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The Honorable Ivan Selin
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Chairman Selin:

SUBJECT: SEVERE ACCIDENT RESEARCH PROGRAM PLAN

During the 387th and 388th meetings of the Advisory Committee on Reactor Safeguards, July 9-11 and August 6-8, 1992, we reviewed the Severe Accident Research Program (SARP) Plan that is being directed by the Office of Nuclear Regulatory Research (RES). This review followed meetings of our Severe Accidents Subcommittee on October 25 and 26, 1991, May 27, 1992, and June 25, 1992, at which this matter was discussed. We had the benefit of discussions with representatives of the NRC staff and of the documents referenced.

GENERAL COMMENTS

First, we consider the updated SARP Plan, described in draft NUREG-1365, Revision 1, a noticeable improvement over what we have seen in the past. The document is well written. The goal of the overall program is said to be the reduction of the likelihood of early containment failure. Generally, the goals and objectives of individual projects are more clearly stated than we have seen in the past. Even so there are occasional ambiguities, and the organization needs improvement. For example, there is duplication as well as some inconsistency among the appendices and the main report. In addition, some project descriptions begin with statements that this is a very complex area, that large uncertainties exist in the understanding of severe accident phenomena, and that the proposed research will remove some of the uncertainty. There is no indication of how much uncertainty is likely to be removed by the proposed research, nor how much must be removed in order that the regulatory program proceed satisfactorily. The objectives of several projects are still described as an effort to "gain insights" without an indication of how much or what type of insight is required, or to achieve a "better understanding" of some phenomenon without an indication of where the existing understanding is deficient or of what will be contributed to the regulatory process by an increased understanding. We do observe that effort is now being made to identify the point at which the objectives of a project will have been achieved.

Second, we commend the staff for the extensive peer reviews that are now being required. The planning of research, the results of the research, and the conclusions drawn from the work are now being subjected to review. Our observations lead us to believe that, as a result, the current research activities are making more efficient use of resources. Further review of the results and of their interpretation by those outside RES should produce conclusions that have greater general acceptance and are more broadly useful than

has been the case in the past.

Third, we observe that those responsible for severe accident research labor under a significant handicap. As we have reported to you earlier, there has not yet been a decision as to how the severe accident issues are to be dealt with in the regulatory arena, either for evolutionary or advanced reactor designs. The Office of Research is thus in the position of a traveler with no road maps.

COMMENTS ON SPECIFIC ACTIVITIES

The Mark I Liner Failure Issue

RES reported to us that the Mark I liner issue is close to resolution based on the following developments:

- The report, NUREG/CR-5423, "The Probability of Liner Failure in a Mark I Containment," has been extensively reviewed and revised to take account of the reviewers' comments.

- The core-concrete interaction (CCI) issue has been resolved.

We agree that NUREG/CR-5423 provides a coherent treatment of early failure of the Mark I liner. We note that the effects of ex-vessel steam explosions, which might result if water is on the containment floor, were not treated. We also call attention to and agree with the observation of Dr. S. Hodge, Oak Ridge National Laboratory (ORNL), in his letter appended to the report, that the report concludes only that early failure is implausible. Later failure is not ruled out by the results of the report.

Chemical Form of Iodine Released to Containment

We discussed work recently completed at ORNL (NUREG/CR-5752) on the chemical form of iodine expected to be released to containment. This work contributes to the formulation of the new source term, and should lead to a more reliable calculation of iodine released outside containment. It is not clear how these results will influence calculated risk of existing plants nor how the information will be used in the review of the individual plant examinations (IPEs) being performed. This should be investigated further.

Direct Containment Heating

An experimental program expected to produce information that will provide a resolution of the direct containment heating (DCH) issue is now said to be on a solid technical base. A resolution is expected within about a year. The program was delayed because of questions about scaling. The recently issued severe accident scaling methodology (SASM) report, NUREG/CR-5809, provides the needed guidance. Experimental work at Sandia National Laboratories (SNL) has begun. Work at Argonne National Laboratory (ANL) is also under way. Early results indicate that a defensible case can be made for the loads on containment being well below the structural

failure loads, at least for the large dry containments.

We note, however, that for many of the PWR PRAs, including two of those treated in NUREG-1150, containment bypass is the risk-dominant failure mode. Thus, it is expected that resolution of the DCH issue will not have a significant effect on the estimated risk or on the risk uncertainty for these plants. We are encouraged that useful guidance in this area has been provided by the severe accident scaling methodology.

Hydrogen

We have some concerns about the conclusions concerning effects of hydrogen detonations on containments such as the steel shell proposed for the Westinghouse AP600. It appears that the NRC staff has not considered thin shell containments, nor have they gone beyond planar or spherical shocks. Some recent conversations that we have had with the members of the German RSK indicate that their investigations have convinced them that three dimensional calculations are required because of the shock interactions that will occur.

We are not satisfied that there has been adequate investigation of the following questions for containments generally:

Where is the hydrogen in containment?

How is appropriate igniter placement determined?

How effective are igniters in removing hydrogen from mixtures of steam and other noncondensable gases?

How effective are containment passive cooling systems as hydrogen concentrators?

How likely is a detonation?

Core-Concrete Interaction

We agree with the report by Dr. D. Powers, SNL, that, in his view, the experimental work that has been completed is adequate for the validation of the models in the NRC severe accident codes that model core-concrete interaction. A major uncertainty in the results of calculations using current codes is the state of the molten material that exits the vessel. He considers the agreement between CORCON calculations and the German BETA Test to be very good.

Debris Coolability

This research is particularly important to an evaluation of the effects of molten corium on the containment loading for the new reactor designs currently being reviewed. A number of programs over the past several years, both in the U.S. and abroad, have investigated the cooling of molten corium on the containment floor covered by a layer of water. Data are sparse, and the issue of whether cooling will occur in actual containments under accident

conditions is still open. How applicants will be required to demonstrate debris coolability in containments is also still not established. If it is to be done experimentally, additional research will be required. The small-scale Melt Attack and Debris Coolability Experiment (MACE) tests at ANL, scheduled for completion in FY 1993, are expected to provide additional information, but are unlikely to provide conclusive evidence of coolability of debris. Some additional experiments may be required after the results of the MACE tests are analyzed. The magnitude and scope of these should be determined by regulatory needs. Work on debris spreading, an important consideration in coolability, is planned for 1994.

Fuel-Coolant Interactions

The principal concern is whether explosive energy releases can occur when molten corium encounters coolant either in the vessel or after the corium has left the vessel. Despite a recognition of the problem almost two decades ago, no generally accepted method exists for calculating the conversion of thermal energy to mechanical energy in this situation. Currently there are several small programs in the U.S. being supported by the NRC, as well as a program in Europe in which the NRC is participating. It is questionable whether any of these will produce information that will resolve the issue. We recommend further research in this area.

In-Vessel Core Melt Progression

The staff proposes relatively modest expenditures for core-melt progression research. The purpose of the work is said to be:

> the resolution of the question of whether to expect TMI-like blockage as a general behavior for BWRs, and
>
> to provide some technical basis for validation of blocked-pool models under development, and their predictions regarding the failure location of the crust and the melt relocation into the bottom head.

The above items, along with new models, may permit better estimates of the amount, superheat, metal content, and timing of melt relocation into and subsequent failure of the bottom head. This should provide a basis for better models for quantifying risk. If interpreted properly, the results may also provide guidance in the choice of accident management strategies, assist in the Safety Goal Policy implementation, and remove some of the uncertainty from cost/benefit analysis for backfit decisions.

We suggest, however, that the models that result from this work should be taken as representing only one possible severe accident progression. Future severe accidents, if they occur, may take as unexpected a course as those few that we have experienced. Thus predictions of their course and consequences with models based on limited past experience may be misleading. Analyses of the type reported by Dr. S. Levy (S. Levy, Inc.) in the SASM report could be useful for evaluating the uncertainties associated with such

incomplete models.

We also believe that additional fundamental separate effects experiments are needed to better define the crusting behavior and the thermal hydraulics associated with molten pool conditions.

Lower Head Failure Analysis

Lower head failure analysis (NUREG/CR-5642) of the TMI-2 vessel should be of considerable value if it can be shown that what happened there has general applicability. We suggest that further attention be given to:

How typical is the TMI-2 accident, even for a PWR, and how well is it understood? For example, it was reported to us that SCDAP/RELAP5 still does not provide a good estimate of the lower head temperature rise.

What are the uncertainties or the contributors to uncertainty in the results of the lower head failure analysis?

Review of Severe Accident Codes

We were told that a program of peer review of the codes that RES expects the NRC staff to use over the next few years is under way. Dr. B. Boyack of Los Alamos National Laboratory (LANL) reported on a peer review of MELCOR that has been completed (LA-12240). After an extensive study of the code, the review group, chaired by Dr. Boyack, reported a significant number of deficiencies. It appears that the code should be used with considerable caution until these deficiencies have been corrected. It would also be desirable, before deciding on performance goals for the code, to decide how it is to be used in the regulatory process. We note that it is not being used in the formulation of the source term, which will replace the one that has been used as part of the siting rule (10 CFR Part 100). It is not clear whether the staff plans to use MELCOR in evaluation of IPE results. Such use appears undesirable until the code has been improved.

In light of the rather significant number of problems identified by the peer review, the RES staff should consider the development of procedures to make it less likely that so many problems would exist at such an advanced stage of a code's development.

We understand that a peer review of the SCDAP/RELAP5 code is under way. Since the results are not yet available, we choose not to comment generally on that code in this report. However, we are concerned that the modeling of parts of the severe accident sequence, which the code treats, are said to be based on bounding models rather than on best estimates. This could lead to generation of misinformation, especially if used in formulating accident management strategies, or in evaluating the results of Level 2 and Level 3 PRAs that may be submitted in response to the IPE program.

Use of Risk Analysis in the Planning of Severe Accident Research

We are not convinced that enough attention is being given to the

results of risk analysis in the planning of severe accident research. Both operating experience and analysis provide convincing evidence that severe accidents are low-probability and in many cases low-risk events. Further, as the industry accumulates additional experience, the risk should decrease. Indeed, there are some who would argue that the risk is already sufficiently low that additional research is unwarranted. We have not yet reached that conclusion. Nevertheless, we would like to see more evidence that the choice of research areas and the approach to the research is made with risk reduction as a principal focus.

The work at SNL described by Dr. F. Harper may be an effort in this direction. It is, however, at a very formative stage. The general approach, i.e., development of simplified event trees to approximate complex structures such as those found in NUREG-1150, might be a useful complement to engineering judgment in planning research or in making closure decisions on severe accident issues.

Whatever method is finally used, we believe that more attention should be given to the risk expected from an accident scenario before investments are made in its further elucidation.

Summary of Comments on Specific Activities

We see no reason for further work on the Mark I early containment failure issue.

The work on the chemical form of iodine released to containment provides important input to formulation of a new siting source term. The implication of the new information to risk of existing plants should be explored.

The experimental program on DCH is soundly based, and should resolve the issue.

We do not believe that some important aspects of the hydrogen issue have received the attention they deserve.

Existing information is adequate to treat core-concrete interaction on a dry floor.

Debris coolability is still an open issue. It will probably not be resolved by existing or planned programs.

The question of energy release associated with violent interaction of liquid corium and water is unresolved, and a resolution is not in sight. We recommend additional research in this area.

Significant weaknesses have been identified by the peer reviewers of the MELCOR code. Decisions on the use of severe accident codes and on their required capability are needed before plans for further developments are made.

We endorse, with the caveats noted, the core melt

progression program.

CLOSING COMMENTS

The description of the Severe Accident Research Program Plan provided by draft NUREG-1365, Revision 1, is a significant improvement over previous reports that we have reviewed. The descriptions of the proposed research are generally clear and specific. The report defines a goal for the program, i.e., the exploration of phenomena that are expected to influence early containment failure.

We see a need for better communication among the various units working on parts of a larger problem. During the course of our review, we encountered several examples of lack of communication between the Accident Evaluation Branch and other branches engaged in closely related work. For example, we asked about the MACCS code, a key code in the evaluation of severe accident risk. The answer we got was that it was in another branch. Yet it is the MACCS code that eventually calculates risk, and unless its limitations and capabilities are well understood, information provided as input to the code may not be appropriate. We received a similar response when we asked about work on component heating due to natural convection of gases in a core damaging accident. But if either steam generator tubes or other upper reactor coolant system components are overheated to failure by this process, the course and consequences of the accident can be markedly affected.

Finally, lest this report seem overly negative, we emphasize that we concentrated our comments primarily on areas that were perceived to require further attention. We thank the NRC staff for the time and effort that was put into preparing for the many presentations that were part of this review. In general the presentations were well organized and well presented, and our questions were dealt with patiently and with good humor.

Dr. Thomas S. Kress did not participate in those Committee deliberations that would impact directly on his outside interests.

Sincerely,

David A. Ward
Chairman

References:

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Survivability Issue," S. Hodge, November 12, 1990
3. U. S. Nuclear Regulatory Commission, NUREG/CR-5732, "Iodine Chemical Forms in LWR Severe Accidents" (Draft Report for Comment), E. Beahm, et al. (ORNL), July 1991
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5. U. S. Nuclear Regulatory Commission, NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," Office of Nuclear Regulatory Research, December 1990
6. U. S. Nuclear Regulatory Commission, Draft NUREG/CR-5642, "Light Water Reactor Lower Head Failure Analysis," J. Rempe, et al. (EG&G), March 1992 (Draft Predecisional)
7. Los Alamos National Laboratory, LA-12240, "MELCOR Peer Review," B. Boyack, et al., March 1992
8. Verbal presentation by Dr. D. Powers (SNL) to the ACRS Severe Accidents Subcommittee, October 21, 1991
9. Verbal presentation by Dr. F. Harper (SNL) to the ACRS Severe Accidents Subcommittee, May 27, 1992
10. Letter dated April 24, 1990, from Carlyle Michelson, Chairman, ACRS, to Kenneth M. Carr, Chairman, NRC, Subject: Severe Accident Research Program