

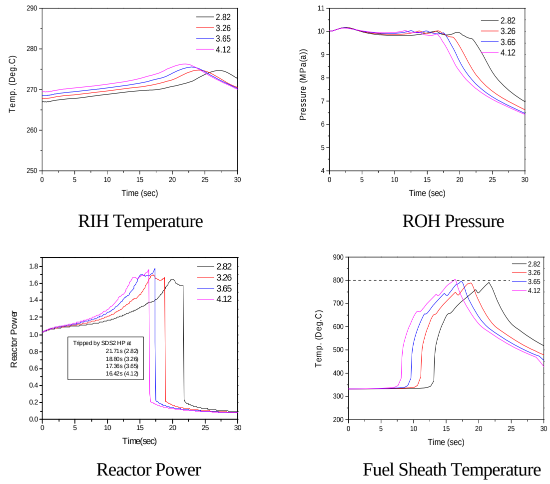


Fig. 2. Comparison of TH Analysis Results with Various ROH Qualities for SBLOCA (Tripped by SDS2 2nd Trip parameter – SDS2 HP)

3.3 Loss of Flow (Loss of Class IV Power)

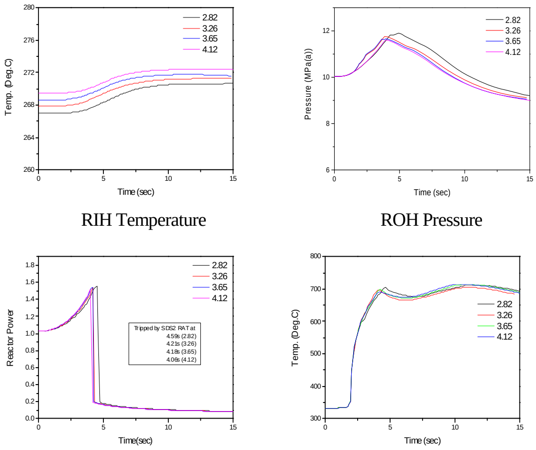
Total loss of Class IV Power was evaluated with various ROH qualities as a representative event of the loss of forced coolant flow event.

This event is also characterized to be fast proceeding, so the various ROH qualities do not lead to noticeable effects on the trip time (Table 4). Larger ROH quality give rise to a little fast reactor trip alike SBLOCA, so that peak coolant pressure is smaller than that of reference case of ROH quality (2.82%) (Fig. 3). Similar to SBLOA, the integrity of coolant system boundary and fuel can be maintained sufficiently with various ROH qualities up to 4.12%

Table 4 SDS1/2 Trip Signal Occurrence Time with Various ROH Qualities for LOCL4

		#1 (Ref.)	#2	#3	#4
ROH Quality (%)		**2.82**	3.26	3.65	4.12
RIH Temp (℃)		**267**	267.9	268.6	269.5
SDS1	HNP	2.72	2.57	2.56	2.57
	High Press	2.89	2.90	2.88	2.86
	RAT	3.18	3.10	3.17	3.15
	Low Flow	3.58	3.50	3.47	3.45
SDS2	HNP	2.72	2.57	2.56	2.57

	RAT	4.59	4.21	4.18	4.06
	High Press	4.88	5.03	5.30	5.71
	Low DP	4.91	4.82	4.82	4.84



RIH Temperature ROH Pressure

Reactor Power Fuel Sheath Temperature

Fig. 3 Comparison of TH Analysis Results with Various ROH Qualities for LOCL4 (Tripped by SDS2 2nd Trip parameter – SDS2 RAT)

4. Conclusions

The effects of various ROH qualities from 2.82% up to 4.12% on the safety analysis results of LBLOCA, SBLOCA and LOCL4 were evaluated.

The initial conditions of various ROH qualities do not give rise to noticeable effects with respect of thermal hydraulics of coolant system and containment for the LBLOCA event.

SBLOCA and LOCL4 got a little effect from various ROH qualities - larger increase rate in the reactor power and coolant pressure due to larger qualities. However, the effects are not significant to have an effect on the integrities of fuel and coolant system boundary.

The various ROH qualities up to Design Limit of 4.0% would not bring significant safety effects for the three DBAs in the Trip Coverage viewpoint.

REFERENCES

[1] KHNP, Wolsong NPP Unit 1 ITS (Improved Technical Specifications).

[2] B.N. Hanna, Editor, "CATHENA MOD-3.5d/Rev 2 Input Reference", 153-112020-UM-001, Revision 0.0, 2005.

[3] B.N. Hanna, Editor, "CATHENA MOD-3.5d/Rev 2 GENHTP Input Reference", 153-112020-UM-002, Revision 0.0, 2005

[4] KHNP, Wolsong NPP Unit 1 FSAR Chapter15.