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ACTIVITIES OF THE PNC NUCLEAR SAFETY WORKING GROUP [a]

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ABSTRACT

The Nuclear Safety Working Group of the Pacific Nuclear Council promotes nuclear safety cooperation among its members. Status of safety research, emergency planning, development of lists of technical experts, severe accident prevention and mitigation have been the topics of discussion in the NSWG. This paper reviews and compares the severe accident prevention and mitigation program activities in some of the areas of the Pacific Basin region based on papers presented at a special session organized by the NSWG at an ANS Topical Meeting as well as papers from other sources.

INTRODUCTION

The Nuclear Safety Working Group (NSWG), since the organization of the Pacific Nuclear Council (PNC) and its predecessor the PBNCC, has worked actively to promote cooperation in the field of nuclear safety among its members. This cooperation has involved discussions in such areas as current status of safety research, emergency planning, initiation of the development of lists of technical experts for emergency conditions, exchanges of technical papers, and the organization of a special session on Severe Accident Prevention and Mitigation at a ANS topical meeting on Nuclear Power Plant Operations in August 1991 in Seattle, WA.

The special session on Severe Accident Prevention and Mitigation had papers from Korea, Mexico, and the United States. Each described operator training and procedures which had been adopted to prevent and mitigate severe accidents in these areas.

This paper will briefly review the Severe Accident Prevention and Mitigation papers presented at the ANS International Topical Meeting held in August 1991. In addition supplemental information on activities in the Severe Accident Prevention and Mitigation field in the US, Taiwan and Japan will also be presented.

SEVERE ACCIDENT PREVENTION AND MITIGATION PROGRAMS

Since the TMI-2 accident in March 1979 and the Chernobyl-4 accident in April 1986, there has been recognition that the possibility of occurrence of accidents more severe than design basis accidents should be considered in the safety assessment of nuclear power plants. This has resulted in severe accident research programs and operation assessments for the prevention and mitigation of severe accidents which might release significant quantitites of radioactivity. All of the areas in the Pacific Basin region having nuclear power plants have taken steps to develop a policy on severe accidents. The United States having the largest number of operational nuclear power plants in this region appears to have taken the lead on this subject.

The US Nuclear Regulatory Commission (USNRC) developed an integration plan for the closure of severe accident issues in 1988.[1] Reference 1 discusses the six elements of the plan: Individual Plant Examinations (IPE), Containment Performance Improvements (CPI), Improved Plant Operations, Severe Accident Research Program (SARP), External Events, and Accident Management (AM). It also includes a discussion on supporting elements such as: Reactor Risk Reference Document (NUREG 1150), Safety Goals, Generic Safety Issues, and the Integrated Safety Assessment Program.

Since the issuance of the integration plan the Commission has issued the IPE Generic Letter 88-20[2] which requires licensees to perform a systematic examination of their existing nuclear plants to identify any plant-specific vulnerabilities to severe accidents and report the results to the Commission. The IPE requires that a Level 1 Probabilistic Risk Assessment (PRA) or similar analysis be conducted. There have been four

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supplements to the original letter: Supplement No. 1, "Initiation of the IPE for Severe Accident Vulnerabilities",[3] Supplement No. 2, "Accident Management Strategies for Consideration in the IPE process",[4] Supplement No. 3, "Completion of Containment Performance Improvement Program and Forwarding of Insights for Use in the IPE for Severe Accident Vulnerabilities",[5] and Supplement No. 4, "IPE of External Events for Severe Accident Vulnerabilities".[6]

F.J. Congel and T.P. Speis[7] quotes SECY-89-012 which places the responsibility for the development of an "Accident Management Plan" upon the Licensee for each nuclear plant. They refer to SECY-90-313, "Status of Accident Management Program and Plans for Implementation" (September 1990) which describes the industry program which is coordinated by Nuclear Utility Management and Resources Committee (NUMARC). In the area of Accident Management Shotkin[8] reports that the utilities through NUMARC, EPRI, and Owners Groups are developing an accident management program which consists of five elements: strategies, instrumentation, guidance and computational aids, organization and decision making, and training. He also reports that there are research activities being pursued in each of the above five severe accident management elements.

During May and September 1990 workshops on accident management for PWRs and BWRs respectively were held at UCLA in Los Angeles, CA. to address the uncertainties of severe accident management for these LWRs.

The major conclusions resulting from the PWR Workshop[9] are summarized as follows:

1. "As a severe accident progresses from initiation at core uncovery through melting, slumping and vessel attack, to vessel failure; and then from penetration of the vessel to concrete attack, the uncertainties in terms of phenomena, availability of key systems and instrumentation, and operator behavior, will increase.

2. During the in-vessel progression, there is general consensus that water should be added whenever and wherever possible. The key issues are rate of water addition and primary system depressurization. Depressurization:

   a. increases the number of potential water sources available, and

   b. reduces the threat of direct containment heating (DCH); but it also

   c. increases the probability of a steam explosion.

3. During the in-vessel progression stage of a severe accident, in-core instrumentation will be lost. The operators will have to rely on containment instrumentation when applicable, and computer simulation by the Technical Support Center (TSC) staff.

4. During the transition between the in-vessel and ex-vessel progression, the operators and TSC staff will not know where the molten core is. If the water supply is limited, the key question is whether or not water should be injected into the primary system or into the containment via the sprays?

5. The major ex-vessel considerations are:

   a. pre-flooding the cavity up to the bottom head to prevent vessel failure,

   b. knowing when, and if, the core debris is quenched,

   c. turning on the sprays in a steam inerted containment when there is significant hydrogen present,

   d. deliberate venting of the containment (without a filter) is failure is imminent.

   It was suggested that a pressure vessel cavity water level monitor might prove useful for some accident management strategies.

6. From a fission product view point, sequences such as interfacing systems loss of coolant accidents (V-sequences) and the steam generator tube rupture accidents lead to direct paths for release. Water addition should always help, secondary side depressurization could make releases worse. It was concluded that accident management does not stop if the containment fails, or isolation is lost. Sprays and foams could still mitigate the consequences of containment failure.

7. Judicious use of computer codes and models is essential if severe accident management is to be viable. At present, there is a tendency to a priori determine the course of an accident, including the effects of accident management. A key issue is whether or not there is a need to improve the codes to the point most uncertainty is removed, and at what cost? Or would the operators and TSC staff use their knowledge of the plant, irrespective of what the codes indicate?"

The concluding comments from the BWR workshop[10] are as follows:

"The phenomena associated with core degradation are very complex and at present our understanding of these phenomena is very limited. It is uncertain that a significant improvement in our understanding of these phenomena will occur in the next few years. In this context, a defence in depth approach will be the most prudent. Irrespective of the large degree of uncertainty that exists in modelling severe accident progression, there is much to be gained from the evaluation of the viable accident management strategies. In the same view, research to confirm model results should continue. There should be tight coupling between experiments and models, and pre-experimental review.

Current symptom oriented EOPs already contain many of the strategies discussed at the Workshop. The EOPs provide a good basis for accident management. Some are already implemented as substantial accident management by BWR owners.

Innovative recovery actions that are implemented in the EOPs should be carefully walked through and pre-staged in order to determine if they are feasible. Because of the unique nature of plant design and equipment, such approaches must be plant specific. There is some concern that symptom oriented EOPs will replace the need for Operators understanding the evolution of a core melt accident. A review and reconsideration of some strategies continued in current EOPs may be appropriate, assuming severe accident conditions, i.e., flooding containment.

Recovery of failed equipment and instrumentation needs to be carefully considered. Severe accident management has as its focus recovery. Once achieved, post recovery actions also pose large uncertainty."

W.J. Luckas et al. report on Assessment of Candidate Accident Management Strategies in a NUREG/CR report.[11] BNL is currently studying accident management strategies which could help preserve containment integrity and minimize radioactive releases during a severe accident. The objective of this study is to provide useful information to licensees who are formulating severe accident management plans for their respective plants. The study considers strategies which make use of existing plant systems in innovative ways to mitigate the consequences of a severe accident. The details of the investigation into accident management strategies for a typical BWR have been reported by J.R. Lehner et al.[12] and by C.C. Lin and J.R. Lehner.[13]

The Severe Accident Research Program (SARP) is a major component of a severe accident prevention and mitigation program in the United States. Since 1979 there has been an extensive severe accident research program and this report will not attempt to discuss this effort. The status and latest SARP activities can be found in the Proceedings of the 19th Water Reactor Safety Meeting held in Bethesda, MD, October 28–30, 1991.[14]

In Japan as reported by Soda et al.,[15] the regulatory authorities currently license a nuclear plant on the basis of guidelines whose requirements on safety design are prescribed within the design basis accident. He reports that the Nuclear Safety Commission (NSC) of Japan has initiated a discussion of severe accident issues and that the NSC's position is summarized as follows:

1. The knowledge of severe accident is one of the most important basis for the formulation of safety design criteria, siting criteria, and guideline for emergency planning.

2. The Plant Operator should have knowledge of severe accident and reflect upon the plant management so as to be able to cope with it properly even in cases of beyond design basis accidents.

3. Industry and research organizations should perform severe accident research whose purposes are:
   To identify phenomena associated with a severe accident,
   To develop analytical tools for source term analysis,
   To estimate a risk and safety margin of plant and,
   To evaluate measures to prevent and mitigate severe accident by design and/or accident management.

The NSC recommended emphasis on severe accident research which is being followed by the Japan Atomic Energy Research Institute. The Nuclear Power Engineering Center also conducts demonstration tests with emphasis on the quantification of safety margins for a nuclear power plant for conditions beyond design basis.

In Taiwan at the Taiwan Power Company (Taipower) as reported by S. Chiang[16] they have approached the severe accident issue in a manner similar to the approach by the USNRC.[1] They have developed for their three LWR nuclear power stations (four BWRs and two PWRs) a severe accident policy integration plan which consists of three elements: (1) Conduct a Level 2 PRA for each of the plants for plant improvements as well as to confirm the size of their emergency planning zone; (2) Implement Containment Performance Improvement Program; and (3) Develop Severe Accident Management Guidelines. Under the containment improvement program they have inerted the Mark I containment of their first BWR plant as well as updated its emergency operating procedures. Other improvements which are being considered are: a backup water supply for core injection and containment heat removal; an alternate boron injection system using the reactor water cleanup system; a core debris control system; and improving the reliability of the automatic depressurization system (ADS).

In addition they have a training program to improve operator understanding of severe accidents and the procedures for mitigating such accidents. They have conducted a training workshop for key safety personnel to help operators understand how to handle situations beyond the design basis accidents. In the workshop subjects such as: severe accident phenomena, PRA methodology, plant specific PRA results and recommendations, emergency planning, and accident management were covered.

To round out their severe accident prevention and mitigation program they are conducting a severe accident research program at domestic research institutes and universities as well as participating in international cooperative programs such as the USNRC's Severe Accident Research Program and EPRI's Advanced Containment Experiments Program (ACE).

S.H. Lee and S.Y. Kim[17] report that severe accident policy is currently being developed in Korea. Although the utility in Korea has developed various programs such as simulator training programs, development and exercising emergency operating procedures (EOP), for the prevention and mitigation of accidents, they have not as yet developed severe accident management programs. The Korea Institute of Nuclear Safety (KINS) which supports the regulatory authorities has been developing integrated accident mitigation plans to cope with severe accidents by investigating design vulnerabilities for their nuclear plants. The overall requirements and scope for severe accident assessment are in the process of development by KINS. For future licensing activities KINS has developed the Korea Standard Review Plan for the review of severe accidents analysis and Probabilistic Safety Assessment (PSA). IPEs, accident management, and containment performance improvement programs utilizing PSA methodology are required for plants under construction.

In the area of operator training, Lee and Kim report that in Korea the operator training for the mitigation of severe accidents is in its infancy. The short term goal is to improve the operator's ability to handle severe accidents by improving his understanding of severe accident phenomena and technical background on emergency responses so that he will be able to conduct knowledge based actions with the help of symptom-oriented EOPs. They are providing training so that operators have the knowledge and skills to recognize potentially hazardous plant conditions and make effective decisions regarding accident mitigation. Some of the major areas for severe accident mitigation training which will be developed include: core cooling mechanics, recognizing core cooling, core recriticality, hydrogen hazards during an accident, monitoring of critical parameters, radiation hazards, and criteria for operation and cooling mode selection.

Mexico has one 675 Mwe BWR in operation at the Laguna Verde Nuclear Power Station as reported by I.M. Rico.[18] This paper reports that a Level 1 PRA, based on the methodology described in NUREG/CR-2815 and NUREG/CR-2300, was developed in carrying out an IPE which determined that class I transients are the dominant contributor to the overall core damage frequency. Station blackout (SBO) is the second largest contributor to core damage frequency. Although no hardware modifications were found to be required, improvement of the ADS and SLC systems availability is desirable. Other actions as a result of the PRA include: an emergency diesel generator reliability program, development of procedures for restoration of on and off site power, plant preparation procedure for severe weather conditions. They are also conducting studies on severe accident due to external events, and severe accident management guidelines development, as well as the development of emergency operating procedures. In addition as a part of research activities on severe accident analysis they are implementing and using USNRC developed computer codes such as TRAC-BF1, RAMONA-3B, STCP, and MELCOR.

CONCLUSION

In comparing the activities for severe accident prevention and mitigation in several of the Pacific Basin areas, it is found that they are developing or have developed severe accident closure integration plans similar to that of the USNRC which is outlined in Reference 1.

The PNC Nuclear Safety Working Group meeting periodically in an informal atmosphere, thus, provides a forum for discussing and comparing issues such as the Severe Accident Prevention and Mitigation issue in an collegial atmosphere.

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