

Qualitative Safety Analysis for a Guaranteed Shutdown Condition of CANDU 6 Reactor

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1. Introduction

The safety analysis of the Wolsong CANDU Reactors was conducted based on AECB C-6 Rev.0[1]. According to this document, there is no requirement to perform a safety analysis under the guaranteed shutdown condition. The guaranteed shutdown condition is a condition in which the reactor is fully shut down and cannot return to criticality, even if safety systems are unavailable. Therefore, it is sufficient to conduct safety analyses solely for power operation conditions. However, according to recent regulatory document such as REGDOC-2.4.1, the performance of safety analysis for all operational modes is required[2]. From this perspective, this study qualitatively examines the potential consequences of accidents occurring under a guaranteed shutdown condition. The focus is on the CANDU 6 reactor type, and the analysis is qualitatively evaluated based on the safety analysis previously conducted under power operation conditions, in order to determine whether the existing safety analysis remains applicable to the guaranteed shutdown condition.

2. Methods and Results

2.1 Methods

Deterministic safety analysis groups together events with similar accident progression and consequences, and analyze the most limiting accident among them. This process is at times carried out through qualitative review. In this paper as well, a qualitative review was conducted with the entire set of FSAR(Final Safety Analysis Report) Chapter 15 accidents in mind, under the assumption that an accident occurs at the guaranteed shutdown condition[3].

2.2 Qualitative review and screening out

In the guaranteed shutdown condition, the reactor remains shut down; hence, trip coverage analysis applicable to the majority of non-LOCA(Loss-Of-Coolant-Accident) events are not required. Furthermore, as no feedwater is supplied to the secondary side, it is unnecessary to analyze accidents related to the feedwater and steam systems of the secondary circuit. Accordingly, in the guaranteed shutdown condition, the review may be limited to LOCA events in the primary side.

2.2 Qualitative review results

The LOCA events in the existing FSAR Chapter 15 of Wolsong NPPs are broadly classified and analyzed as large-break LOCAs and small-break LOCAs based on the guillotine break size of a single feeder pipe. Taking into account a partially drained condition, the PHTS(Primary Heat Transport System) level is lowered to the reactor inlet and outlet headers, and thus break sizes typically postulated in large-break LOCA may be excluded from consideration.

If a small break accident is assumed to occur under conditions where shutdown cooling system is connected and residual heat is being removed, both scenarios with and without ECCS(Emergency Core Cooling System) operation may be considered. Although ECC injection is normally isolated under such conditions, adequate fuel cooling would be ensured if the operator were to initiate ECC injection. In the absence of ECC injection, the primary coolant will continue to heat up reaching boiling at 100°C. The primary side system pressure under this condition is considered to be atmospheric. Alternatively, in the event of complete coolant depletion, the worst-case scenario involves the fuel bundles being heated within a steam environment. Under these atmospheric pressure conditions, fuel behaviour with exposure exclusively to a steam environment has been analyzed in a case of small-break LOCA involving loss of ECC injection in FSAR Chapter 15[3]. Therefore, a quantitative new analysis for the guaranteed shutdown state is deemed unnecessary.

3. Conclusions

A qualitative review was performed to evaluate the safety of the guaranteed shutdown condition of a CANDU 6 reactor. The results indicate that no further quantitative analysis is required, and for the small LOCA without ECC injection, the assessment relies on the existing safety analysis results for power operation presented in Chapter 15 of the FSAR. Thus, a LOCA under the guaranteed shutdown condition is bounded by the small break LOCA accompanied by loss of ECC injection. In conclusion, this simple and qualitative assessment confirms the safety of the guaranteed shutdown state.

REFERENCES

- [1] AECB, Requirements for the Safety Analysis of CANDU Nuclear Power Plants, Consultative Document C-6, June 1980.
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- [3] Korea Hydro & Nuclear Co. Ltd., Final Safety Analysis Report Chapter 15 for Wolsong NPP Units 2, 3 and 4, July 2023.