June 23, 2000

MEMORANDUM TO: William D. Travers
Executive Director for Operations

FROM: Ashok C. Thadani, Director **/RA/**
Office of Nuclear Regulatory Research

SUBJECT: SIGNIFICANT CONCLUSIONS FROM THE COOPERATIVE SEVERE ACCIDENT RESEARCH PROGRAM (CSARP) TECHNICAL REVIEW MEETING HELD ON MAY 8–11, 2000

The purpose of this memorandum is to inform you of significant conclusions from the recent Cooperative Severe Accident Research Program (CSARP) Technical Review Meeting held on May 8–11, 2000, in Bethesda. As you know, this meeting is held annually to discuss progress made in severe accident research in the CSARP Partner countries. With the resolution of many severe accident issues in recent years and maturation of knowledge base on other issues, there has been an overall reduction of severe accident research in the United States as well as in many other countries. This particular meeting served as an important forum for distilling our current knowledge base of severe accidents, and future challenges that we may experience.

This memorandum summarizes the insights that resulted from two separate panel sessions. The first panel session was devoted to severe accident phenomenology while the second was devoted to analytical tools (codes) for plant applications.

The first panel concluded that the current understanding of severe accident phenomena is, in large part, complete from a risk-informed regulatory perspective. Our current understanding is also deemed sufficient, for many phenomena to ensure the efficacy of severe accident management guidance and/or actions. For some phenomena, however, our understanding is limited and there are areas of remaining uncertainties. In many cases, the uncertainties can be addressed using currently available analytical tools. However, in certain areas, the panel concluded that uncertainties were too large, or our understanding insufficient, such that, it warranted further research to ensure closure. The panel summarized its discussion in four broad categories which are described below.

The first category covers areas where research needs are identified as critical in terms of the data or knowledge required to close an issue, or the potential impact of the outcome of research on severe accident management. This category includes the issues of ex-vessel debris coolability, ex-vessel steam explosions, and long-term core-concrete interactions. Given the findings from past research on in-vessel phenomena, in particular, in-vessel melt retention, it is recognized that melt retention is not assured for high power reactors, such as many of the operating ones. Therefore, in the progression of a severe reactor accident, the likelihood of a core-on-the-floor event cannot be considered physically unreasonable. Efforts in the past devoted to demonstrating coolability of core in this configuration have not been successful. From the severe accident management standpoint, it is very important to know when and how a core-on-the-floor accident can be stabilized and terminated. Thus, a fresh and concerted approach to this issue is warranted.

In the event of vessel breach, and prior to a core-on-the-floor configuration, the ejected melt may interact energetically with water in the cavity leading to the likelihood of steam explosions. This is an issue of early containment failure which may arise as a consequence of accident prevention measure (pre-flooded cavity in some reactors) or accident management measure (introducing water in the otherwise dry cavity at vessel failure). The related research need is to generate experimental data on fuel-coolant interactions at low pressure, prototypic of ex-vessel conditions. With the premature termination of the cooperative FARO program last year in which NRC participated, this data is not forthcoming. An ancillary issue is concerned with the explosivity of oxidic reactor melts. Available data suggests that oxidic melts may be resistant to triggering of steam explosions and produces very low energetics, if triggered. An improved understanding of the explosivity of oxidic reactor melts would resolve this issue.

The long-term core-concrete interaction is germane in terms of its impact on emergency evacuation plans, particularly for those sites that are nearby densely populated areas. The issue is the timing of concrete basemat failure from a multidimensional erosion process as a result of core melt interaction. Currently available analytical tools, developed on basis of essentially one-dimensional experiments, are viewed as somewhat conservative in terms of their long-term predictive capability. Opportunities for improvement are recognized, however, the driving issue (i.e., prediction of basemat failure timing) can be muted by success in cooling effectively the core on the floor. Thus, it provides yet another incentive for a fresh approach to the ex-vessel core coolability issue.

The second category of severe accident research scope is more of the evaluative type. For the types of issues covered by this category, existing phenomenological knowledge base appears to be adequate with perhaps some uncertainties which can be treated in a bounding manner. The relevant need in this category is more in terms of orderly closure of issues and appropriate documentation. The issue of hydrogen mixing and combustion falls in this category. Much work has been done on this issue, but to date a comprehensive document does not exist to ensure that the current understanding of phenomena and current accident management approaches are sufficient with the requisite high degree of confidence from a risk-informed perspective. RES is currently preparing such a document for the agency, and plans to transmit the same to you in due course.

Failure of steam generator tubes under high pressure scenarios is another issue which falls in the second category. It is generally accepted that natural circulation under high pressure severe accident conditions will result in failure of the pressurizer surge line or hot leg. However, the steam generators also participate in the process, and of concern is the potential for tube failure, especially in the presence of pre-existing flaws, as well as the potential for tube-to-tube failure propagation. Again, the knowledge base largely exists to address this issue but the issue closure needs to be achieved in an orderly manner (i.e., further evaluation of tube integrity under accident conditions) and furthermore, the process needs to be documented.

Although not explicitly discussed by the panel members, certain emerging severe accident issues may fall in the second category. For example, the success of in-vessel melt retention by external flooding has been demonstrated for low power reactors such as the AP600 design. The in-vessel retention prospect for high power reactors needs to be evaluated. Another example is the potential impact of fuel type (high burnup, MOX, etc.) on source terms. Again, the issue is considered more of the evaluative type, based on the current state of knowledge.

The third category covers topical research areas where limited to significant progress in understanding has been made previously. Research is ongoing in these areas and the results are expected to be used in addressing unresolved severe accident issues or in confirming further the robustness of the closure process. The lower head failure research, conducted under the auspices of OECD, will generate data to better define initial conditions for ex-vessel phenomena (steam explosions, core-concrete interactions, core coolability, etc.). Core quenching during reflood of a degraded but not molten core is not well understood, but is needed for development of a mitigation strategy.

The fourth and the final category focuses on strategic needs to maintain a knowledge base and readiness in response to severe accidents. It is recognized that the risk from nuclear power reactors primarily stems from severe accidents. Therefore, it is crucial to maintain a knowledge base of phenomenological understanding that is essential for instituting appropriate severe accident management actions. In this context, readiness refers to immediate availability of expertise and information while in a severe accident situation. Having complex analytical tools for off-line plant analysis may not be very useful during the event. Rather, a real-time analysis of plant response to mitigative measures would provide insights for accident management response. This can be achieved by distilling phenomenological understanding of severe accidents into a research insight type document that can be used, for example, at an incidence response center. Such an effort has recently been undertaken by RES through a cooperative grant program with the University of California at Santa Barbara.

The second panel addressed capabilities of current generation severe accident codes for plant applications. The unanimous view of the panel was that severe accident codes in use around the world possessed the necessary capabilities for modeling nuclear power plant responses to severe accidents. The codes were seen to embody physical models consistent with the current understanding of relevant phenomena, albeit, with various degrees of uncertainties. The panel did not have a unanimous view on whether the uncertainties can be dealt with in a bounding manner. However, it was widely held that continued assessment of the codes against experimental and plant data was an important component to the reduction of uncertainties, and further improvement and maturation of the codes. Focused code improvements should continue in order to improve the quantification of dominant phenomena with greatest uncertainty. Application of the codes to plant analysis, to aid in either design evaluation or risk assessment, is seen to increase as industry and regulatory authorities address severe accident risk and accident management issues. With regard to code consolidation, there appears to be a general trend in that direction and there appears to be a preference for a system-level, full-plant code with a modular architecture. The experience base suggests that such a code is relatively easy to use for plant calculations, and provides sufficient information, in most cases, for estimating plant response during severe accidents. There also is a recognition that in some specific cases, system-level code calculations can be supplemented with more detailed code calculations to get a better perspective on risks.

In summary, the CSARP meeting highlighted significant accomplishments in severe accident research, identified areas where further research is needed to reduce uncertainties and addressed future challenges and opportunities. The NRC has ongoing and planned research programs (mostly leveraged through cooperative international agreements) to address some of these needs. However, some significant issues (e.g., ex-vessel core coolability and potential issues related to AP1000) are not being addressed at present. Also, RES severe accident capability has reduced over the last few years to below the level we had identified as the minimum needed core capability.

The meeting pointed out a need for use of available severe accident research products (phenomenological understanding, analytical tools, etc.) for regulatory and accident management decision making, and recommended ways (e.g., maintenance of expertise and knowledge base) to achieve that goal. Furthermore, the meeting emphasized a need to maintain readiness and recommended ways as before to achieve the goal. Specifically, maintenance of knowledge base and expertise involves continued code assessment and improvement, supplemented by focused experimental programs, which is the essence of ongoing research programs at the NRC.

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