

Applicability of Leak-Before-Break (LBB) Technology for the Primary Coolant Piping System to CPR1000 Nuclear Power Plants in China

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1 ABSTRACT

The China Nuclear Power Design Company LTD., (CNPDC) plans to apply Leak-Before-Break (LBB) technology in the reactor primary coolant piping of CPR1000 nuclear power plants, and has done a lot of comprehensive research, analysis, feasibility studies, aiming at practical application into GUANGDONG YANG JIANG nuclear power plant Unit 3 before 2010 (It is a new project and construction has not started yet). As a first step, CNPDC has completed the J-R curve test of the Primary Coolant Piping material under a range of various temperatures and loading rates, including dynamic loading conditions. At the same time, CNPDC has made an extensive research, to develop and verify the evaluation method for fracture behavior of Chinese piping material. In this paper, we reviewed all sub-steps of LBB application based on the LBB design analysis procedure. It will be possible for CNPDC to successfully apply LBB technology for primary coolant piping in YANG JIANG nuclear power plant Unit 3.

2 INTRODUCTION

Since the early 1980's, the Leak-Before-Break (LBB) technology is widely used in the nuclear industry to describe the idea that in the piping carrying the coolant of a power reactor a leak will develop before a catastrophic break will occurred. The LBB concept could be accepted as a technically justifiable approach for eliminating postulated double ended guillotine break (DEGB) in high energy piping systems with respect to resulting dynamic effects, in accordance to the General Design Criteria (GDC)-4 which was then the U.S licensing requirement. This conclusion has resulted from extensive research, development, and rigorous evaluations by the United States Nuclear Regulatory Commission (USNRC) and the commercial nuclear power industry and its organizations since the early 1970s. In this paper, we reviewed the applicability of Leak-Before-Break (LBB) technology for primary coolant piping systems to CPR1000 nuclear power plants in China, based on LBB design concept analysis procedure, results and standard design certification document.

3 THE PRIMARY COOLANT PIPING SYSTEM DESCRIPTION

The primary coolant piping system of the CPR1000 (the Improved Chinese Pressurized Water Reactor with 1000MW class) nuclear power plant consists of 3 loops, each comprising one steam generator, one reactor coolant pump and reactor coolant piping connecting these components to the reactor vessel. For each loop, the reactor coolant piping comprises the following sub-assemblies:

- 1) A hot leg, connecting the reactor vessel to the steam generator, comprise: a straight section and a 50° elbow.
- 2) A crossover leg, connecting the steam generator to the pump, comprise: a 40° elbow, two 90° elbow, a straight vertical section and a straight horizontal section.
- 3) A cold leg, connecting the pump to the reactor vessel, comprise: a straight section and a 28° elbow.

Addition, each leg is provided with a certain number of 90° nozzles, one of which, located on a cold leg, comprises a thermal sleeve, and each cold leg is also provided with a 45° inclined nozzle.

The straight sections are made of centrifugally cast pipes, the chemical composition and mechanical properties are given in § M 3406(grade Z3CN20-09M) of RCC-M,2007; the elbows and the 45°inclined nozzles are cast in a single piece, the chemical composition and mechanical properties are given in §M 3403(grade Z3CN20-09M) of RCC-M,2007; the 90°nozzles and the thermal sleeve are made from forged rounds or blanks, the chemical composition and mechanical properties are given in § M 3318(grade Z2CND18-12) of RCC-M,2007.

The pipe connections are field weld using Gas-Tungsten-Arc-Welding (GTAW) root and filled with Shielded-Metal-Arc-Welding (SMAW) process.

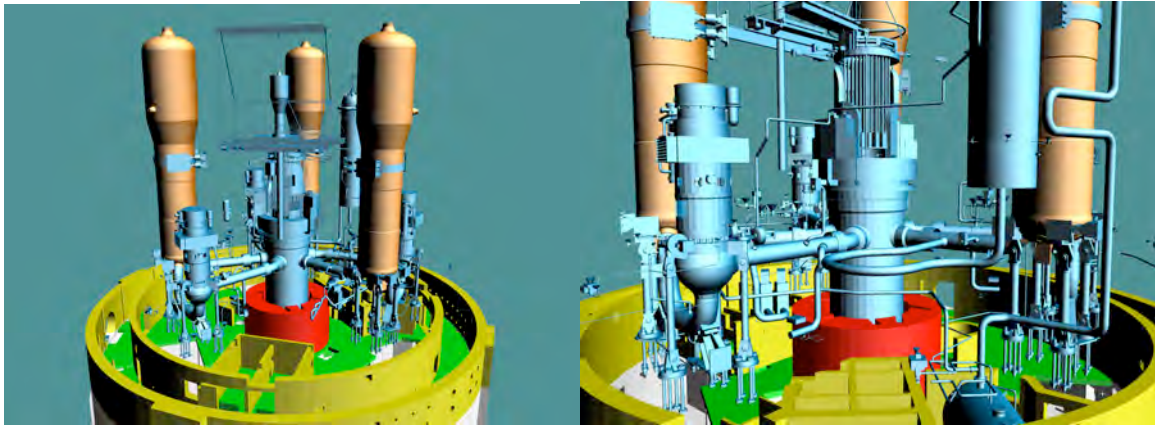


Figure1. Schematic of three-dimensional geometry of the primary coolant piping system of CPR1000

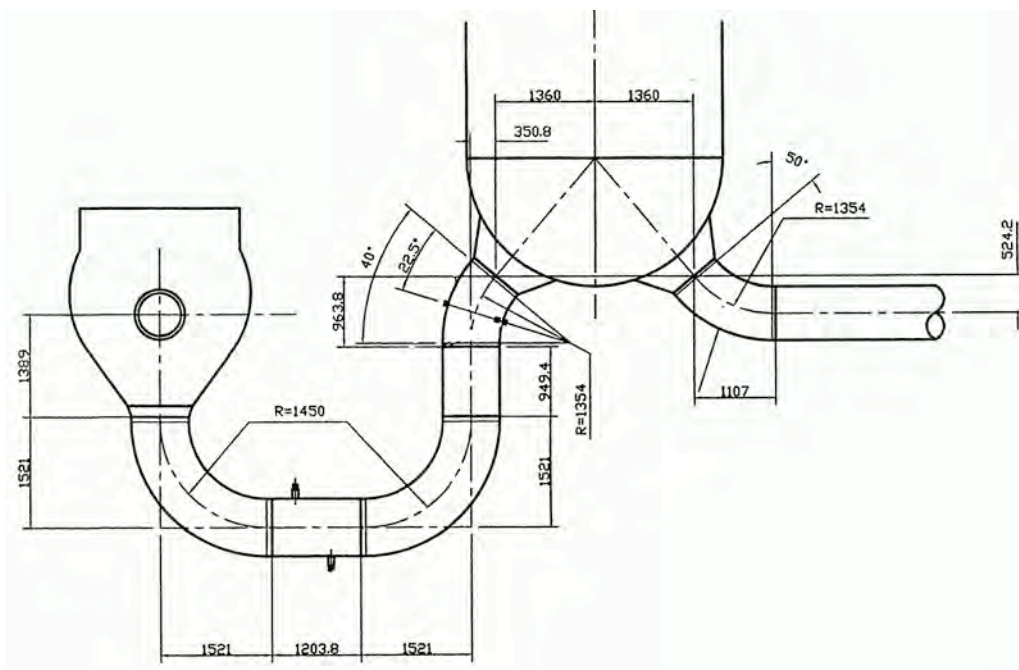


Figure2. The primary coolant piping system of CPR1000 layout

4 REVIEW OF THE TECHNICAL FEASIBILITY

To apply LBB technology in the reactor primary coolant piping system of CPR1000 nuclear power plants, CNPDC has basically completed the assessment and analysis work or under way, mainly include the following aspects:

4.1 Mechanical analysis of the primary coolant piping system

Object: establish mechanical analysis model of the primary coolant piping system; finish the mechanical analysis under design, normal operation, expecting transient and accident working condition; and provide

result of SSE analysis, and rupture loading analysis of all high energy pipelines connected to the primary coolant piping system. The aforementioned analysis result shall be the input of LBB analysis.

4.2 Identify the location of the most unfavourable combination of stress and material

Object: locate the most unfavourable combination of stress and material through stress analysis on main piping system.

4.3 Hypothesis crack leakage rate calculation

Object: make the hypothesis crack locating at the most unfavourable combination of stress and material, and calculate the relation between leakage rate and crack size under normal operating condition.

4.4 J-integral and critical flaw size calculation

Object: calculate J-integral and critical flaw size calculation.

4.5 Stability analysis of detectable leakage size flaw

Object: evaluate the stability of detectable leakage size flaw in every operating condition.

4.6 Invalidation analysis on water hammer, corrosion, erosion, creep damage, fatigue and environmental conditions

Object: analysis and identify the impact of water hammer, corrosion, erosion, creep damage, fatigue and environmental conditions on the rupture of main piping, and demonstrate the probability of main piping rupture caused by aforementioned reasons is extremely low and confirm that the piping is not sensitive to those phenomena

4.7 Material and welding requirements

Object: to evaluate and determinant of the whole set of required input data. The aim of the formulation of a materials testing program (base metal, weld metal) are to elaborate fracture toughness data for more advanced quantitative FM calculations (J-R curves and true stress strain curves). A more detailed stress analyses will be made, to show that the criteria for static and seismic strength for all selected highly stressed and weak points were met. Fatigue cyclic strength calculations will be carried out to compare designed and realized cumulative usage factor.

4.8 Assessment of the Leak Detection and In-Service Inspection system required.

Object: to evaluate the existing Leakage Detection System of CPR 1000 NPP to meet the LBB technology application requirements, mainly based on the USNRC Regulatory guide 1.45 "Guidance on monitoring and responding to reactor coolant system leakage". The Leak Detection System capability at the CPR1000 must be able to detect a leakage which is 10 times smaller than the leakage through a "reference leakage crack". The critical crack size for a TWC must be 2 times larger than the reference leakage crack. When a piping fulfils above LBB criteria emergency pipe whip restraints are not needed in order to provide access for In-Service Inspection system.

5 CONCLUSION

All missions are concluded that LBB methodology is successfully applied to CPR1000 NPP with word practices, and that postulated fractures in deterministic analyses are unlikely to occur. It will be possible for CNPDC to successfully apply LBB technology for primary coolant piping in YANG JIANG nuclear power plant.

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