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PWR INTERFACING SYSTEM LOCAs: ANALYSIS OF RISK REDUCTION ALTERNATIVES*

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Interfacing system loss-of-coolant accidents (ISLs) refer to events where the integrity of the Reactor Coolant System (RCS) pressure boundary is breached through failure of isolation valves which separate a support or safety system of lower design pressure. The resulting overpressurization will affect the availability of the low pressure system to mitigate the accident. In addition, it may result in a scenario (V-event) where primary coolant is directly discharged into the auxiliary building bypassing the containment. The Reactor Safety Study (WASH-1400)[1] predicted that ISL events were significant contributors to risk even though they were calculated to have a relatively low frequency of occurrence.

The risk potential of ISL events was confirmed in subsequent probabilistic risk assessment (PRA) studies. However, in spite of the numerous PRA analyses, substantial uncertainties remained in determining the frequency and consequences of ISL scenarios (e.g., valve failure modes, common cause contributions, location of the break/leak etc. all of which influence the predicted risk).

Because of the high risk potential and the uncertainties involved, a reexamination of the ISL issue[2] was performed for the Nuclear Regulatory Commission by Brookhaven National Laboratory. The subject study was aimed to a) investigate the vulnerability of PWRs of different designs to all kinds of ISL events including those which do not bypass the containment, b) provide more realistic estimates for the core damage frequencies (CDFs) and to reduce the uncertainties as low as possible, and c) identify any improvements with an emphasis on instituting appropriate valve testing requirements that could significantly reduce the frequency of these events.

Three reference plants (representative of different PWR designs as well as architect engineers) were selected for the analysis and all major ISL pathways were investigated. The dependencies due to common or shared pathways with the accumulators were specifically treated. For each pathway an appropriate initiator model was developed corresponding to the specific valve arrangement. The initiator models involved all of the relevant check valve and MOV failure modes. For the isolation check valves, flow-dependent leak failure rates were used which allowed consideration of the effects of the relief valves of the low pressure systems. The analytical initiator models also enabled the incorporation of the effects of different test and/or leak monitoring practices for sensitivity studies. The initiator models were quantified by appropriate new data derived by searching the data bases[3] for ISL precursors and by using established generic valve failure data.

Specific event trees were developed for each pathway, which included pipe rupture probabilities as well as the expected plant responses and operator actions. The timing of expected operator actions and the progression of the

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plant responses were determined using the results of various thermal-hydraulic studies (e.g., Ref.4). The end states of the event trees were connected to plant-specific event trees (contained in the reference plant PRAs) through conditional core damage frequency multipliers which also included the effect of any spatial interactions.

The CDFs due to ISL events that bypass the containment were calculated to range from 3×10^{-6} to as low as 3×10^{-9} per year depending on the plant features. In general, two groups of lines (the residual heat removal suction and the low pressure injection) were found to be the dominant contributors to CDF. One of the major findings of this study was that the most likely direction of an ISL through the low pressure injection lines would be through the accumulators; representing a LOCA inside containment.

In order to identify possibilities for improvement in reducing the frequency of ISLs, the BNL investigation focused on current industry testing practices for the pressure isolation valves. Under present conditions, there is a wide range of testing policies across the U.S. PWR population. For purposes of the study, this range of PIV testing policies was represented by two cases. One case (represented by the reference plants) in which leak testing of most or all of the PIVs is done on some frequency according to the Technical Specifications and the other case in which the Technical Specifications do not include such provisions. This second case (for bounding purposes) assumes no leak testing of the PIVs. Based upon these two cases, two separate groups of actions were considered to determine effective methods of reducing the risks due to ISLs.

First, for plants with few or no present Technical Specification requirements for any leak testing of the pressure isolation valves, the effect of leak testing as a basic requirement was analyzed with respect to test frequency and placement of testing. In the other group (those with some leak testing requirements already established), corrective actions such as additional leak testing, continuous leak monitoring, improved operator training and refueling water storage tank (RWST) makeup procedural changes were examined for their potential to enhance the effectiveness of an already instituted test program.

Since all of the three reference plants already performed some level of leak testing for their pressure isolation valves, a fourth plant model representing a generic base case was also created and evaluated to focus on the cost-benefit considerations of the effects of instituting comprehensive leak testing programs on plants that do not currently have such programs.

Table 1 presents the calculated reduction factors in core damage frequency by applying various corrective actions. The data indicate that the institution of new leak testing programs is capable of reducing the CDF due to ISLs by two orders of magnitude depending on the specific testing strategies. It is important to note that the difference between the 18 months (Case C) and the nine months critical path testing (Case B) is only about a factor of four, suggesting that a program with 18 month test intervals may be almost as effective in reducing the CDF as a program with more frequent tests. In addition, substantial cost savings may be achieved by performing the leak testing during descent from power without significantly increasing the risk of an ISL event (only a factor of about two difference between Case C and D).

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Table 1 also lists the results of plant-specific analyses for the second group of corrective actions, which attempts to increase the effectiveness of already established testing programs. These reductions, however, are rendered largely ineffective when the corresponding cost considerations are also included in the analysis. The cost considerations are dominated by testing performed during power ascension thus becoming "critical path" activities.

In summary, the present analysis suggests that the most cost-effective method to reduce the risk due to ISLs would be to establish a minimum testing frequency for pressure isolation valves. The suggested minimum frequency would be to perform leak testing of the pressure isolation valves at each refueling and after specific individual valve maintenance. In addition, it would also appear that the tests could be performed during descent from power without significantly increasing the risk of an ISL event and effecting considerable cost savings to the utilities. The full paper will provide an in-depth description of the analysis, the results and the insights which will be factored into the resolution of this issue. A summary paper[5] on this topic was presented at the June 1988 ANS Meeting in San Diego and focussed on the benefit of various valve leak testing schemes.

References

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Table 1
Reduction in CDF - Generic Model

Corrective Actions

Group 1				Group 2	
	CDF Reduction Factor (Relative to Case A)	Benefit/Cost Ratio*			CDF Reduction Factor (Relative to Present Practice)
Cases (CDF)		Nonsubmerged Release	Submerged Release	Cases	
A-Base Case w/o Leak Test (3.26-04)	——	——	——	1-Leak Test After Each Cold Shutdown	~1-6
B-Leak Test Every Nine Months/ Critical Path (8.42-07)	~400	1.7	1.0	2-Continuous Leak Monitoring	~1-2
C-Leak Test Every 18 Months/ Critical Path (3.28-06)	~100	3.3	1.9	3-Improved Operator Training	~1
D-Leak Test Every 18 Months/Not in Critical Path (6.11-06)	~55	78.2	46.0	4-RWST Makeup Procedure	~1-2

*In order to bound the benefit calculation, two sets of source terms were used. One source term representing a reduction factor associated with a submerged release and the other representing a nonsubmerged release.