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FEASIBILITY OF DEVELOPING GENERIC PIPING INSERVICE INSPECTION REQUIREMENTS

T. V. Vo
B. W. Smith
F. A. Simonen

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INTRODUCTION

The objectives of a multiyear program entitled Nondestructive Evaluation Reliability for Inservice Inspection of Light Water Reactors (LWR), which is being conducted at Pacific Northwest Laboratory (PNL), are to determine the reliability of current inservice inspections (ISI) of pressure boundary systems and components and to develop recommendations that can ensure a suitably high inspection reliability. The long term objective is to propose changes to Section XI of the American Society of Mechanical Engineer's code for inspection of nuclear power plant components.

In evaluating methods that could be used to provide a technical basis for improved ISI plans, PNL developed a method that uses results of probabilistic risk assessment (PRA) to establish piping system ISI requirements. The feasibility of generic ISI requirements is being evaluated in two phases. Phase I involves identifying and prioritizing the systems most relevant to plant safety. In this phase, PNL establishes the extent to which generic insights drawn from detailed evaluations of selected plants can be extrapolated to different classes of LWRs. This paper presents Phase-I results of evaluations for eight selected plant PRAs. The results of these evaluations will be consolidated into requirements for comprehensive piping system inspections that will be developed in Phase II.

METHODOLOGY

The Weld Inspection Importance Measure (Iw) defined by PNL (1) is used to rank systems in this study. Physically, Iw is an approximation of core melt risk due to weld failures. Iw for a system is defined as the product of the Birnbaum Importance Measure multiplied times the weld failure probability for that system.

$$Iw = Ib*Pi \qquad (1)$$

where

Ib = Birnbaum Importance Measure (the change in risk that is associated with a total system failure)

Pi = estimated system pipe break probability.

Other importance measures (e.g. the risk achievement and the risk reduction worth) were calculated to obtain more information concerning the Birnbaum Importance Measure for a given system (2). The Birnbaum Importance Measure, Ib, is defined as the sum of the risk increase and reduction worths on the interval scale.

$$I_i^B = Ai + Di \qquad (2)$$

where

Ai = risk achievement or risk increase (i.e., the increase in risk if the component was assumed to be failed)

Di = risk reduction (i.e., the decrease in risk if the component was assumed to be made perfectly reliable)

Evaluation of system priorities using the Birnbaum Importance Measure is readily accomplished by using Equation (2) and the results of the PRA, (i.e., the sum of the A and D for components is then Ib for the given system.) It is worth noting that the methodology may be generalized to address pipe cracking and wall thinning as well as to weld failures; however, this paper focuses on welds as welds are more susceptible to failure.

The system pipe break probability (Pi) can be evaluated by either fracture mechanics analyses or can be based on historical pipe failure data. For this study, the estimates were based on observed weld failure data from operating nuclear power plants in the United States (1).

PLANTS SELECTED FOR STUDY

Because the scope of the feasibility study does not permit evaluations of all LWRs in the United States, the analyses have focused on inspection requirements for a few well documented plants. The criteria used for selecting these plants include: the reactor vendor, vendor's plant type, the architect-engineer (A-E), and the availability of a state-of-the-art PRA.

The analyses began with a review of the commercial LWRs designed by the four reactor vendors: Westinghouse, Combustion Engineering, Babcock and Wilcox and General Electric. For a given reactor vendor, the specific reactor types were also considered, particularly for Westinghouse and General Electric designs. Because of differences in support system designs, even for plants from the same reactor vendor, the selection process also considered impacts of A-E design practices. The overall objective was to select a cross section of plants that are representative of all operating reactors.

Seven plants (in addition to Oconee-3 from the earlier study) were selected. These plants are listed in Table 1. Calvert Cliffs-1 was included in large measure because it is the only Combustion Engineering plant that has a completed PRA. To be generic, the Calvert Cliffs-1 results were compared with available information from the Generic Combustion Engineering System 80 PRA.

TABLE 1. Plants Selected for Feasibility Study

Plant Name	Vendor/Type/A-E (a)
Surry-1	W/HP/S&W
Zion-1	W/HP/S&L
Sequoyah-1	W/HP/Utility
Oconee-3	B&W/-/Bech-Utility
Crystal River-3	B&W/-/Gilbert
Peach Bottom-2	GE/BWR4/Bechtel
Grand Gulf-1	GE/BWR6/Bechtel
Calvert Cliffs-1	CE/-/Bechtel
System 80 PRA	Combustion Engineering

(a) W = Westinghouse design.

B&W = Babcock and Wilcox design.

CE = Combustion Engineering design.

GE = General Electric design.

HP = high pressure plant type.

RESULTS

Applying the methodology presented above to the plant PRAs listed in Table 1, the system Weld Inspection Importances for the first four plants (Oconee-3, Crystal River-3, Surry-1, and Calvert Cliffs-1) were calculated and are presented in Figure 1. The calculated system importances were based on the total core damage frequency (Level I PRA).

From Figure 1, the system Weld Inspection Importance Measures indicate that the front-line systems (e.g., low-pressure injection, high-pressure injection, etc.) are the most risk-important, because these systems have functions that are important in preventing the uncovering of the reactor core following an accident. The support systems (e.g., the emergency feedwater, service water systems, etc.) follow in risk-importance ranking. The remaining systems (e.g., reactor coolant, power conversion, etc) have the least risk-importance primarily because of their low weld-break probabilities.

Based on these initial results, it appears that there are generic insights that can be extrapolated from the selected plants to specific classes of LWRs. Information and insights from this paper will be compared in future work to results of additional plant-specific studies to validate the preliminary conclusions. The results of these future activities will be consolidated to develop a plan for comprehensive piping inspection requirements that will be formulated in Phase II of the PNL study.

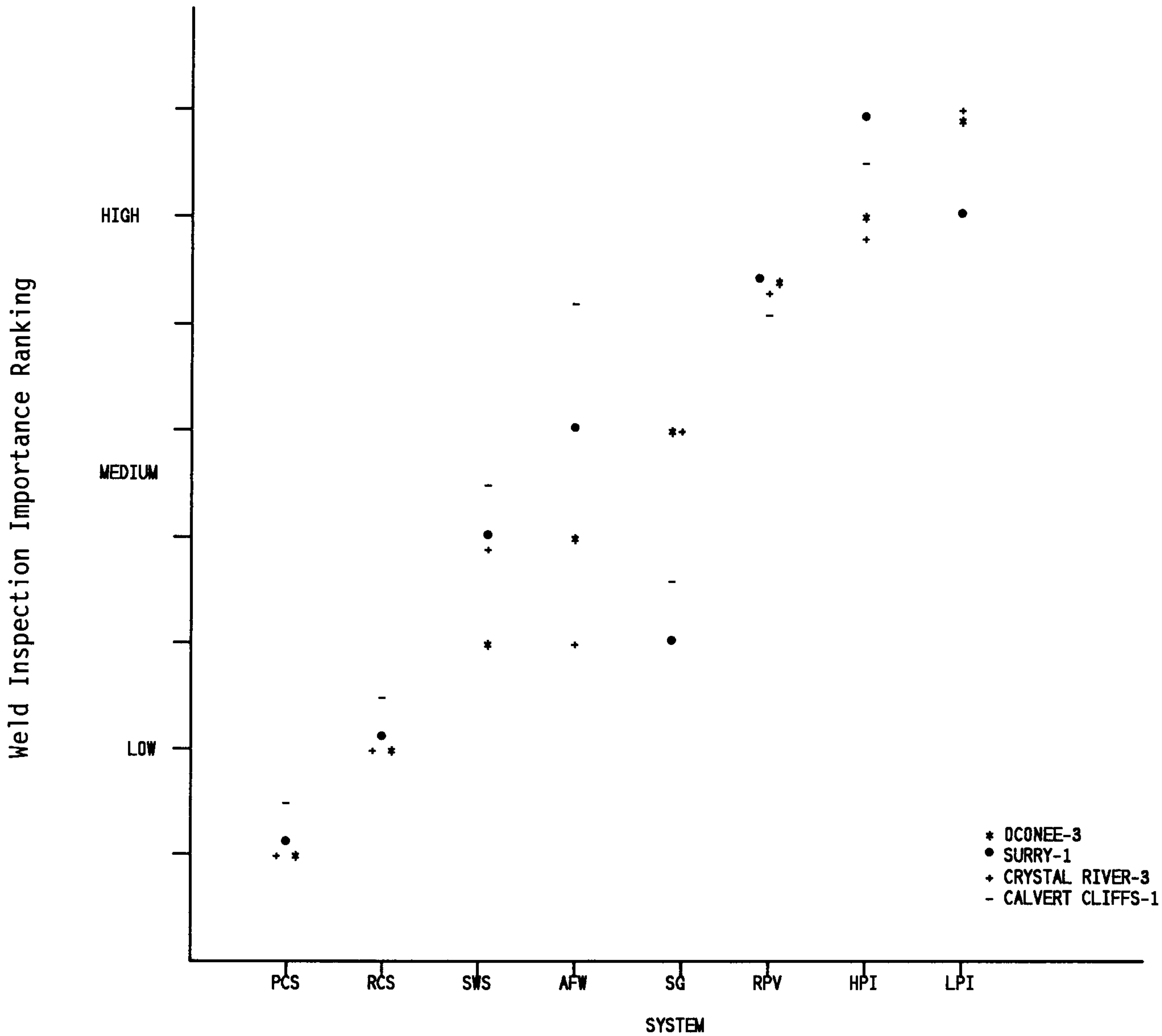

FIGURE 1. Weld Inspection Importance Ranking for Various Systems Based on Core Melt Frequency

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