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AUXILIARY FEEDWATER-SYSTEM RELIABILITY STUDIES*

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The purpose of this paper is to describe the BNL review process applied to the reliability analyses of Auxiliary Feedwater Systems (AFWS) submitted by operating license applicants to NRC in order to satisfy the pertinent Standard Review Plan requirements. Some generic comments on the availability characteristics of the AFWS are also presented. This work represents an application of a quantitative reliability goal to the regulatory process.

After the accident at Three Mile Island, the Auxiliary Feedwater Systems of all then-operating plants were studied in an effort to assess variations in the reliability of different AFWS designs. For Westinghouse plants, results were given in NUREG-0611 Appendix III, where it was shown that AFWS unavailability (defined below) ranged over two orders of magnitude for operating plants.

Since then, operating license applicants have been required to perform similar analyses of their AFWS. The new Standard Review Plan (NUREG-0800) states: "An acceptable AFWS should have an unreliability in the range of 10^{-4} to 10^{-5} per demand based on an analysis using methods and data presented in NUREG-0611 and NUREG-0635". Several of these analyses have been reviewed by BNL as part of a technical assistance program with the Reliability and Risk Assessment Branch, NRR/NRC.

The important features of the approach are the following. The top event of interest is failure to deliver AFW in sufficient quantity and within a short enough time to prevent steam generator dryout, given each of the following three initiators: loss of main feedwater (LMFW), loss of offsite power (LOOP), and loss of all offsite and onsite AC (LOAC). The boil-dry time, the quantity of water necessary, and the number of steam generators required to

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remove decay heat vary from plant to plant. The probability per demand that the AFWS will fail according to the above definition is to be calculated using data supplied in NUREG-0611 (Table III-2). The focus is on the response of the AFWS to loss of feedwater events, so some events which might conceivably contribute to boil-dry are not factored into AFWS unavailability (e.g., steam generator depressurization, pipe rupture, failure to isolate blowdown lines, etc.). Events which are included are such things as failure to actuate the AFWS, failure of pumps to start, operator errors causing valves to be misaligned, etc.

BNL's review of these studies covers the following. In order to check for completeness and accuracy, the study's fault trees are requantified at BNL. If failure events have been omitted from the utility-supplied fault tree, they are added; if failure events have been included which are inappropriate given the scope of the present studies, they are removed. If "plant-specific" data have been used in the study, WASH-1400 or NUREG-0611 data are applied as necessary to bring the results into conformity with the SRP's guidelines. If a failure probability has not been given for each of the three initiators (e.g., if only an "average" unavailability is given), the tree is requantified as necessary to provide this information. Plant visits and conversations or meetings with utility personnel are arranged as necessary to provide a basis for a reasonable estimate of AFWS unavailability within the boundary conditions imposed on the review.

Based on experience gained so far, the following comments are in order. It is extremely difficult for a two-train system to meet the SRP requirement, especially given LOOP. The details of this naturally vary from plant to plant, but the essential statement is that a single train whose maintenance unavailability, failure to start, and valve blockages are quantified according to the guidelines will be found to have an unavailability on the order of 10^{-2} or more for LMFW, and this increases substantially for LOOP if the train requires emergency AC. A two-train system unavailability can approach 10^{-4}/D if emergency AC is not a factor, but cannot in most cases properly be said to lie "in the 10^{-4} to 10^{-5} range" unless this is taken to mean "near 10^{-4}".

The emphasis in these reviews is on standardization of the results, so that they can meaningfully be compared with the SRP goal. Sufficient operating experience is being accumulated that it is becoming possible also to make a meaningful comparison with operating experience, to see whether the dominant contributors to actual AFWS failures are being correctly identified. It has been well known for some time that human error is an important contributor, but there is some indication that it is being underassessed in some of these studies. This is not because low values are being used for human error rates, but because the actual range of relevant possible coupled human errors has not been adequately addressed.

The approach to safety discussed here is the imposition of a standard for the probability of failure of a safety system. Application of this approach depends strongly on the scrutability of the analyses. This imposes stringent requirements on their form and their content. In some cases, for SRP purposes, the analysis has had to be substantially repeated. Even within the limits prescribed, however, it is possible to gain significant insight into system characteristics, as was already shown by NUREG-0611, and such analyses can be expected to benefit the utilities in ways that go beyond meeting the SRP requirements.