Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

A Study on the Influence of Boron Injection Tank Removal on (Post) LOCA Long-term core cooling for Yonggwang NPP #1, 2

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1. Introduction

The BIT (boron injection tank) of Kori NPPs #2, 3 & 4 as well as Yonggwang NPPs #1 & 2, an integral part of ECCS (emergency core cooling system), serves as its source of highly concentrated (20,000 ppm) borated water capable of 900 gallons, which is injected into a reactor coolant system via SI (safety injection) pumps. The BIT was designed to ensure emergency safety stoppage capability of the reactor in the event of MSLB (main steam line break) by preventing the sudden peak output of the core at its initial stage and continually supplying boric acid solution at a concentration of 2,400 ppm from the RWST (reactor water storage tank). Nevertheless, the present study is commenced in an attempt to know more about whether the reactor core will remain subcritical with the sufficient degree of margin during long-term cooling of the core assuming that the BIT is removed, being further intended if so to be utilized for the improvement of spatial efficiency in NPPs through the rearrangement of the facility
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2. Methods and Results

In general, a long-term core cooling analysis consists of such three evaluation items as verification of maintaining the subcritical state in the core, prevention of leakage of boric acid within the core and assurance of minimum safety injection flux.

2.1 Verification of subcritical state in a core

In the postulated event of a LOCA borated water is forced into the primary coolant system of a reactor from the containment sump after entering into the operational mode of cold leg recirculation. Therefore, the post-LOCA containment sump average concentration of blended boron is calculated so as to declare that a subcritical state of the core is secured after the occurrence of the LOCA if it can be verified that the calculated value is greater than the boron concentration that can keep subcritical the specific core replaced.
As the BIT contains highly concentrated boron concentration, the blended boron concentration on average in a containment sump decreases if the BIT is eliminated. According to the evaluation targeting the existing reference cores, it was found that removal of BITs result in reduction by approx 60 ppm as for Kori NPP number 2 and approx 35 ppm as for Kori NPP numbers 3 and 4, and Yonggwang NPP numbers 1 and 2.
In this regard, this study proposes that the minimum boron concentration of RWST and accumulator in Kori NPPs #3,4 and Yonggwang NPPs #1,2 be changed to 2,550 ppm from the current 2,450 ppm; if so, it could be verified that a subcritical state as to cores during the long-term core cooling be satisfactorily met with the margin in a sufficient level even though a BIT is removed.

2.2 Prevention of boron from precipitation within a core

In connection with the injection of cold leg extracted from a new calculation with respect to Yonggwang Units 1/2, the point of boron starting precipitate within a core takes 27,440 seconds, which is faster by about 270 seconds than that calculated under the present conditions, but it still exceeds the time for the switchover to hot leg injection that presently takes 7 hours (25,200 sec). Moreover, it is calculated that time needed up to the point of occurrence of boron precipitation in a core after the hot-leg injection takes 38,498 seconds, which is faster by about 305 seconds than that calculated under the present conditions, but it still satisfies the present interval for the repetitive switchover between cold-leg injection and hot-leg injection, i.e. 10.5 hrs (26,000 sec).
Though not related with boron precipitation within a core, meanwhile, the increase in the maximum boron concentration as to RWST and accumulator has an effect on evaluation of acidity (pH) of the containment sump.
Table I shows the result from evaluating pH of the containment sump assuming that the maximum boron concentration as to RWST and accumulator is increased. In order that, as shown in this table, acidity of the containment sump under the assumption of upwardly adjusted maximum boron concentration meets the requirement of FSAR acidity (8.5 ~ 11.0 as for Kori Units 3/4 and 8.5 ~ 9.5 as for Yonggwang Units 3/4), the minimum concentration of NaOH in a spray additive tank shall be greater modulated from the current 29 w/o to 30 w/o.

2.3 Verification of minimum safety injection flux

Though admitting that removal of the BIT and the resultant modification of safety injection paths may cause resistance in terms of flow path, the safety injection flux having been applied to the conventional loss-of-coolant accident analysis still remains effective, if it is assumed that the flux balance test performed after the BIT removal meets the flux conditions as set out in Sec 16.4.5.2, Operational Technical Guidance (as for Kori NPP #2) or Table 11 of FSAR Appendix A (as for

Kori NPPs #3,4 and Yonggwang NPPs #1,2). In this case, the result from verification on minimum safety injection flux prior to removal of the BIT still survives as adequate even after removal of the BIT.

	Existing FSAR		Change Proposed	
	Min Const.	Max Const.	Min Const.	Max Const.
Boron concentration of RWST and accumulator (ppm)	2,450	2,600	2,550	2,650
NaOH concentration of SAT (w/o)	29	32	30	33

Table I. : Changes in concentrations of NaOH as per SAT in cases of removing BITs in Kori NPPs #3,4 and Yonggwang NPPs #1,2

2.4 *Evaluation of reactor core loading pattern*

Fig. I shows the post-LOCA containment sump boron concentrations under the assumption of the BIT eliminated in Kori NPPs #3,4 (cores for enhanced power output) and Yonggwang NPPs #1,2 (cores for non-enhanced power output) compared with those in which the BIT removal is not made. As addressed by this figure, removal of the BIT allows the post-LOCA containment sump boron concentration to lower by about 35 ppm. As shown in Table Ⅱ and Fig. I, the subcritical state of the core can be maintained even though the BIT is removed with regards to the current core loading model as well as the conservative loading model expected in the future. In this case, however, the difference between the boron concentration needed for maintaining a subcritical state and the boron concentration of the containment sump is very small to be at least 2 ppm. Under the context, we elected to raise the minimum boron concentration of RWST and accumulator by 100 ppm from 2,450 ppm at present to 2,550 ppm, in which case the subcritical state of the core is secured while having comparatively affordable degree of margin.

Case	Boron concentrations of RWST and accumulator		Loading model
	2,450 ppm	2,550 ppm	
1	62	147	K4C19 ; present
2	2	87	K4C23, 4.65 w/o concentration
3	50	135	Y1C19
4	17	103	Y1C18
5	50	135	Y2C19
6	20	105	Y2C18

Table Ⅱ: Margins (ppm) by which the reactor is subcritical after a LOCA in the case of the BIT removal as for Kori NPPs #3,4 and Yonggwang NPPs #1,2

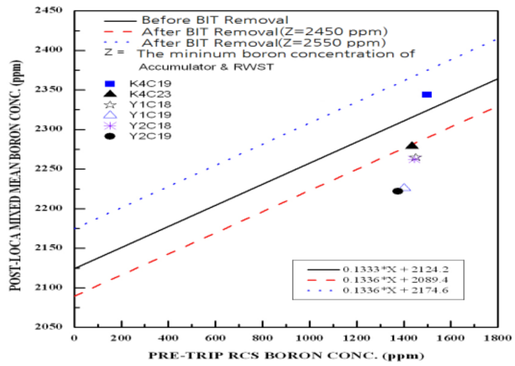

Fig. I : The post-LOCA containment sump boron concentrations under the assumption of the BIT eliminated in Kori NPPs #3,4 and Yonggwang NPPs #1,2

3. Conclusions

As far as Kori NPPs #3,4 and Yonggwang NPPs #1,2 are concerned, either the currently applied loading model or the loading model applicable in the future can secure the subcritical state of the core, but margins thereof significantly decrease. Therefore, the minimum boron concentration of RWST and accumulator is required to rise by 100 ppm from the conventional value of 2,450 ppm to 2,550 ppm; in addition, it is further required for operational convenience to raise the maximum boron concentration by 50 ppm from the conventional 2,600 ppm to 2,650 ppm.

Irrespective of upward adjustment of the boron concentration as such in Kori NPPs #3,4 and Yonggwang NPPs #1,2, it was proven that time for the switchover to hot-leg injection as well as interval for the switchover to hot-leg injection from cold-leg injection and vice versa as already defined are still effective. It shall be noted that increase in the maximum boron concentration of RWST and accumulator is influential to acidity (pH) of the containment sump. The requirement in this regard could be satisfied by raising the minimum concentration of NaOH in a spray additive tank by 1 w/o to 30~33 w/o from 29~32 w/o at present.

REFERENCES

[1] KOREA NUCLEAR UNITS 7&8 STATION MANUAL
[2] Operational Technical Guidance for Yonggwang Units 1/2 & Technical Background Thereof
[3] "Final Safety Analysis Report for Kori Units 3,4," KHNP.
[4] "Final Safety Analysis Report for Yonggwang Units 1,2," KHNP.
[5] "Safety Analysis Standard 12.2, Rev. 8, "Mass and Energy Releases to Containment Following a Steamline Rupture," September 2000.
[6] "Safety Analysis Standard 12.2, Rev. 6, "Mass and Energy Releases to Containment Following a Steamline Rupture," September 1996.
[7] A Study on Boron Injection Tank Removal for Kori 2, 3/4 and Yonggwang Units 1/2