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Consideration of Seismic Events in Severe Accidents

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ABSTRACT

In 1985, the U.S. Nuclear Regulatory Commission issued the Severe Accident Policy Statement requiring all licensees to perform a systematic evaluation of their plant to determine plant specific vulnerabilities. At the present time licensees are required to proceed with examinations only for internally initiated events; examinations of externally initiated events will proceed separately on a later schedule. Staff activities concerning how to best proceed with implementing the severe accident policy with respect to externally initiated events are described.

INTRODUCTION

The Severe Accident Policy Statement, issued by the U.S. Nuclear Regulatory Commission (U.S. NRC, 1985) calls for a systematic examination, defined as an Individual Plant Examination (IPE), to determine plant specific vulnerabilities to severe accidents at nuclear power plants. Although the policy does not differentiate between internal and external accident initiators, licensees are required to proceed with examinations only for internally initiated events at the present time. Generic Letter 88-20 (U.S. NRC, 1988) contains NRC guidance concerning the objectives and scope of the internal initiator examination and specifies approved methods of examination. Examination of externally initiated events (e.g., earthquakes, internal fires, high winds) will proceed separately and on a later schedule from that of internal events (1) to permit the identification of which external hazards need a systematic examination, (2) to permit the development of simplified examination procedures, and (3) to integrate other ongoing Commission programs that deal with various aspects of external event evaluations to ensure that there is no duplication of industry efforts.

The NRC has established an External Events Steering Group (EESG) to make recommendations to senior management concerning how best to proceed with implementing the severe accident policy with respect to externally initiated events. The EESG has established three technical subcommittees dealing with seismic, fire and "other" external initiators. Seismic Subcommittee activities related to: defining scope of examinations, acceptable examination methodologies, integrating ongoing seismic issues, and developing seismic related IPE guidance are described in this paper. In addressing these topics, both policy and technical issues need to be examined. This paper also discusses the means of developing the technical bases on which these issues can be decided.

ISSUES RELATED TO SEISMIC IPE METHODOLOGY

Based on the results of several probabilistic risk assessments (PRAs) summarized in an NRC sponsored study (Prassinos, 1988) the seismic event is one of the external events that needs to be included in the review for severe accident vulnerabilities. Two methodologies are being evaluated by the subcommittee to identify seismic vulnerabilities at nuclear power plants. The first, a seismic PRA (The American Nuclear Society, et al., 1983), the second, seismic design margins methodologies as described in Budnitz et al., 1985 and NTS Engineering, et al., 1988.

A seismic design margins methodology provides a potential alternative method to a seismic PRA for consideration of seismic events in the severe accident policy implementation. The margins approach reduces the scope of systems and components to be looked at and seismic hazard curves are not used. However, the margins approach retains the most important features of a seismic PRA; that is, plant walk-downs and an evaluation of an integrated plant response. Margin is demonstrated by showing there is a high confidence of a low probability of failure (HCLPF) for a given earthquake level.

The NRC sponsored seismic design margins methodology (Budnitz, et al., 1985), derived from reviews of past seismic PRAs, aims at establishing HCLPF plant capacity with respect to core damage. HCLPF capacity is reported in terms of a ground acceleration level with reference to a specific spectrum. The NRC methodology uses an event tree/fault tree approach after screening out certain

plant systems and components based on PRA insights and fragility considerations. The EPRI sponsored seismic design margins methodology (NTS Engineering, et al., 1988) uses the same definition of HCLPF, however, the demonstration of plant capacity is made through a selection of "success paths" for shutting down the reactor and maintaining core cooling for a specified number of hours.

Some enhancements to the margins approach are needed prior to its general use in severe accident policy implementation. To this end, a meeting was held with experts in this area to discuss the specific enhancements and their feasibility and necessity. Major elements under consideration by the subcommittee with assistance from its contractors, the Lawrence Livermore National Laboratory, Sandia National Laboratories, and various consultants are briefly described below.

Review Level Earthquake

The review level earthquake used in conjunction with seismic design margins review is specified "a priori" and should be sufficiently high to uncover vulnerabilities but such that the number of systems and components to be examined are minimized. Plant HCLPF capacities are determined by comparing structure and component HCLPF capacitities to the review level earthquake. Structures or components having HCLPF capacities higher than the review level are screened out from further consideration. As such, a number of issues are tied to the selection of the review level earthquake. For example, implicit in the selection of the review level is the judgment that a plant with HCLPF greater than the review level earthquake has no seismic vulnerabilities from the severe accident point of view. Conversely, when the plant HCLPF is less than the review level questions may arise as to whether further action is warranted.

The subcommittee is currently considering a generic review level for central and eastern U.S. plant sites and site specific review levels for western U.S. plants. Before making a final decision, and to develop a rational basis for such a decision, the subcommittee is reviewing past PRAs to estimate the relationship between seismic hazard, plant HCLPFs, and core damage frequencies. Several studies have suggested that one can in a generic sense, define correlation between annual probabilities of exceeding the review level earthquake and

seismic induced core-damage frequency. In determining the review level earthquake, the subcommittee is also assessing the impact of the two sets of hazard curves (Bernreuter, et al., 1989 and Risk Engineering, Inc, et al., 1986) currently available for central and eastern U.S. plant sites.

Earthquake Magnitude/Duration

The screening table developed as part of the NRC seismic design margins method (Budnitz, et al., 1985) is stated to be valid for up to a magnitude 6.5 earthquake. The EPRI sponsored methodology which adopted this table stated it could be used for up to a magnitude 7.0 earthquake. The subcommittee is evaluating the applicability of earthquake magnitude and duration on screening table use.

The fragility screening tables and systems insights used in the seismic design margins methodology are based on ground motion records and observations from the 1971 San Fernando, 1979 Imperial Valley and 1983 Coalinga earthquakes. The subcommittee is comparing the range of durations recorded during those earthquakes at near-source (damaging) distances with existing estimates of duration for eastern and western U.S. earthquakes. This will enable the subcommittee to determine at what magnitude (mb, MS, ML or MW) and distance strong motion duration significantly exceeds that assumed in the seismic design margins methodology. It is expected that this will not significantly limit the applicability of the seismic design margins methodology.

High Frequency Ground Motion

The spectra from new ground motion models gaining acceptance by the earth science community have identified higher ground motions at higher frequencies and lower ground motion at lower frequencies than used in the past. The assumptions and philosophy used in the development of the NRC seismic design margins methodology will be revisited to determine if the method accommodates (or can be modified to accommodate) increased high frequency motions. In particular, it will be determined if the fragility data base used in the margins methodology is applicable when high frequency motions are considered. As part

of this effort, a recent EPRI sponsored study (Benjamin, 1988) which addresses the impact of high frequency motion is being reviewed by the NRC. It will be determined whether modifications to the spectral shape of the review level earthquake should limit use of the screening tables (Budnitz et al., 1985).

Risk Insights

Margin methodologies in their current form do not provide insights on plant damage states or quantitative results in terms of core damage frequencies or other risk measures. Risk insights may be needed in some cases for the severe accident policy implementation if questions arise regarding the effectiveness of resource allocation. The subcommittee is developing guidance to extend the NRC methodology (Budnitz, et al., 1985) to obtain plant damage state insights.

Suggested enhancements will be evaluated using the Maine Yankee, Catawba and Hatch plants margins studies. In addition, the subcommittee is developing guidelines to obtain risk insights from the NRC margins methodology. The guidance will address the methodological aspects as well as the usefulness of these insights in decision making. The EPRI margins methodology (NTS Engineering, et al., 1988) will also be examined to determine if it can be extended to obtain risk insights with reasonable effort.

Containment Performance

As stated in the Severe Accident Policy Statement (U.S. NRC, 1985), the systematic examination of the plant needs to include specific attention to containment performance relative to accident prevention and consequence mitigation. For large dry PWR containments, and BWR Mark II and Mark III containments, the effect of containment systems on core damage has already been integrated into the original development of the margin methodology and screened out as appropriate. However, not enough plant specific PRAs were available for the PWR Ice Condenser or BWR Mark I containments. The subcommittee is evaluating which containment functions, systems and components may significantly affect plant HCLPF estimates and need to be included in the NRC margins methodology (Budnitz, et al., 1985). Also, the subcommittee is

developing guidelines to address containment mitigation aspects which, by definition, were not included in the development of the margins methodology. Mitigation aspects include: containment system vulnerabilities to a seismic event which causes containment integrity to be jeopardized, or failure of containment to isolate which causes containment to be by-passed. Two categories of systems and components will be identified. The first is associated with early containment failure, the second is associated with long term containment integrity.

In the context of an IPE, there are several considerations associated with containment performance. First, the vulnerabilities that lead to early failure are most important from the perspective of risk to the public. Second, by looking at the most risk sensitive components (those associated with early failure), the scope of the review can be reduced (compared to a seismic PRA) consistent with the philosophy of the margins approach. Finally, performing an early containment failure HCLPF analysis at a review level larger than the HCLPF core damage analysis (e.g., 0.5g for containment failure, 0.3g for core damage) could be both intuitively meaningful and risk consistent.

Thus, there are a number of policy and technical issues that need to be resolved before the subcommittee can decide how to address containment performance issues in the seismic IPE. The staff is reviewing a number of recent PRA and containment improvement studies to identify containment challenges which coupled with seismic vulnerabilities may be important for seismic IPE.

Decay Heat Removal

The objectives of USI A-45, "Shutdown Decay Heat Removal Requirements," were to evaluate the safety adequacy of decay heat removal (DHR) systems and assess the value and impact of alternative measures for improving the overall reliability. The A-45 program was integrated into the severe accident policy implementation and the DHR assessments will be accomplished as part of the IPE reviews. Therefore, the subcommittee is reviewing seismic PRAs conducted in support of USI A-45 and will identify any additional systems and components, and human actions which have to be added to the NRC margins methodology (Budnitz, et al., 1985). It is expected that this will result in minor additions to the current scope of the margins methodology.

Relay Chatter

A number of studies have been recently completed to examine the effects of relay chatter on plant risk during a seismic event. Specific guidance has been given in NRC Unresolved Safety Issue (USI) A-46, "Seismic Qualification of Equipment in Operating Plants", and the EPRI margins methodology (NTS Engineering, et al., 1988). Additionally, a number of test programs are currently underway to develop relay fragilities. These programs will identify which relays and breakers are particularly susceptible to seismic events. Based on the above, the subcommittee will identify which relays need particular attention, and modify, as appropriate the NRC margins methodology (Budnitz, et al., 1985).

Liquefaction

EPRI has proposed a procedure for liquefaction analysis in context of its margins methodology (NTS Engineering, et al., 1988). No specific procedure for liquefaction analysis is presented in the NRC margins methodology (Budnitz, et al., 1985). The subcommittee will examine procedures proposed in recent PRAs and recommend adoption of a procedure to be used in conjunction with the NRC margins methodology.

Integration of Various Ongoing Seismic Issues

There are two considerations in attempting to integrate seismic programs. The first and most important is to identify efficient and effective methodologies for satisfying the severe accident policy; the second consideration is to provide a procedure that will provide the basis for a closure of current seismic safety issues. It is of prime importance to avoid duplication of effort so that review steps will not have to be repeated for other programs. The most common elements of many current seismic evaluations are plant walkdowns and spatial interaction (e.g., interaction between adjacent equipment or interaction between equipment and structures).

The subcommittee is reviewing implementation and documentation procedures for existing seismic issues, such as, USI A-46, "Seismic Qualification of Equipment

in Operating Plants," USI A-40, "Seismic Design Criteria," and USI A-17, "Systems Interaction," noting equipment scope, seismic review level, and schedule. Having considered the advantages and disadvantages related to schedule, resources and effectiveness an integration plan will be developed and included in the IPE guidance document. Similarly, integrated documentation or reporting procedures to address the implementation of the severe accident policy and other seismic issues will be developed.

The subcommittee, based on its review of walkdown procedures for current seismic issues (e.g., USI A-46), margins methods, and PRAs, will develop an integrated walkdown procedure identifying critical components and systems to address the implementation of the severe accident policy and other seismic issues. Information gathering guidance will be prepared that will facilitate a single walkdown for multiple seismic issues.

GUIDANCE FOR SEISMIC RELATED IPE

Consistent with guidance related to internal initiator event examinations (U.S. NRC, 1988) the subcommittee will develop guidance for seismic related examinations. The guidance will identify acceptable methodologies; identify structures, systems, components and phenomena (e.g., relay chatter, liquefaction) that the examination must include; provide review levels, reporting and documentation requirements; and integrate ongoing seismic issues.

CONCLUSION

The Seismic Subcommittee expects to complete its technical program by the end of September 1989. The ongoing seismic margins review of the Hatch Unit 1 plant is expected to provide significant technical input. Issues such as differences in insights obtained from the two margins methodologies (fault tree vs success path) will be clear after completion of the Hatch study. Also, the relay review procedures and the integration of equipment qualification (USI A-46) with seismic margins evaluations will have gone through a trial plant implementation.

The Seismic Subcommittee is maintaining a constant dialogue with a counterpart industry group organized under the auspices of NUMARC. This group (NUMARC Seismic Issues Working Group) is performing technical studies to address a number of the issues discussed in this paper. Through these meetings perceived differences are identified and discussed or clarified.

The subcommittee expects to prepare a straw man guidance document by May 1989 based on the on-going technical programs. The final draft guidance document will be issued in October 1989, followed by a workshop with industry in January 1990.

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