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MEMORANDUM FOR: Distribution

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SUBJECT: SUMMARY OF NRC/IDCOR MEETING ON INTEGRATED ANALYSIS OF SEVERE ACCIDENT CONTAINMENT LOADS - MAY 15-17, 1984

The Industry Degraded Core Rulemaking Program (IDCOR) is an effort on the part of nuclear utilities to develop the technical basis for determining whether changes in regulatory requirements are needed to reflect severe accident considerations. The NRC has recognized the potential benefit of factoring the IDCOR methods and results into the agency's decision process on severe accidents. A series of meetings has been arranged for NRC to examine and evaluate IDCOR's methods, assumptions and results. The purpose of this interaction is to take advantage of the technical programs and information developed by IDCOR, understand its bases, and identify what use we can make of it.

The first two meetings, held in Harpers Ferry, W. Va., and Hunt Valley, Md., concentrated on the fundamental physical and chemical processes governing accident progression, containment loading, and fission product behavior. This memorandum is a summary of the third meeting, held in Rockville, Md., which dealt with integrated analyses of containment loads for a variety of plants and accident sequences. The principal technical findings are described in Enclosure 1. A meeting agenda and a list of attendees are included as Enclosures 2 and 3, respectively.

The technical presentations covered three main topics: (1) presentation of the accident sequences chosen for analysis; (2) a description of the IDCOR MAAP integral analysis code, and (3) comparison of IDCOR and NRC containment load results for several types of containments and sequences. At the end of the meeting, summary presentations were given by NRC and IDCOR contractor representatives, in which both parties outlined the principal areas of

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agreement and disagreement for the PWR and BWR plants analyzed and discussed at the meeting. Enclosure 4 contains viewgraphs from the summary talks. Enclosure 5 contains viewgraphs from all other technical presentations.

Although the meeting resulted in general agreement between NRC and IDCOR on the majority of technical issues, the meeting summary presentations highlighted several areas of disagreement and several issues requiring further study. The main points of technical disagreement are briefly summarized in Enclosure 1.

The next technical exchange meeting, tentatively scheduled for late August 1984, will concentrate on integral analysis of fission product behavior. Subsequent meetings will deal with the quantification of risk from severe accidents and the assessment of possible improvements in plant design, operation, and emergency preparedness.

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Enclosures:
1. Technical Findings
2. Agenda
3. List of Attendees
4. Summary Viewgraphs
5. Technical Presentation Viewgraphs

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ENCLOSURE 1

SUMMARY OF THE PRINCIPAL TECHNICAL RESULTS

OF THE MAY 15-17, 1984 IDCOR/NRC MEETING

The meeting revealed some areas of disagreement between IDCOR and NRC and many topics that would require further analysis by both parties in order to reconcile differences of understanding. These insights were outlined in the summary statements presented on May 17 (Enclosure 4).

The discussion below briefly describes the most important areas requiring further work, namely:

- Hydrogen Production
- Hydrogen Combustion
- High Pressure Melt Ejection
- Core-Concrete Interaction
- Containment Response
- In-Vessel Fuel Coolant Interactions
- In-Vessel Melt Progression
- Sensitivity and Uncertainty Analyses

Hydrogen Production - IDCOR's MAAP model for hydrogen production includes two effects that tend to truncate all hydrogen production after the onset of core liquefaction; (1) the assumption that the zirconium-water interaction stops at a user-specified temperature (usually 2300°K) and (2) the assumption that melting fuel causes blockage of the coolant channels and cuts off the steam supply for further reactions. IDCOR has performed sensitivity calculations in which one or the other of these restrictions has been disabled, but no calculations have been done for the case where both are turned off.

NRC's MARCH code allows Zr-H_2O interactions to continue beyond 2300°F and incorporates the assumption that fuel melted early will enter the water in the lower plenum and boil off additional steam for hydrogen production.

The difference between the two approaches is illustrated by the results of calculations with MAAP and MARCH of the TMLB' sequence for Sequoyah. In the time period prior to the onset of core slump, both codes calculated hydrogen production equivalent to oxidizing about one fourth of the zirconium. After the onset of core slump, however, calculations employing MAAP showed essentially zero hydrogen production, while calculations with MARCH showed continued production at a high rate. Overall, MAAP calculated 23% zirconium oxidation in-vessel, while NRC consultants using MARCH calculated 49%.

Ex-vessel hydrogen production is also calculated differently by the two codes.

MAAP assumes instantaneous quench when water is present, and there is no time for hydrogen production. MARCH allows for extended quench during which significant quantities of hydrogen can be produced.

Hydrogen Combustion - The MAAP code model for combustion of hydrogen in containment uses a calculated flame temperature criterion based on the concentration of steam and hydrogen. If the flame temperature exceeds the critical value of 1310°F, a global burn is assumed to take place. The model assumes an ignition source and does not account for the suppression of combustion above 60% steam concentration. By allowing combustion at low hydrogen concentration in most cases, this model precludes the higher pressures that would result from combustion initiated at higher hydrogen concentrations.

IDCOR has examined the combustion of hydrogen in the reactor cavity in some detail. The combination of high temperatures and high hydrogen concentrations caused by core-concrete interactions promotes the burning of hydrogen with oxygen drawn into the cavity by natural convection currents. In some of our work as well as work performed by NRC's consultants, steam inerting or oxygen starvation precluded combustion in the cavity. This is a phenomenon that NRC needs to evaluate more closely.

Finally, the point was made that both IDCOR and the Containment Loads Working Group (CLWG) have ignored the potential for detonable hydrogen mixtures near the outlet of ice condenser cabinets.

High Pressure Melt Ejection - In high-pressure sequences, it is likely that portions of the molten core will be expelled from the reactor cavity. In a worst case scenario, a large fraction of the molten core could be suspended as an aerosol in containment, directly exchanging heat with the atmosphere and chemically reacting with oxygen. NRC staff and consultants are divided on the question of the likelihood and severity of such an event. IDCOR does not consider this worst-case scenario credible.

In the IDCOR calculation of TMLB for Zion, the high ejection pressure pushes half of the core out of the cavity where it spreads out evenly on the floor of the steam generator room without significant energy transfer to the containment atmosphere. The resulting thin layer never gets hot enough to attack the concrete floor of the SG room.

The NRC Containment Loads Working Group continues to work toward a technical resolution of the question of direct heating of the containment atmosphere including the performance of true prototypic experiments.

A related issue under review by NRC is whether the reactor coolant system will fail prior to vessel lower head failure. Neither NRC nor IDCOR has developed

a position on the likelihood that this phenomenon will preclude high-pressure-melt ejection, and the problem is under study by both groups.

Core-Concrete Interaction - For several sequences, there was disagreement between IDCOR and the NRC contractors on the partitioning of energy during core-concrete interactions. In general, the NRC calculation showed greater energy transfer to concrete structure. The latter results produced more noncondensible gases and higher containment pressures. These differences are due to modeling assumptions and initial conditions (such as the temperature and thickness of the melt).

Containment Response - Although containment response was not a subject of this meeting, there was a great deal of discussion of differences between NRC and IDCOR on this question. The NRC consultants suggested that IDCOR consider the possibility of containment leakage before containment failure, (i.e., threshold type of failure) especially for MARK I containment. It was also pointed out that liner burn-through in the MARK I and pedestal failure followed by reactor vessel collapse in the MARK III were failure mechanisms that should be considered by IDCOR.

In-Vessel Fuel Coolant Interactions - Although not discussed in depth at this meeting, fuel coolant interactions (FCI) continue to be a source of uncertainty with respect to accident progression, steam and hydrogen production and fission product behavior. Molten fuel entering the lower plenum can interact with the remaining water in a number of ways ranging from stable boiling to steam explosions.

The IDCOR methodology essentially precludes energetic fuel coolant interaction in-vessel. This is a major point of technical disagreement. The NRC MARCH code allows for energetic fuel coolant interactions, but the phenomenon has not been included in the CLWG standard problems. An assessment of this phenomenon and its impact on accident progression is needed.

In-Vessel Melt Progression - It is becoming increasingly apparent that the mode and timing of containment failure is sensitive to the details of in-vessel melt progression. For instance, differences between IDCOR and NRC approaches to modeling fuel relocation lead to large differences in hydrogen production. More effort by both parties would be needed to better characterize in-vessel melt phenomena and to reflect those phenomena in the codes in order to resolve these differences.

Sensitivity and Uncertainty Analyses - Although IDCOR has performed several studies of the sensitivity of containment loads to individual parameters, NRC believes it is necessary to evaluate the effect of simultaneously varying multiple parameters. An example of this is the sensitivity of hydrogen production to the assumptions that (1) the Zr-water interaction is cut off at 2300°K and (2) fuel melt will block steam flow channels and inhibit Zr-water reactions. To realistically evaluate

the effect of these assumptions, both restrictions should be simultaneously relaxed. Future sensitivity studies should cover such synergistic effects. Furthermore, the effects of modeling assumptions as well as parameter choices should be explored more completely. It is our understanding that such studies are currently underway at IDCOR and will be presented in the future.

In addition to sensitivity analyses, there was agreement that uncertainty analyses should be performed. In sensitivity analyses the independent variables can be varied over arbitrary ranges. In uncertainty analyses, an effort is first made to determine the ranges over which the independent variables can reasonably be expected to vary. The resulting variations in dependent parameters then represent an estimate of the real uncertainty.