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MEMORANDUM FOR: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

FROM: Richard H. Vollmer, Director
Division of Engineering

SUBJECT: EXTERNAL EVENTS IN PROBABILISTIC RISK ASSESSMENTS (PRA)

In September of 1981 and March of 1982, the Zion and Indian Point (Z/IP) probabilistic risk assessments (PRAs) were submitted by the utilities operating these plants. These PRAs included analysis of risk due to accident initiators commonly called external events. External events include earthquakes, fires, floods, high winds, including missiles picked up by such winds, aircraft impacts, turbine missiles, and hazards due to river barge traffic and nearby gas pipelines. In spite of the fact that the Z/IP analyses provided numerical results, this Division believes that external events should not be included at this time in the National Reliability Evaluation Program (NREP). This statement would similarly apply to PRAs for standard plants such as GESSAR II.

PRA techniques for external events, of the types utilized in the Z/IP analyses and discussed in detail below, are relatively new as compared to those for internal events. In our reviews of the existing external events PRAs, we have observed that conservative assumptions are frequently used in these analyses because of the lack of mature methodology. It is generally agreed that the results obtained from PRA of external events are more conservative than the results from internal events. Significant development will be required to understand and reduce the sources of uncertainties in the present methodologies and to develop an accepted approach that is based on consistent assumptions for all types of accident initiators. It would be inconsistent with the basic concept of NREP to include analysis areas that will be changing during the course of the program and, in fact, that would be advancing partly as a consequence of the experience gained from the analyses. For decision-making it is important to develop methodology that can be consistently applied to plants to assess the impact of real design differences and not different methodological assumptions. The development of the methodology will require the combined resources of RES, NRR and industry. With proper direction and adequate resources devoted to advancing these PRA techniques, it may be possible to start analyzing some external event initiators in the third group of NREP plants (FY 1985 time frame). In the following paragraphs I have indicated the basic shortcomings of the present methodology that will have to be addressed by the probabilistic community

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before a mature methodology is available for inclusion in a program such as NREP.

BACKGROUND

The basic approach to the probabilistic analysis of external initiating events consists of four different types of analysis which are then coupled together. First, the expected probability that a plant might experience the particular external event must be quantified. This is called the hazards analysis. Second, the effect of various sizes or severities of external initiating events on specific structures, components, and systems and operator functions, must be determined. This is called the fragility analysis. Third, in the systems analysis, the effect of degraded or failed structures, systems, components or operator functions on the ability of the entire plant to reach a safe, stable shutdown state is analyzed. Finally, an analysis is performed to determine the phenomena and consequences associated with those accident sequences that could lead to offsite exposure. The plant systems analyses and consequence analyses are similar to those carried out for other aspects of a full PRA.

The most significant limitations in the analysis of external event initiators lie in the determinations of the hazards and the fragility. Of these, the fragility analysis is the least susceptible to quantification for PRA analysis. The external events that we have devoted the most resources to in typical staff reviews are seismic, fires and floods. Of the three, the most attention in the development of PRA methodology in the Z/IP PRAs has been given to seismic.

EARTHQUAKES

With respect to seismic hazard, the basic problem is that there is not a long historical record of large earthquakes. There is only one recorded earthquake in the eastern U.S. of magnitude greater than 6. There are a few recorded earthquakes in the central U.S. of magnitude greater than 6. This is the range of most damaging earthquakes. Most instrumental information we have for eastern and central US seismic events is at relatively lower magnitudes, intensities, and accelerations. Consequently, the critical parameters for larger earthquakes in this region, including the likely recurrence intervals between the large earthquakes, cannot be predicted at this time without wide bands of uncertainty. In the western US, where the earthquake activity is higher, there is a more substantial accumulation of data and this includes large magnitude earthquakes.

In addition to the above noted uncertainties associated with earthquake occurrence modeling, there is uncertainty in the ground motion modeling used to relate the size of the earthquake to the ground motion experienced at the reactor site.

The seismic hazard analysis is used to provide accelerations that feed into the structural and component fragility analysis. In a fragility analysis, the probability of equipment or structural failure is determined as a function of a single characteristic of the seismic motion. Since actual earthquakes are so complicated in detail, the use of a single parameter approach to characterize fragility involves unavoidable compromise, and hence error and uncertainty.

For the purpose of probabilistic analysis, failure for a structure is typically defined as sufficient deformation that operability of systems attached to or dependent on the structure is compromised. Experimental data for complete building structures are generally not available for seismically-induced failure. Experiments that have been performed were conducted on structural elements to understand structural behavior. Applicable data from actual earthquakes is limited. Therefore, the determination of these fragilities is heavily reliant on judgment and analysis.

In the analysis of fragility of equipment, the general approach is similar to that with structures. For equipment, experimental data has been collected because of equipment qualification requirements. However, this data is generally in terms of qualification to specified acceleration levels and does not indicate actual fragility levels. Therefore, the development of fragility curves for equipment is also heavily reliant on judgment and analysis. Because items of equipment that could fail under seismic load are so numerous, the problem of fragility analysis is further complicated by the necessity to group equipment into classes characterized by a single fragility curve. This necessity to group equipment is another source of uncertainty.

Our judgment is that the extent of the above-mentioned uncertainties in seismic fragility analyses preclude the use of PRA at this time for absolute risk evaluations, but PRA can be used for making certain types of relative evaluations. The current state-of-the-art for seismic PRA has the potential to provide insights on what the sources of high risk are likely to be. PRA can be used to identify likely high risk candidates and in many cases these insights would not be arrived at from a deterministic review. The numerical results of these analyses alone, however, are not sufficiently reliable quantitatively to be compared with the results of internal events PRAs nor to determine if the sources of high risk should be upgraded.

FIRES

With respect to fires as an accident initiator, the judgment of the staff is that the uncertainties associated with these probabilistic techniques have not been developed enough to use PRA for absolute risk evaluations and even for most relative risk evaluations. The basis for this assertion arises from an examination of the uncertainties in any quantitative analysis of the basic elements that produce a fire. These basic elements are the failure of administrative controls, combinations of equipment failures, and other external events combined with equipment failures. In performing a probabilistic analysis uncertainties are also associated with the assumptions regarding the location of fires, conditions necessary for fire growth to occur and the extent of fire damage, the timeliness of fire discovery, the effectiveness of fire protection features and the fire brigade such that fire growth can be terminated, and the condition of the plant's shutdown systems such that the safe shutdown condition can be maintained. These aspects indicate the large number of parameters that must be understood in order to carry out a PRA for fires. At this time the technology lacks the basic data on fire dynamics and a developed methodology for integrating the fire dynamics, human factors and plant systems needed to conduct reliable and consistent analyses.

FLOODS

Current practice in statistical hydrology involves using annual river flood data from records usually decades long, with a statistical model to estimate return periods of floods. This methodology gives reasonable flood probability estimates for floods with return periods of about the length of record or less. It can, and has, been extended to estimate probabilities of floods with return periods well beyond the record length (e.g., hundreds of years), although this practice can sometimes lead to very misleading results.

Some analysts have tried to extend this methodology to floods of the severity considered in nuclear power plant licensing (i.e., the maximum credible flood that could occur at the site). The major problem with this approach revolves around the following considerations: Extrapolation of events beyond the record length results in error bounds that increase greatly as the return periods increase. Also, the statistical model used for the extrapolation may not be valid for the very low probability floods under consideration. One reason for this is that extremely rare and severe floods may be caused by mechanisms not represented in the relatively short data record.

Another approach is to perform a "mini-PRA" for flooding. In this approach the probabilities of the components that produce floods are estimated. These components include such factors as rainfall depth and duration, storm centering and track, and initial conditions in the river and the drainage basin. Once the probabilities of the components are estimated, they are linked together to determine an overall flood probability. Although this approach may be promising, it is currently not well developed. The problems with this approach arise from the difficulties in estimating probabilities of the components, and the degree to which individual components are interdependent.

Basic research in hydrometeorology will be needed to produce a methodology capable of calculating credible absolute risk estimates. RES is starting to undertake a program to advance the state-of-the-art, but we do not expect an adequate methodology to be available in the near future.

RECOMMENDATION

The Division of Engineering is committed to utilizing its staff and consultants for review of current PRAs containing external events and for furthering the development of PRA methodology in these areas. To accomplish the latter, I would recommend that a plan be provided to you, by October 31, 1982, which would lay out the steps, resources, and schedule for bringing external event PRA methodology to proximate parity with internal event PRA. RES, DST and DSI also need to be involved in the development of this plan. If you concur with this recommendation, the lead for such an effort should be discussed.

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