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ASME Code Case N-481 Evaluation for Kori Units Reactor Coolant Pump Casing

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1. Introduction

ASME Boiler and Pressure Vessel Code, Section XI requires the periodic inservice inspection of various nuclear power plant components. Specifically, the inservice inspection requirements of pressure retaining welds of pump casings (Category B-L-1) are delineated in Table IWB-2500-1 of the Code. The requirements call for the periodic visual and volumetric examinations of the welds using radiography or ultrasonic inspection (UT). To perform a volumetric inspection, complete disassembling of the pump, lowering of primary coolant water level and unloading of core are required. The inservice inspection of cast stainless steel pump casing using radiography or UT has proved to be a very difficult challenge in nuclear industry. The primary coolant pump casings are inspected twice prior to placing in service. There are no significant mechanisms for crack initiation and propagation. In recognition of these facts the ASME approved Code Case N-481 which provides an alternative to the volumetric inspection requirement.

These alternate requirements consist of visual inspections and an analytical evaluation to demonstrate the safety and serviceability of the pump casings in the presence of postulated flaws.

The object of this paper is to address the analytical aspect of Code Case N-481 as it applies to the primary coolant pump casing at Kori.

2. Methods and Results

2.1 Evaluation Procedure of ASME Code Case N-481.

The ASME Code Case N-481 procedure provides fracture toughness criteria for protection against the failure of reactor primary loop pump casings with a postulated flaw. Figure 1 shows the procedure.

2.2 Description of the Primary Coolant Pump Casings of Kori Units.

The primary loop pump casings of Kori Unit 2 are Westinghouse Model 93A design. The primary loop pump casings of Kori Units 3 and 4 are Westinghouse Model 93A-1 design. The Geometry of the pump casing model 93A is shown in Figure 2. The casing geometry of 93A and 93A-1 models is identical.

2.3 Material Prosperities

The Kori Units pump casings are fabricated from SA351 CF8. The pump certified material test reports (CMTRs) were used to establish the tensile properties for the fracture mechanics analysis.

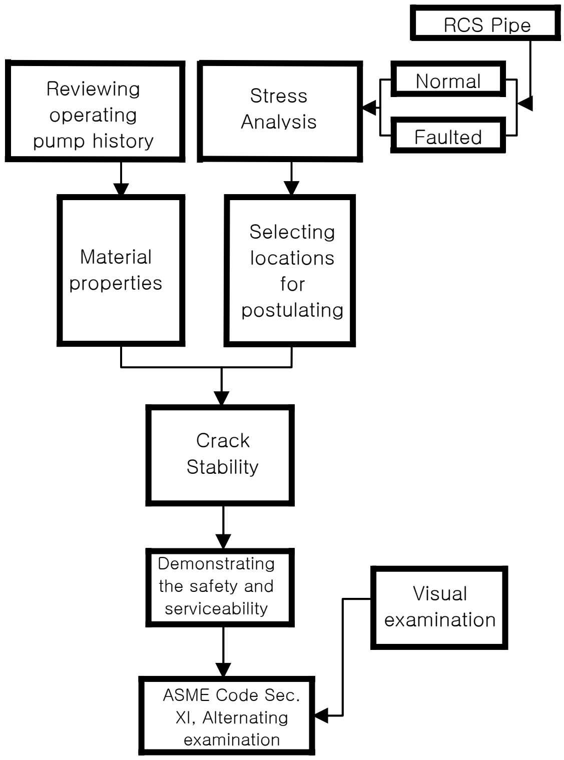

Figure 1. Procedure for ASME Code Case N-481

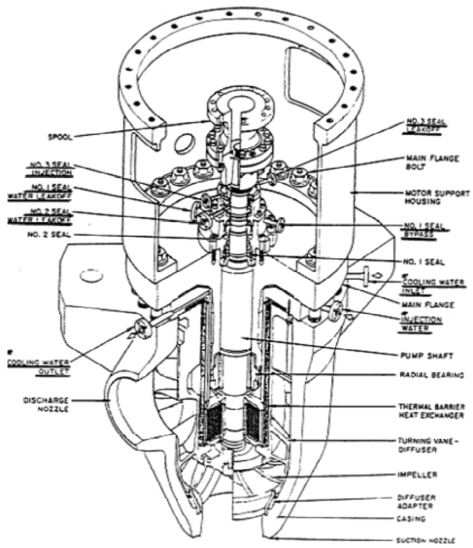

Figure 2. Model 93A Pump Casing

The chemical composition of each heat of material used in fabricating the Kori Units pump casings is taken from the certified material test reports (CMTRs).

During service at operating temperature, the cast austenitic stainless steels become embrittled with time. Predictions for the end-of-life fracture toughness values are based on the material chemistry content. The kinetics of thermal embrittlement has explained in detail by Chopra, et el [6]. The chemical composition of the casting is important parameter which influences the embrittlement. The SAW and electroslag welds respond in a very limited manner to thermal aging and are not limiting for the enveloping toughness criteria.

2.4 Stress Analysis of the Pump Casing

Detailed stress analyses for Model 93A were performed by Witt and Petsche [3]. A large three-dimensional (3D) finite element model, containing the nozzles, was developed for the pump casing by Westinghouse.

Using the finite element stress analysis results, plant specific through-wall stresses for Kori Units at postulated flaws locations can be obtained.

2.5 Selection of Locations for Postulated flaws

Three criteria for flaw location selections are applied as follows:

- for each weld, a flaw will be located in the highest stressed region
- flaws will be located in regions of significant stress concentrations
- flaws will be located in welds not affected by discontinuities such as nozzles.

Four locations were selected for postulating quarter thickness flaws in the Model 93A pump casing.

2.6 Stability Analysis

An analysis is conducted to determine whether enough margin is available to allow the Kori Units pump casings to meet the stability criteria. A postulated flaw is stable if either:

- $J_{applied} < J_{Ic}$ or
- If $J_{applied} \geq J_{Ic}$ then
  $T_{applied} < T_{material}$ and $J_{applied} \leq J_{max}$

All flaws postulated in Kori Unit 2, 3 and 4 pump casing per Code Case N-481 meets the stability criteria.

2.7 Operation and stability of the Reactor Coolant System

The primary loop of Westinghouse reactor coolant system has an operation history which demonstrates the inherent stability characteristics of the design. This includes a low susceptibility to cracking failure from the effects of corrosion, water hammer, or fatigue.

3. Conclusion

The evaluations demonstrate that the Kori Units pump casings meet the safety and serviceability requirements of ASME Code Case N-481. The actual fracture toughness and yield strength values of Kori units were used in the analysis. Stress analyses of a representative primary loop pump casing are presented in reference 3. The operating history of Westinghouse design primary loop pumps is reviewed. Flaws are postulated in the pump casings and evaluated the stability criteria. The effect of thermal aging has been evaluated. No other mechanism is known to degrade the properties of the pump casing during service.

The primary loop pump casing of Kori Units 2, 3 and 4 are in compliance with ASME Code Case N-481.

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