Design Modification of Boron Injection Tank for a Westinghouse type NPP

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1. Introduction

The boron injection tank (BIT) can provide highly concentrated boric acid to the reactor in order to mitigate the consequences of postulated main steam line break (MSLB) accidents. Although the BIT plays an important role in mitigating such accidents, the high concentration of 20,000 ppm causes valve leakage, pipe clogging, and precipitation meaning that continuous heat tracing has to be provided. Therefore, design improvements to mitigate the burden of maintenance, such as maintaining a high temperature with heat tracing to prevent boric acid precipitation of relating systems, are necessary. This paper presents a comparison of boron concentration (Cb) reduction strategies in BIT and the removal of the BIT as this pertains to the reactor core and containment integrity of the Westinghouse type of Nuclear Power Plant (NPP).

2. Evaluation of core response

2.1 Evaluation Method

The main steam depressurization (MSD) and the main steamline rupture (MSR) during hot zero- power events are analyzed for an evaluation of core response. The analyses are performed with the same methodology used with the current type of licensing analysis in the Final Safety Analysis Report (FSAR). To analyze the BIT design modification, three cases are selected, as shown in Table 1.

Table 1 Analysis cases for BIT removal

	Boron Concentration (ppm)	Volume (m^3)
Case 1 (Current)	20,000	3.4
Case 2 (Cb Reduction)	2,450	3.4
Case 3 (BIT Removal)	0.0	0.0

2.2 Evaluation of Main Steamline Depressurization (MSD)

An inadvertent opening of a valve is termed a main steamline depressurization event. This event is considered to be a condition II event. Fig. 1 and Fig. 2 show the core reactivity and nuclear power during a main steamline depressurization event. The quantity of boron has a direct effect on the change in the reactivity. Fig. 1 demonstrates that the criticality can be prevented for case 1 and case 2. For case 3, a return to the critical condition is reached without a BIT about 300 seconds, but the maximum power is less than 5% of the nominal power. Therefore, the core integrity is not challenged.

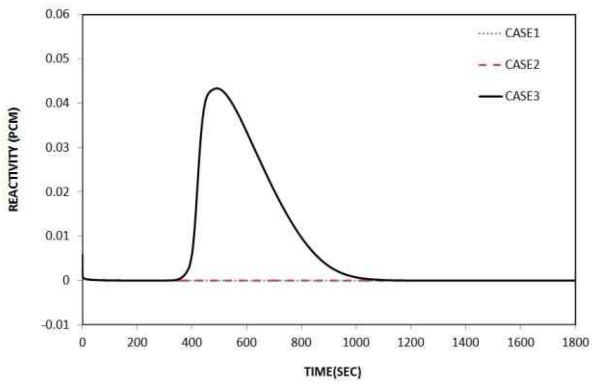

Fig. 1 Core reactivity during a MSD

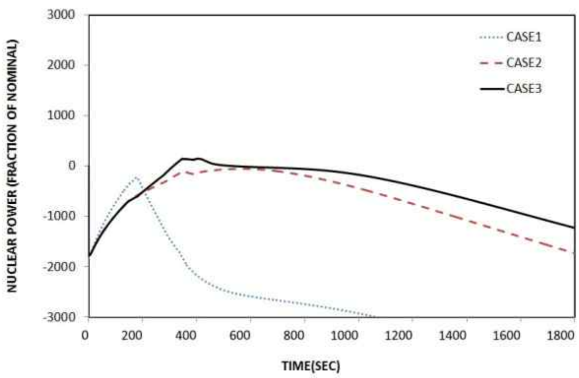

Fig. 2 Nuclear power during a MSD

2.3 Evaluation of Main Steamline Rupture

A double-ended guillotine rupture is termed a Main Steam Rupture. This event is considered to be a condition IV event. Fig. 3 and Fig. 4 show the core reactivity and core power during a main steamline rupture event. The quantity of boron has a direct effect on the reactivity and core power. Case 3 depicts the highest core power because only water is injected without any boron until the accumulator boron reaches the core. A detailed analysis of the DNBR shows that the minimum DNBR does not go below the safety limit and the fuel integrity can be maintained without a BIT.

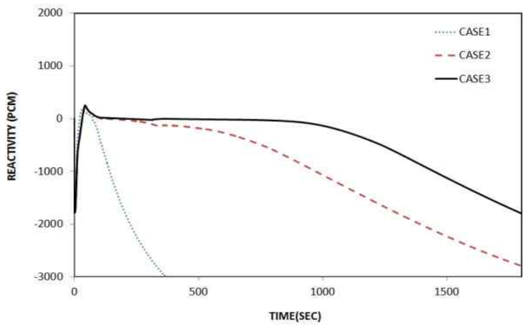

Fig. 3 Core reactivity during a MSR

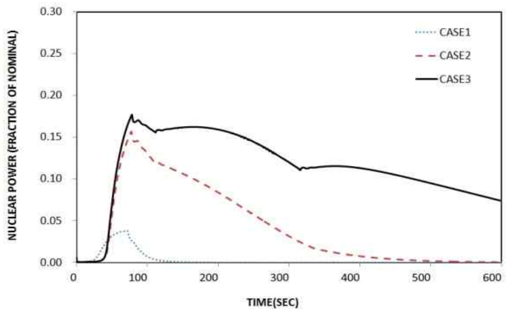

Fig. 4 Nuclear power during a MSR

3. Evaluation of containment integrity following a MSLB accident

3.1 Code Verification

The COPATTA code is used for the containment pressure and temperature prediction in FSAR of NPP. In this study, the CONTEMPT code is used. Both COPATTA and CONTEMPT codes use the Tagami equation which, is applicable during the forced convection period [1,2]. The maximum heat transfer coefficient depends on the energy, volume and the time. The Tagami equation can be expressed as [3]

$$h_{\max} = 72.5\left(\frac{Q}{t\ V}\right)^{0.62} \qquad (1)$$

where, Q : Total released energy
V : Volume of the containment
t : Decompression time

The decompression time t is defined as the time from the start of an accident to end of the blowdown event in the CONTEMPT code. In contrast to this, the decompression time t in the COPATTA code is the time from the start of an accident to the first peak pressure. However, it has been demonstrated that the two codes are compatible [4, 5].

3.2 Containment Evaluation

The containment integrity is confirmed with the peak pressure based on the amounts of mass and energy (M/E) released during a MSLB accident. The MSLB M/E values calculated for three categories for the spectrum analyses, as follows:

- Power levels: 0%. 30%, 70%, 100%
- Break types and areas: Double-ended rupture (DER), small break(0.1~1.4ft^2)
- Single failures: Loss of offsite power (LOOP), MSIV failure, auxiliary feedwater failure

3.3 Containment analysis

Fig. 5 shows the predicted pressure curve using the CONTEMPT code from the core power. The peak pressure with Cb reduction in the BIT is less than the design pressure. Though the peak pressure is slightly higher than the current case, the overall containment integrity is slightly affected by the change in the boron quantity. The primary reason for this is the spray system which is actuated within 100 seconds because the pressure reaches a High-3 pressure level.

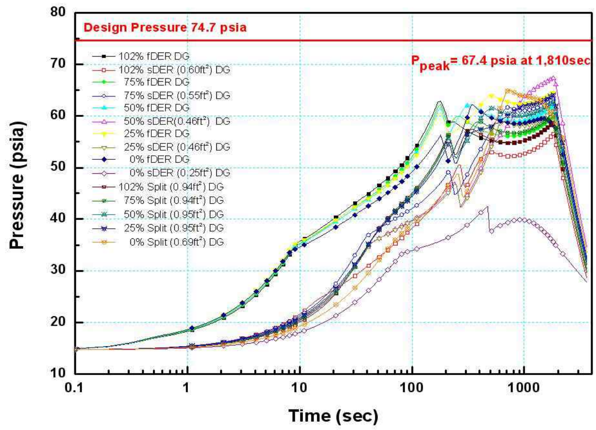

Fig. 5 Containment peak pressure analysis

4. Conclusions

The core response and the containment peak pressure were analyzed in this study. The change in the boron concentration of the BIT has an impact on the core response but containment integrity is not sensitive to it. According to the results of an investigation of both core response and the containment integrity, the design modification of the boron injection tank is likely to be feasible.

REFERENCES

[1] CONTEMPT-LT/028 A computer program for predicting containment pressure-temperature response to a Loss-of-Coolant Accident user's manual, January, 1983.

[2] COPATTA-Containment pressure/temperature transient analysis code, Vol Ⅱ(Theoretical user guide)

[3] M.Zelinsky, "Pressure-Temperature Transient Containment Analyses Loss of Coolant Accident", Bechtel, 2004.12.20.

[4] K.H. Seo, D.S. Song, C.S. Byun, Investigation CONTEMPT and COPPA condensing heat transfer modeling, KNS, 2006.

[5] K.H. Seo, W.J. Song, D.S. Song, C.S. Byun, Benchmarking analysis between CONTEMPT and COPATTA containment codes, KNS, 2007.