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NUCLEAR REGULATORY COMMISSION

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NUCLEAR REGULATORY COMMISSION

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BRIEFING ON SEVERE ACCIDENT RESEARCH PROGRAM

- - - -

PUBLIC MEETING

Nuclear Regulatory Commission  
One White Flint North  
Rockville, Maryland

Tuesday, October 26, 1993

The Commission met in open session,  
pursuant to notice, at 10:00 a.m., Ivan Selin,  
Chairman, presiding.

COMMISSIONERS PRESENT:

IVAN SELIN, Chairman of the Commission  
KENNETH C. ROGERS, Commissioner  
FORREST J. REMICK, Commissioner  
E. GAIL de PLANQUE, Commissioner

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## STAFF SEATED AT THE COMMISSION TABLE:

SAMUEL J. CHILK, Secretary

KAREN CYR, Office of the General Counsel

JAMES TAYLOR, Executive Director for Operations

ERIC BECKJORD, Director, Office of Research

THOMAS MURLEY, Director, NRR

BRIAN SHERON, Director, Division of Systems Research,  
RES

ASHOK THADANI, Director, Division of System Safety and  
Analysis, NRR

FAROUK ELTAWILA, Chief, Accident Evaluation Branch,  
RES

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P-R-O-C-E-E-D-I-N-G-S

10:00 a.m.

CHAIRMAN SELIN: Good morning.

We're pleased to welcome members of the staff to brief the Commission on the Severe Accident Research Program. The goal of this research is to achieve an adequate level of understanding of severe accident phenomena in order to allow regulatory decisions to be made on these severe accident issues.

Understanding severe accident phenomena is necessary for evaluating the extent to which a plant has design features which will prevent these severe accidents or, if necessary, to mitigate their consequences.

As most of you know, the NRC has sponsored an active research program on severe accidents in light water reactors for quite a few years. Substantial benefits have also been derived from our cooperative agreements on severe accident research with other countries. The focus of the research has been on specific severe accident phenomena that could result in early containment failure and also on code development.

Today's briefing will focus on staff accomplishments since the issuance of its last program

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1 plan update in September 1992. The briefing will  
2 cover the current status of the severe accident  
3 issues, as well as closure plans for issues that have  
4 not yet been closed. The research results are also  
5 being used in support of the certification reviews for  
6 the evolutionary and for the advanced light water  
7 reactors. So, the staff will discuss not only the  
8 research program itself and its results, but also the  
9 use of those results in our regulatory programs.

10 Copies of the viewgraphs are said to be  
11 available at the entrances of the room.

12 Commissioners?

13 Mr. Taylor, would you proceed?

14 MR. TAYLOR: Good morning. With me at the  
15 table from the Office of Research, Eric Beckjord,  
16 Brian Sheron, Farouk Eltawila. From NRR, Doctor Tom  
17 Murley and Ashok Thadani.

18 Mr. Chairman, I won't repeat. You've  
19 outlined the basis upon which we do most of our work  
20 in the severe accident arena and its contributions to  
21 the review of the evolutionary and passive reactors.  
22 But as you'll hear from the staff this morning, this  
23 program has undergone a significant revision in its  
24 scope and priorities since being set up in 1987. A  
25 number of key issues associated with our understanding

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1 of severe accidents have been resolved over the last  
2 few years and current plans are to resolve the  
3 remaining issues by 1996.

4 I'm pleased with the scope of the program  
5 that is currently ongoing and also the progress.

6 With that, I'll turn the meeting over to  
7 Eric, who will continue.

8 DOCTOR BECKJORD: Thank you.

9 (Slide) Mr. Chairman, Commissioners,  
10 slide 2 shows the presentation outline. I'm going to  
11 give a background in brief. Doctor Sheron will review  
12 the revised Severe Accident Research Program and the  
13 update since September 1992. Doctor Eltawila will  
14 give a presentation on fuel coolant interactions and  
15 debris coolability. Doctor Sheron will then review  
16 the utilization of the research results, plans for  
17 future work in the international programs, and if we  
18 have some time Doctor Eltawila will come back to the  
19 additional information.

20 (Slide) If I could have the third slide,  
21 please.

22 This is the background. Severe accidents  
23 are important safety considerations for several  
24 reasons. First, we're able to calculate in many cases  
25 severe accident loads from first engineering

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1 principles, and they can exceed design limits in some  
2 cases. Also, we are able to estimate the frequency of  
3 severe accidents by means of probabilistic analysis  
4 and equipment failure rates that are derived from  
5 operating experience. The combination of these two  
6 flows of information by means of what we call the PRA  
7 shows that severe accidents are major contributions to  
8 risk. We know this from WASH-1400, from the update a  
9 few years ago of NUREG-1150. We know it from PRAs  
10 that have been done on individual plants over a period  
11 of 15 years and we also know it from the experience of  
12 Three Mile Island Unit 2.

13 The margins, as to margins in existing  
14 plants, we have studied the failure of primary systems  
15 and subsequent possible containment failures and we  
16 are able to evaluate the margins in plant designs to  
17 accommodate severe accident loads, the frequencies of  
18 the challenge and the probability given the challenge  
19 that the containment would fail.

20 The containment, the importance of  
21 containment has been recognized for a long time. I  
22 would say it goes back to certainly the Brookhaven  
23 Report, WASH-740 which came out many, many years ago.  
24 I think it was 1957 and this was clearly demonstrated  
25 at Three Mile Island.

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1           The source term, which is listed here, has  
2           been investigated very thoroughly. After Three Mile  
3           Island, questions about the size of the source term  
4           came up and spurred an extensive review which was  
5           carried out by an office, the source term office  
6           established by the Commission. The conclusion was  
7           that the source term magnitude and the composition of  
8           radionuclides depends on accident sequences and on  
9           severe accident phenomena. It is not a single value  
10          for a reactor type and it had to be determined  
11          sequence by sequence.

12           As a consequence on that conclusion, the  
13          Severe Accident Research Program was undertaken in the  
14          early 1980s and its purpose was to develop an  
15          understanding of severe accident phenomenon and to  
16          provide a technical basis for regulatory decisions.

17           In 1985, the Commission approved a severe  
18          accident policy statement. That statement, in brief,  
19          said that based on then current knowledge of operating  
20          plants that there was no undue risk posed by the  
21          operation of those plants. However, the Commission  
22          called in that statement for a systematic evaluation  
23          of all operating plants to identify the  
24          vulnerabilities to severe accidents that could be  
25          corrected, all vulnerabilities and with focus on those

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1 that could be corrected in a cost effective way.

2 The next item is NUREG-1150. That was an  
3 assessment of five nuclear power plants which, in  
4 effect, updated the technology of doing risk  
5 assessment from the WASH-1400, making use of the  
6 available results from the Severe Accident Research  
7 Program, which were beginning to come forth in the  
8 1986 to '88 period. In 1988, there was issued a SECY  
9 paper, 88-147, on the subject of the individual plant  
10 examination, the Containment Performance Improvement  
11 Program, accident management, the Severe Accident  
12 Research Program and the use of operating experience.  
13 In effect, this document described how the Severe  
14 Accident Research Program was being focused on the  
15 vulnerabilities of severe accidents that had important  
16 risk significance. In particular, the core damage  
17 frequencies and the containment failure mechanisms and  
18 risks.

19 There have been several revisions of the  
20 Severe Accident Program since that time. The latest  
21 is NUREG-1365 and that is the December 1992 update and  
22 Doctor Sheron will take over to describe that to you.

23 DOCTOR SHERON: Thank you.

24 (Slide) The next slide, please.

25 As Jim and Eric said, in 1988 we undertook

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1 a complete reexamination of the Severe Accident  
2 Research Program. Prior to that it had focused  
3 principally on just generating general information  
4 about severe accidents. What we wanted to do with  
5 this reexamination was to refocus it on those areas  
6 where there were larger remaining uncertainties and on  
7 the phenomena which seemed to be posing the highest  
8 risk in terms of severe accidents.

9 We did this reexamination and went through  
10 a rather extensive review process with the ACRS and  
11 the NSRRC. It was documented in NUREG-1365 and that  
12 was issued in August of '89. So, you can see this  
13 took us about a year to really refocus the program.

14 (Slide) Next slide, please.

15 The refocused program tried to focus in on  
16 four major areas. One was we tried to emphasize  
17 resolving uncertainties associated with scenarios that  
18 produced early containment failure because these are  
19 the scenarios which lead to the highest risk. The two  
20 major issues there were the Mark I -- the BWRs with  
21 the Mark I containment, the liner failure issue. What  
22 this was was basically that in a core melt accident  
23 you would postulate the melt, after it is released  
24 from the vessel would spread through the pedestal  
25 region into the dry well and contact the liner of the

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1 containment. It was postulated that this would then  
2 burn through or fail the liner, which then gave you a  
3 direct pathway to the environment. The question was  
4 would this liner fail under these conditions.

5 The other main issue we were focusing on  
6 is the direct containment heating. This basically  
7 pertains to PWRs and a few postulated core melt  
8 accident with the primary system remaining at a  
9 relatively high pressure. When the vessel fails the  
10 high pressure steam that is in the vessel would drive  
11 the core material out into the key way, up into  
12 intermediate and perhaps even into the main  
13 compartments of the containment. This high  
14 temperature melt would interact very quickly with the  
15 containment atmosphere, causing an over pressurization  
16 and a failure.

17 Other areas were the source term research  
18 we were using to update the source term, core concrete  
19 interactions which generate the non-condensable gases  
20 basically that would cause a slow over pressure  
21 failure of the containment, hydrogen combustion which  
22 also contributes to the containment loads.

23 The other thing we focused on was our  
24 computer codes. At that time when we took a look at  
25 our suite of codes there were numerous codes which

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1 seemed to duplicate one another. They were actually  
2 calculating the same thing or nearly the same thing,  
3 they were just being done at different laboratories or  
4 different groups. Our objective was to eliminate any  
5 duplication and just have one code to do a single job.

6 The other thing we also discovered was  
7 that many of our severe accident experiments really  
8 had not put together a very rational scaling analysis.  
9 By this I mean that we wanted to be able to take the  
10 results from smaller scale experiments and extrapolate  
11 them up to a large plant. The detailed scaling  
12 analysis, the dimensionless groups, whatever, that  
13 would provide that rationale had really not been  
14 developed to the extent that we would like. So, we  
15 focused in on developing a scaling rationale.

16 Then also, some of our other research was  
17 refocused. One area is the melt progression, the core  
18 melt progression, which we'll talk more about, fuel  
19 coolant interactions, which can provide a source of  
20 energy to possibly fail certain parts of the primary  
21 system and so forth, debris coolability which is an  
22 issue not only from the standpoint of accident  
23 management, also for the advanced passive reactors,  
24 and then hydrogen combustion.

25 (Slide) The next slide.

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1                   This just is a little cartoon which tries  
2 to illustrate where the loads on a containment come  
3 from during a severe accident. As you can see,  
4 pressure is the driving force. What we're worried  
5 about is really over pressurizing containment beyond  
6 its ultimate strength and failing it. The things that  
7 can contribute to increasing the pressure obviously is  
8 if you put a break in the primary system you'll  
9 release steam and possibly hydrogen from the primary  
10 system. Melt, as it relocates to the lower part of  
11 the vessel and perhaps out in -- if it fails the  
12 vessel into the containment, will interact with the  
13 concrete base mat. It will generate non-condensable  
14 gases, hydrogen. Also, the melt itself can interact  
15 with the containment atmosphere producing heating and  
16 a pressurization. All of these contribute to  
17 pressurizing the containment and ultimately to its  
18 possible failure.

19                   (Slide) Next slide, please.

20                   In the intervening period from 1988 to  
21 '92, after we had revised the program and refocused  
22 it, we in fact completed research on a number of these  
23 issues that I just mentioned. The first one being the  
24 Mark I liner failure issue. The results of that  
25 research demonstrated that the Mark I containment

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1 integrity would be maintained provided water was added  
2 to cover the core debris. This was documented in  
3 NUREG/CR-5423 and it underwent a peer review, a very  
4 extensive peer review. As a result of that peer  
5 review, we identified four areas that required some  
6 confirmatory research to confirm the conclusions of  
7 the report. We set forth and did that research,  
8 carried it out, completed it. The results of that  
9 research were incorporated back into the report. It  
10 was then peer reviewed a second time to make sure that  
11 we had, in fact, addressed the issues of the first  
12 peer review. It was and the final report, NUREG/CR-  
13 6025, was issued in October of '93.

14 And we have taken the results of that  
15 research and we are using it as we review the IPES  
16 right now. So, as we review IPES, in particular the  
17 plants with the Mark I containments, we are looking at  
18 how they were dealing with the question of having  
19 reliable water supplies to provide water to the dry  
20 well.

21 (Slide) On the severe accident scaling  
22 methodology, we had a task group that was put together  
23 consisting of a number of experts in the country which  
24 met over a period of -- I guess it was well over a  
25 year, to put together this methodology. They applied

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1 it as an example to the direct containment heating  
2 issue and it was done successfully and we now have a  
3 NUREG report, NUREG/CR-5809, which is sort of a  
4 guidance document for all of our contractors to  
5 follow. For any new experiments that are being  
6 considered, they have to do a thorough scaling  
7 analysis to show why the results of that experiment  
8 can in fact be extrapolated up.

9 On source term issues, our research  
10 program is essentially complete with regard to the  
11 quantity of the source term, the timing of it, its  
12 release and the chemistry or its composition. One  
13 thing we are doing right now is participating in the  
14 Phebus project in France which you may know something  
15 about. That's a large scale, an integral experiment  
16 designed to look at the source term behavior not only  
17 in the primary system but as its transported basically  
18 from the core to the containment.

19 In terms of our source term research, we  
20 are planning on updating the source term. There's a  
21 SECY-92-127, which i believe has already been sent  
22 down to the Commission last year, and we have a final  
23 report, NUREG-1465, which we plan to publish at the  
24 end of '93.

25 COMMISSIONER REMICK: Brian, before we go

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1 on, I have a couple questions.

2 DOCTOR SHERON: Yes, sir.

3 COMMISSIONER REMICK: Do we know if other  
4 groups are using our scaling methodology that we've  
5 developed here?

6 DOCTOR SHERON: Other groups, you mean --

7 COMMISSIONER REMICK: International  
8 groups.

9 DOCTOR SHERON: International groups. Let  
10 me ask Farouk.

11 Are you aware of any?

12 DOCTOR ELTAWILA: I'm not aware of any,  
13 but we received a request for the report from  
14 different people in the -- member of the CSR, but we  
15 have not got any clear indication if they have used it  
16 or not.

17 COMMISSIONER REMICK: You indicate that  
18 the research program is complete in source term.  
19 What's the final resolution? I think there was a  
20 difference between EPRI and the staff on the low  
21 volatility radionuclides. Has there been anything  
22 more recent?

23 DOCTOR ELTAWILA: I think that difference  
24 still exists between us and the reason for the  
25 database that we have is not that complete to cover

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1 all the expected range of severe accident. So, the  
2 staff still believe that the source term that we  
3 propose in that NUREG document is still adequate. So,  
4 I don't think that difference has been resolved yet.

5 COMMISSIONER REMICK: Nothing on that?

6 At the meeting in Seoul on advanced  
7 nuclear power system, Pierre Bashear from, I think,  
8 EDF, and some others made some strong statements about  
9 the need to get various international regulatory  
10 groups to come to closure on source term and there  
11 were statements that there are differences of several  
12 orders of magnitude between source terms in different  
13 countries. Would that be related to results from the  
14 Phebus project or would you have any idea what would  
15 be the basis of the concerns like that that different  
16 regulatory bodies were using source terms that  
17 differed by several orders of magnitude?

18 DOCTOR ELTAWILA: I think the main reason  
19 I think some of the other countries that they have not  
20 developed their database as much as we developed ours  
21 in the United States here and they are relying in a  
22 much more conservative estimate in their evaluation  
23 until they have their own information. I don't  
24 believe that the Phebus project is going to change our  
25 opinion about the source term. I believe it's going

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1 to confirm that we are choose the source term. The  
2 source term that we are developed in this country is  
3 based on a lot of experimental data and the Phebus as  
4 an integral experiment is not going to assess each  
5 individual issue, but rather is going to give us the  
6 overall picture and our ability in calculating the  
7 source term can't confirm that rather than to produce  
8 any new information in that area.

9 COMMISSIONER ROGERS: Could I just --

10 COMMISSIONER REMICK: Excuse me. Go  
11 ahead, please.

12 COMMISSIONER ROGERS: -- piggyback on that  
13 a little bit?

14 Earlier you mentioned that the source  
15 term, in fact, depends very much on the particular  
16 reactor in the scenario that you're considering. The  
17 question is the variability in those results for U.S.  
18 reactors in different scenarios, is that outside of  
19 this gap between that Bashear is referring to of  
20 orders of magnitude difference between U.S. results  
21 and estimates done elsewhere.

22 COMMISSIONER REMICK: Yes. I have to say  
23 he did not say U.S. and elsewhere, he just said  
24 between different regulatory bodies, yes.

25 MR. TAYLOR: Maybe when we finish NUREG-

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1 1465 we ought to be sure it gets distributed widely  
2 and then perhaps have a meeting of people on the  
3 subject in an international forum since this  
4 represents the best of the efforts that we have had.

5 COMMISSIONER ROGERS: That would sound  
6 like a very useful --

7 MR. TAYLOR: And I think that would be  
8 very useful among the people who practice severe  
9 accident --

10 COMMISSIONER REMICK: Yes. I did not read  
11 his comments with any difference of U.S. necessarily.  
12 It was kind of an appeal internationally to the need  
13 for regulatory bodies to come to closure and be  
14 consistent because otherwise it will lead to lack of  
15 public confidence.

16 MR. TAYLOR: Maybe if we stimulate  
17 that description.

18 COMMISSIONER REMICK: Yes.

19 MR. TAYLOR: That sounds to me if we're  
20 about to wrap up our review, it would be appropriate  
21 to do that.

22 Eric, how do you feel about that? I think  
23 that we could make those types of arrangements.

24 DOCTOR BECKJORD: Yes, I think so. Did he  
25 give a paper? Is it available? Could we --

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1 COMMISSIONER REMICK: These were ad hoc  
2 comments --

3 DOCTOR BECKJORD: I see.

4 COMMISSIONER REMICK: -- of a discussion.  
5 I'm trying to think if Pierre gave a paper. I'm not  
6 sure. I'll check on that. But the comments came as  
7 part of a discussion of an international regulatory  
8 body, a harmonization basically.

9 DOCTOR BECKJORD: The director and some of  
10 his staff from the CEA's Institute of Safety are here  
11 this week and we can talk to them and see if they have  
12 some insight on this.

13 COMMISSIONER REMICK: Yes.

14 DOCTOR MURLEY: Could I add a point here?  
15 I don't think the situation is as divergent as its  
16 been portrayed. We've, in the context of the EPRI  
17 requirements document, of which EDF is a member of  
18 this, we've resolved the source term basically for  
19 evolutionary plants and also we've issued our FSER for  
20 the passive plant. So, we've at least got a  
21 regulatory resolution of how to proceed.

22 There will always be some loose ends, of  
23 course, but I don't see it as being a major issue  
24 that's going to affect the designs for the passive or  
25 the evolutionary.

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1                   COMMISSIONER REMICK: No, that certainly  
2 was not the point. In no way do I want to infer that  
3 there was a difference with U.S. source term. It was  
4 an appeal to international bodies to come together and  
5 on what should be the source terms used to have some  
6 kind of consistency. He claimed there were several  
7 orders of magnitude in different parts of the world.  
8 He said nothing specifically about U.S. and indicating  
9 that this can result in lack of public confidence if  
10 one nation are using this source term and another  
11 nation are using another and so forth.

12                   DOCTOR MURLEY: I do agree that we need to  
13 understand any differences. It may be the difference  
14 between a source term for design basis accidents and  
15 a source term for severe accidents. It may be used  
16 differently.

17                   COMMISSIONER REMICK: Yes.

18                   DOCTOR THADANI: In fact, I think -- as  
19 Tom was saying, I think that's where the difference  
20 is. What source term do you apply for design basis  
21 accident? Do you include in-vessel as well as ex-  
22 vessel part? As Commissioner Rogers said, that's  
23 definitely driven by sequences and the source term  
24 will depend on specific sequences. The concept,  
25 however, in terms of design basis accident would be a

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1 recoverable accident. So, perhaps one would only  
2 consider the in-vessel aspects. But for severe  
3 accidents, where you're looking at containment  
4 performance, you do have to look at the sequences and  
5 the challenges to the containment and actually what  
6 you would expect in terms of ex-vessel interactions as  
7 well. That's the approach we've been using in  
8 evolutionary and passive designs.

9 DOCTOR ELTAWILA: Can I add one more  
10 thing, just not to belabor the points here? There is  
11 an inconsistency in the definition of the source term.  
12 In the United States we define the source term as the  
13 amount of fission product in the containment itself.  
14 Some other country defines the source term about  
15 what's released outside the containment. So, if you  
16 take the effect of contamination due to the  
17 containment, that can be the reason for the  
18 differences. So, what we might need is a consistent  
19 definition of the source term, rather than the  
20 quantity of it.

21 DOCTOR SHERON: (Slide) Slide 9, please.

22 In the area of core concrete interactions,  
23 we've completed all of our dry core concrete  
24 interaction experimental research. By dry I mean that  
25 there is no overlying pool of water. We have

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1 validated models that are currently available for  
2 assessing a plant's response and we are continuing to  
3 do additional validation on experiments that are being  
4 conducted worldwide, both in the U.S. as well as in  
5 the Russian Republic.

6 In hydrogen transport and combustion, a  
7 major effort has been completed on a deflagration to  
8 detonation transition criteria under a variety of  
9 conditions. This is one that transitions from burning  
10 to a detonation.

11 We have research going on right now on  
12 some residual issues related to high temperature  
13 hydrogen combustion research. This is going on at  
14 Brookhaven National Laboratory and it's a joint  
15 program between the NRC as well as NUPEC in Japan.

16 (Slide) Next slide, please.

17 We have just recently completed our TMI-2  
18 vessel investigation project. This was -- I guess, as  
19 you know, we had a meeting in Boston just a week ago  
20 which was the final meeting in which we presented the  
21 results. What this program did is it provided a  
22 substantial amount of information to help us benchmark  
23 some aspects of our core melt progression models. We  
24 gained a lot of information about reactor vessel  
25 integrity. It gave us significant insights on

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1 accident management and, most importantly, it allowed  
2 us to evaluate the margin of failure of the TMI  
3 vessel.

4 Some of the highlights we had uncovered  
5 from this program is that we saw a hot spot on the  
6 lower head of the vessel, about a median diameter. It  
7 reached a temperature of 1100 degrees C for about 30  
8 minutes. But away from the hot spot the vessel  
9 temperature was below the 727 degree C transition  
10 temperature for the steel and, as a consequence, we  
11 were able to conclude that from that the vessel was  
12 not that close to failing under the conditions that  
13 were seen at TMI.

14 There was a number of other highlights  
15 there, I think, from the program. Instrument tube  
16 failures, for example, for the TMI type scenario are  
17 not considered to be a dominant failure mode. Creep  
18 rupture is the more controlling failure mode. The  
19 other thing we inferred from the results is that there  
20 is greater heat transfer between the core debris and  
21 the overlying pool of water. There may have been  
22 water ingress into the melt and that removed much more  
23 heat from the melt than what would be expected if we  
24 did our calculations with our current codes.

25 All of this indicated that there was

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1 substantially more margin in that vessel than we would  
2 have predicted had we just done an outright  
3 calculation with our analysis codes.

4 COMMISSIONER REMICK: Have we attempted to  
5 calculate the progression of the melt with our codes,  
6 what we believed to be the case in TMI and if we did  
7 so how accurately were we able to do that? Have we  
8 attempted to use MELCOR or something?

9 DOCTOR BECKJORD: Yes, we did  
10 calculations.

11 Farouk?

12 DOCTOR ELTAWILA: There was an effort  
13 under the sponsorship of OECD, a comparison exercise  
14 using the different code and we used the SCDAP/RELAP  
15 code and the MELCOR code. But that was done about  
16 five years ago, an older version of this code. We are  
17 planning now after we add all the updates to our code  
18 to go over the scenario again and see how well we  
19 predicted.

20 COMMISSIONER ROGERS: Just before you  
21 leave that topic, as you know I was at that  
22 presentation last week and I just want to say that I  
23 think that whole project was an enormous success. I  
24 think it was very well managed and I think the NRC did  
25 a superb job in bringing the international effort

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1 together, getting the support from overseas that was  
2 vital to be able to do the job as well as it was done,  
3 and the quality of the work. I couldn't stay for the  
4 whole meeting, but certainly what I heard was very  
5 impressive indeed. I think that it really was a  
6 superb piece of work. I think that a great deal of  
7 credit should go to NRC's management of that effort in  
8 bringing it all together. Fine effort.

9 DOCTOR BECKJORD: Thank you very much.

10 (Slide) Slide 11, please.

11 Last year, which was around four years  
12 since we started to look at our revision to the Severe  
13 Accident Research Program -- as you remember that was  
14 done in 1988 with the 1365 being issued in 1989 -- we  
15 decided that we ought to take another look and now  
16 update and see where we are again. What we did is we  
17 updated it through revision 1 of NUREG-1365 and what  
18 this revision done is it identifies the issues that  
19 have now been completed or are very near completion.  
20 It describes the progress and our understanding of  
21 important severe accident phenomena. It defines the  
22 research that would lead to closure of core melt  
23 progression, direct containment heating, which as I  
24 said before was an early containment failure mode, and  
25 fuel coolant interactions and it includes research

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1 that would be applicable to the advanced passive light  
2 water reactors, especially in the area of containment  
3 performance criteria during severe accidents.

4 (Slide) Next slide, please.

5 In the revised Severe Accident Research  
6 Plan we're focusing our research on three  
7 phenomenological issues and on code development and  
8 assessment.

9 One thing I want to point out is, and I  
10 think I said this a couple weeks ago at our -- I may  
11 have mentioned this at the thermal hydraulic briefing,  
12 and important aspect of our code development program  
13 now is peer review. Each one of our major codes has  
14 or is undergoing a peer review. These are with  
15 outside experts, not within the agency, but people  
16 that are knowledgeable in the area with a wide variety  
17 of backgrounds, both in large codes as well as in  
18 phenomena and so forth. And the objective is to  
19 identify deficiencies in the code and to identify any  
20 necessary further work in order to say these codes  
21 have reached a good state of maturity and which we can  
22 have confidence in their application to severe  
23 accidents.

24 COMMISSIONER ROGERS: How was that being  
25 conducted? How was that peer review actually carried

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1 out? Some of these codes are enormous things that are  
2 developed over many, many years. How are they  
3 actually doing a peer review of the codes?

4 DOCTOR BECKJORD: What we do is --

5 COMMISSIONER ROGERS: Are they piece by  
6 piece?

7 DOCTOR BECKJORD: No. No. It's for the  
8 whole code. Let me give you an example for MELCOR.  
9 What we did is we asked Los Alamos National Laboratory  
10 to head up the peer review effort. They had one  
11 individual who was acting as sort of the project  
12 manager or the coordinator. We wanted to do this just  
13 so that the NRC was still at arm's length from the  
14 peer review process. The individual then selected  
15 peer reviewers and I can't remember how many.

16 Do you remember how many there were for  
17 MELCOR?

18 DOCTOR ELTAWILA: Maybe eight or so.

19 DOCTOR BECKJORD: It was around eight or  
20 so. They had a wide variety of backgrounds. Some  
21 knew large codes. Some knew certain phenomena better  
22 than they knew others. So, we had a real spectrum.  
23 They would then go off and they would conduct a number  
24 of -- they would do their review. They would come  
25 back, they would periodically meet. During those

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1 meetings the contractors, the developers of the code  
2 would give them presentations on the models,  
3 verification, whatever information that they would  
4 need. Sometimes the peer reviewers would need some  
5 additional calculations done in order that they could  
6 look at, say, sensitivities. So, our contractor would  
7 go back and do those calculations. Then this was all  
8 pulled together again by Los Alamos in the form of a  
9 final peer review report, which was then issued.

10 We, the NRC, then took the peer review  
11 report. We looked at the recommendations and the  
12 conclusions. We had to decide what things were  
13 important for the NRC, for regulatory. In other  
14 words, you would get a lot of recommendations, for  
15 example if some model may not have enough validation.  
16 But the question is was that important for the NRC's  
17 work? If it wasn't, then we may not want to go off  
18 and spend a lot of time or money working on that one  
19 item.

20 We then would take the peer review report  
21 and we would put together an implementation plan on  
22 how we would address the peer review comments. Then  
23 we would go forth and do that.

24 Farouk, do you want to add anything to  
25 that?

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1                   COMMISSIONER ROGERS: What were the most  
2 significant modifications or deficiencies that you  
3 felt should be addressed?

4                   DOCTOR ELTAWILA: The most deficient  
5 things in our code right now is the late phase melt  
6 progression because the database is inadequate. About  
7 two years ago when we started that program the only  
8 database that we had is the TMI accident itself and we  
9 did not have any information about that. Some of the  
10 other important problem is the numerics with the code,  
11 lack of diversions and it's difficult to run.  
12 Documentation was an important issue and assessment of  
13 the codes. So, all of these we had an expedite, very  
14 aggressive program to address all of them. We still  
15 have additional database on late phase melt  
16 progression, but that has not been incorporated in the  
17 codes yet.

18                   COMMISSIONER ROGERS: And the  
19 documentation, where does that stand?

20                   DOCTOR ELTAWILA: The documentation right  
21 now, I think we improved the documentation  
22 tremendously and most of our codes right now, the  
23 documentation is very adequate. I think we have  
24 learned one lesson from the peer review process, that  
25 we should not let -- in the future, anybody develop a

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1 code should not let the code developer start  
2 developing a code and to go along developing very fast  
3 without having a peer review process along the way.

4 So, what we have instituted in the  
5 division and in the branch in particular, that any  
6 time we have a modification to the code, before it is  
7 incorporated in the code we form smaller group of  
8 expert to review the model, to see if the database  
9 support the implementation of that model. Once we get  
10 the approval of the peer reviewer we give the code  
11 developer the go-ahead to add this model into the  
12 code. So, this way we'll not fall into trap that we  
13 have to review a very complex code like we did in the  
14 case of the MELCOR code.

15 COMMISSIONER ROGERS: Thank you.

16 COMMISSIONER REMICK: Has RELAP/SCDAP also  
17 had a peer review and have any issues there been  
18 resolved?

19 DOCTOR ELTAWILA: The SCDAP/RELAP has gone  
20 peer reviewed. The main issue that were resolved is  
21 the user friendliness, the documentation and the  
22 ability to run the code for full plant analysis. We  
23 have resolved all this problem. The peer review was  
24 just finished about six or eight months ago. So, we  
25 have a plan in fiscal year '94 to implement the high

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1 priority issue of the peer reviewer comments.

2 DOCTOR BECKJORD: Okay. On direct  
3 containment heating closure, we've done a lot of work  
4 in this area. We've finished our scaling analysis, as  
5 I mentioned. We started running experiments again at  
6 the SURTSEY facility at Sandia. We also then found a  
7 way to utilize the containment technology test  
8 facility which is a one-sixth scale concrete  
9 containment model at Sandia. So, we had now  
10 experiments at Argonne which we had a small one-  
11 fortieth scale. We had the SURTSEY facility at  
12 Sandia, which was one-tenth scale. We then went to  
13 one-sixth scale. So, I think we have a real good base  
14 to extrapolate to the prototype plant on a DCH.

15 We have developed a resolution for DCH for  
16 the Zion plant. That report has been issued and is  
17 undergoing peer review. We also have a resolution  
18 plan now that has been issued for the Surry plant.  
19 These were the two designs that we looked at  
20 experimentally because of their difference in their  
21 lower compartment geometries.

22 The report on Surry came out about a month  
23 or month and a half after the Zion report. It also  
24 has a generic -- it's called the integrated report.  
25 It also looks at the general methodology of

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1 extrapolating to other designs. Both these reports  
2 are undergoing peer review and will follow basically  
3 the same process we did on a Mark I issue.

4 COMMISSIONER REMICK: In the SECY document  
5 there was no mention of B&W plants. What is being  
6 done for the B&W plants.

7 DOCTOR BECKJORD: On direct containment  
8 heating?

9 COMMISSIONER REMICK: Yes.

10 DOCTOR BECKJORD: Direct containment  
11 heating, B&W plants for direct containment heating  
12 look very similar to a Westinghouse design. The plant  
13 that does not in this case is the combustion. The  
14 reason is because they do not have lower penetrations  
15 on their vessel head and they do not have that keyway  
16 to bring out the instrument tubes.

17 COMMISSIONER REMICK: I see.

18 DOCTOR BECKJORD: Right now we're looking  
19 at whether we have to run one or two more experiments  
20 to possibly get some information on the CE design.

21 (Slide) On core melt progression, early  
22 phase melt progression we think is fairly well  
23 understood. We've run a number of experiments, both  
24 in the U.S. as well as abroad to understand the early  
25 phases of core melt, the candling down of the cladding

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1 and the early relocation. One remaining uncertainty  
2 is the question of blockage versus drainage, which  
3 applies primarily to BWRs. Because you have an ADS  
4 system you blow most of the coolant out of the core,  
5 out of the primary system during the blowdown. So,  
6 when the core melts, it is not melting where the lower  
7 part of the core is underwater still. So, there's a  
8 question as to whether when the melt comes down it  
9 will freeze and the cooler lower portions are whether  
10 it will run right down and relocate immediately to the  
11 lower head.

12 On fuel coolant interactions and debris  
13 coolability, we've completed most of our research on  
14 the fundamentals of fuel coolant interaction. We have  
15 work going on right now cooperatively at the FARO  
16 facility in Ispra, Italy involving a large scale  
17 integral test. But our ex-vessel debris coolability  
18 research results are still inconclusive.

19 These --

20 COMMISSIONER REMICK: How do you see that  
21 closure on that?

22 DOCTOR BECKJORD: On the fuel coolant  
23 interaction?

24 COMMISSIONER REMICK: Yes.

25 DOCTOR BECKJORD: Doctor Eltawila is going

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1 to discuss that in his presentation.

2 COMMISSIONER REMICK: Okay.

3 DOCTOR BECKJORD: (Slide) On our computer  
4 codes we just talked about those. I'll just touch on  
5 these very quickly.

6 Our major severe accident codes are the  
7 MELCOR code, which is an integral risk assessment  
8 code. When I say risk assessment it's used primarily  
9 for risk assessment. This has been peer reviewed.  
10 The comments of the peer reviewers, as I said before,  
11 have been taken into account and we have work going on  
12 to incorporate these. I think most of it's already  
13 been done.

14 On the SCDAP/RELAP code, this is our  
15 detailed core melt progression code. The peer review  
16 is complete and we have a program underway right now  
17 to address the peer review comments.

18 The CONTAIN code, which is our containment  
19 analysis code, a detailed peer review was started in  
20 April of '93 and we expect it to be completed in about  
21 four months or five months, which would be in March  
22 '94.

23 We do have other specialized codes which  
24 we use for specific type phenomena analyses. These  
25 are HMS, which looks at hydrogen transport, COMMIX,

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1 which we are looking at. That's a three dimensional  
2 computer code which looks at the containment behavior  
3 for the AP-600 where you're in a condensing  
4 environment.

5 (Slide) Next slide, please.

6 COMMISSIONER REMICK: For MELCOR,  
7 SCDAP/RELAP and CONTAIN, I'm really pleased with the  
8 fact that you are having the peer review and resolving  
9 issues. How about long-term maintenance? Do you have  
10 plans to make sure that once you've brought them up to  
11 date that we maintain the codes and the expertise  
12 knowledgeable in the codes over a longer period of  
13 time?

14 DOCTOR BECKJORD: I address that in my  
15 last slide.

16 COMMISSIONER REMICK: Okay.

17 DOCTOR BECKJORD: I just want to touch  
18 very quickly on some of the research facilities that  
19 the NRC sponsors. We have funded significant  
20 experimental research in facilities both in the U.S.  
21 as well as around the world. We've done in-vessel  
22 crust behavior studies in the Annular Core Research  
23 Reactor at Sandia. We have ex-reactor experiments to  
24 study this question of blockage versus drainage for  
25 the BWRs, also at Sandia. When we put these slides

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1 together we also had a full-length core melt  
2 experiment scheduled at the Canadian NRU reactor.  
3 Unfortunately, after several delays on the part of the  
4 Canadians, we went to test our test bundle and found  
5 we had a leak in it. So, the test has been canceled.

6 As I said before, we have fuel coolant  
7 interaction experiments going on at the FARO facility  
8 in Ispra, Italy and I think you're probably aware we  
9 are now looking at a lower head coolability program  
10 using a RASPLAV facility in Moscow.

11 COMMISSIONER ROGERS: Could you say just  
12 a quick word or two about that RASPLAV program?

13 DOCTOR BECKJORD: Basically what it is is  
14 we're looking at a scale model of a cylindrical vessel  
15 lower head and what we want to understand are two  
16 things. One is the behavior of the melt in the lower  
17 head itself, the circulatory patterns and therefore  
18 the heat transfer. Then hopefully later on the  
19 question of having -- if there is water on the outside  
20 of the vessel, what kind of cooling that would  
21 provide.

22 The Russians right now are still designing  
23 the test facility itself. There's questions about  
24 whether we go to a complete hemispheric lower head or  
25 whether we use a slab geometry because the heating

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1 obviously is by induction heating and the Lorenz force  
2 becomes very significant when you have a large  
3 hemispherical head and it may distort the phenomena  
4 that you're interested in.

5 DOCTOR BECKJORD: That will become another  
6 OECD Nuclear Energy Agency program. It's been  
7 approved and I think CS&I will put its blessing on it  
8 at the December meeting. As I think you've seen,  
9 there's a very strong logical follow-on to the TMI  
10 vessel program.

11 COMMISSIONER de PLANQUE: Brian, just a  
12 general question and a qualitative answer will do. If  
13 you look at all the experimental research being done  
14 internationally, what proportion of that research is  
15 being done in U.S. facilities and do you see a trend  
16 in the change of that proportion?

17 DOCTOR SHERON: In terms of number of  
18 experiments or in dollars per experiments?

19 COMMISSIONER de PLANQUE: Well, I don't  
20 know what unit I want it in. What will best describe  
21 the situation?

22 DOCTOR SHERON: Well, I mean, I would, and  
23 this is just my judgment, maybe Farouk -- I would say  
24 maybe about, what, two-thirds in the U.S., one-third -  
25 - maybe one-half, one-half. Okay?

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1                   In terms of dollars, there's a couple of  
2 major experiments. For example, the FARO facility is  
3 fairly high cost. We have very good leverage on that  
4 because we're only paying, what, 15 percent, I  
5 believe, of the cost?

6                   DOCTOR ELTAWILA: We have the fixed cost  
7 of close to \$1.75 million that we're sharing with  
8 EPRI, but the FARO or CEC and the European Community  
9 is paying the salaries and the costs of the facility  
10 itself, so we're going to run five experiments over  
11 there at that fixed cost regardless of the outcome of  
12 how long it takes or anything like that.

13                   COMMISSIONER de PLANQUE: Do you see any  
14 indication that more and more of this work as we go on  
15 or get into the advanced reactors will have to be done  
16 at facilities outside the U.S.?

17                   DOCTOR ELTAWILA: In the area of severe  
18 accident, we have not identified any new area that can  
19 affect the advanced light water reactor. The reason  
20 that some of this work now is starting, for example in  
21 Europe, and we don't have any of that work, they start  
22 very late compared to us.

23                   We have our experimental program going on  
24 since the '80s, so we developed a wealth of database  
25 and now they are trying to develop their own database

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1 and we are taking advantage of that by becoming a  
2 member of this international program to get the  
3 information at very cheap cost and we keep our  
4 expertise maintained and involved in this program at  
5 the same time. So although they have started, most of  
6 the work in severe accident will be in European  
7 countries. I think we have our own database that they  
8 are trying to catch up with.

9 COMMISSIONER de PLANQUE: Okay.

10 DOCTOR BECKJORD: I think I'd like to add  
11 something to that. I think it's very clear that there  
12 is a benefit to the international cooperation and I  
13 think that's recognized throughout the world and that  
14 has meant that there are now more cooperative programs  
15 outside of the U.S. whereas before ten years ago it  
16 was primarily inside the United States.

17 I think the direction here is going to  
18 depend very much on the direction of the nuclear  
19 industry in this country. If there's a strong nuclear  
20 industry, I think you will find that there will be a  
21 lot of projects that are carried out with  
22 international cooperation here.

23 COMMISSIONER de PLANQUE: Okay. Thank  
24 you.

25 DOCTOR SHERON: For the sake of time,

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1 slide 16 really doesn't say anything other than list  
2 some facilities we have.

3 I'd like to just -- if you'd look at the  
4 monitors, we've got some much better pictures of some  
5 of these facilities.

6 COMMISSIONER REMICK: Brian, before going  
7 to that --

8 DOCTOR SHERON: I'm sorry.

9 COMMISSIONER REMICK: -- I've recently  
10 heard that the Japanese have a program of severe  
11 accidents called Alpha. It's not listed here. Do we  
12 have any involvement with an Alpha program on severe  
13 accidents?

14 DOCTOR ELTAWILA: Yes. As part of our  
15 severe accident research program, the Japanese are  
16 entitled to our data and we are entitled to their  
17 data. I apologize for not including it here in the  
18 viewgraphs.

19 COMMISSIONER REMICK: So we will get the  
20 data from their programs?

21 DOCTOR ELTAWILA: We will get the data.

22 DOCTOR SHERON: (Slide) Okay. If you  
23 could put the pictures on the monitor, the first one  
24 is a picture of the SURTSEY vessel. As you can see,  
25 this is one-tenth linear scale. This is at the Sandia

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1 Laboratories. At the bottom, it's not very clear, but  
2 right inside the vessel in the lower part is where we  
3 have the melt generator which drives the melt into the  
4 containment and we measure the parameters like the  
5 hydrogen and the pressure and so forth.

6 COMMISSIONER REMICK: What is the melt  
7 material that they're using?

8 DOCTOR SHERON: This is usually Thermite,  
9 which is an iron-alumina compound.

10 (Slide) The next picture is the CTT  
11 facility, the Containment Technology Test facility.  
12 This is a one-sixth linear scale model of the  
13 Westinghouse containment, I believe, and this was  
14 actually tested previously where it was pressurized to  
15 see its failure mode, and so it was pressurized up to  
16 its ultimate strength and then it showed signs of  
17 failure. I think what happened was that the liner  
18 cracked and the pump that was pressurizing it just  
19 could not keep up with the leakage.

20 DOCTOR BECKJORD: Reinforced concrete.

21 DOCTOR SHERON: Yes.

22 DOCTOR BECKJORD: It got up to a little  
23 bit over 130 pounds per square inch.

24 DOCTOR SHERON: So, we decided that we  
25 could use that for our DCH testing as well.

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1 (Slide) The next picture, please.

2 This is a picture of our high-temperature  
3 high-speed combustion facility. I think this picture  
4 was taken at the construction site where it was built.  
5 It has since been taken apart and relocated to  
6 Brookhaven and, if anyone is traveling to Brookhaven,  
7 I think in about another couple weeks you would be  
8 able to see this. It's put in a long tunnel down  
9 there and we will be looking at high-speed high-  
10 temperature combustion phenomena on hydrogen.

11 (Slide) Next slide, please.

12 This is just a schematic of the Phebus  
13 facility which will show you the mock-up of the  
14 primary system and the containment and the -- the  
15 steam generator is in there too and the pressurizer  
16 and, again, it's a matter of looking how fission  
17 products distribute in the core, the primary system  
18 and in the containment.

19 With this, I'm going to let Doctor  
20 Eltawila talk to you about the next two items on the  
21 agenda.

22 DOCTOR MURLEY: Brian, could I just add a  
23 point here?

24 DOCTOR SHERON: Yes.

25 DOCTOR MURLEY: From our perspective, this

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1 is very valuable research and we do use it and I'll  
2 give one example.

3 Brian was talking about the TMI-2 vessel  
4 results and I had -- as we were wrapping up our  
5 reviews of the evolutionary plants and writing our  
6 FSERs, I wanted to know whether there had been any  
7 kind of integral insights, licensing insights, safety  
8 insights that have changed as a result of this  
9 research, and so I asked Ashok's staff what would have  
10 been -- would the containment have failed if the  
11 vessel had failed at TMI-2? Now, there was a  
12 preliminary study done by the Rogovin group right  
13 after the accident, but, in light of all this new  
14 information, I asked them to look into that and maybe  
15 he can say a few words.

16 The bottom line is that probably it would  
17 not have failed using the codes and the best methods  
18 that Research has developed as long as the containment  
19 sprays were available. If they were available, it  
20 would not have failed at all.

21 DOCTOR THADANI: Yes, that's basically  
22 what we concluded and in fact some of the calculations  
23 have helped us think about some helpful accident  
24 management strategies that one can develop to protect  
25 containment for long-term.

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1 DOCTOR MURLEY: I think our FSER will  
2 include a detailed discussion of severe accident  
3 behavior of these evolutionary plants and it will of  
4 course use -- depend greatly, almost totally on the  
5 methods and research that has been developed in the  
6 last decade or so.

7 COMMISSIONER REMICK: That's a good  
8 introduction to a question I was going to ask later  
9 on, a question I was recently asked. How would you  
10 characterize how we are doing severe accident analysis  
11 in the reviews? It's not really a design basis  
12 approach, but how would you express how we are going  
13 about looking at severe accidents in the designs?

14 DOCTOR MURLEY: I can express it broadly  
15 and then perhaps Ashok can add. What we've said from  
16 the beginning is that a core melt accident, severe  
17 accident, is not a design basis accident in the  
18 classical sense because there what one does is insist  
19 on diversity and redundancy and basically gold-plating  
20 all the equipment that needs to deal with it and we  
21 said that's not necessary. But one must consider core  
22 melt accidents in the design and do what you can to  
23 mitigate their consequences and where it makes sense,  
24 where it seems to be cost-effective, put features in  
25 the design to cope with those things, so we're quite

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1 confident that we have reduced the conditional  
2 containment failure probability given a core melt  
3 accident, but we've stopped short of all the  
4 paraphernalia that goes with making it a design basis  
5 accident.

6 COMMISSIONER REMICK: I think I didn't do  
7 too bad in providing an answer. One thing I did add  
8 is rather than conservative calculations too we used  
9 best estimate and realistic--

10 DOCTOR MURLEY: Yes.

11 COMMISSIONER REMICK: That's correct?

12 DOCTOR THADANI: That's right. And where  
13 there are questions -- I'll use an example.  
14 Initially, if you recall, when we came up with SECY-  
15 90-016 we said quench the core debris was our first  
16 thinking and then we realized the experimental basis  
17 couldn't really support that. Well, what was our  
18 goal? Our ultimate goal was to make sure that the  
19 containment integrity would be maintained for those  
20 accidents for some time period. You recall we talked  
21 about 24 hours, and that then required that we do some  
22 analysis and use some best estimate analysis to see  
23 what coolability considerations would be, what heat  
24 transfer mechanisms would be involved and if in fact  
25 one would impact some of the support structures and so

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1 on. And it was these codes that we used to analyze to  
2 get an understanding of what could happen and how much  
3 time there would be before the containment would be  
4 pressurized beyond the ultimate point, so I would say  
5 that this has been very helpful and timely for us.

6 COMMISSIONER REMICK: Are the new designs  
7 using concrete aggregate that produces less of the  
8 noncondensibles or not?

9 DOCTOR THADANI: No. They are using  
10 aggregate that uses less gas production, but then  
11 there are some other downsides to that also. So  
12 that's the way they're going right now and that's  
13 what's in our, in fact, ITAACS.

14 COMMISSIONER REMICK: I see.

15 DOCTOR ELTAWILA: I would like to talk  
16 about two phenomenological areas of research that we  
17 are doing right now in the Accident Evaluation Branch.  
18 The first one is the fuel-coolant interaction and the  
19 second one related to the debris coolability, and they  
20 are related somehow. That's adding water or molten  
21 material and getting in contact with water.

22 But before I start the detailed  
23 discussion, I would like to make a point that whenever  
24 we talk about fuel-coolant interaction people always  
25 think of the alpha mode steam explosion that was

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1 defined in the WASH-1400. There are other aspects of  
2 fuel-coolant interaction that we are interested in.  
3 I will repeat myself later, but we have concluded the  
4 alpha mode containment failure is a low probability  
5 event and we are not looking at it at all.

6 For example, during the TMI event when the  
7 material relocated into the lower head there was a  
8 mild fuel-coolant interaction which had some  
9 beneficial effect which resulted in the quenching of  
10 the material in the lower head and that's why we did  
11 not see the challenge in the lower head that we used  
12 to assume in our analyses before. So, because fuel-  
13 coolant interaction can occur in the vessel itself as  
14 a result of accident management through flooding the  
15 core, it can happen in the lower plenum as a result of  
16 molten material falling into the water coolant and it  
17 can happen ex-vessel as a result of reactor pressure  
18 vessel failure and pouring of the material into  
19 flooded cavity.

20 We have interest in pursuing the issue of  
21 fuel-coolant interaction and our main focus is try to  
22 identify what are the relocation scenario likely to  
23 lead into a coolable configuration, what are the  
24 effects of fuel coolant interaction on lower head  
25 integrity and on the cavity and pedestal integrity,

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1 and what is the likely energy release and resulting  
2 load from containment? Again, we're not talking about  
3 the alpha mode failure. Here we're talking about the  
4 potential of producing large quantities of steam and  
5 hydrogen and see how can that charge the containment  
6 hydrostatically or quasi-static pressurization.

7 COMMISSIONER ROGERS: Excuse me. Just  
8 before you move off that, this question of the  
9 relocation scenarios, do you have in mind that it's  
10 the possibility of influencing the development of  
11 scenarios? In other words, accident management  
12 through this work or is that just beyond what you're  
13 looking at?

14 DOCTOR ELTAWILA: Absolutely not. I think  
15 we -- our position that any time you have a water --  
16 you add the water as much as you can. It's not the  
17 idea of to influence the scenario itself. It's try to  
18 understand the consequences of adding the water, what  
19 a person observing severe accidents should one occur  
20 expect to happen as a result of adding the water at  
21 the different stages of the accident. So, he will  
22 have indication about -- should have an idea about the  
23 amount of steam that would produce, the amount of  
24 hydrogen that can be produced, where that hydrogen  
25 will go, how the water addition itself can influence

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1 the source term, can influence the result the rest of  
2 the core melt progression.

3 So, it's not to alter anything, but to  
4 understand the consequences of the action that we'll  
5 be taking.

6 COMMISSIONER ROGERS: Well, that troubles  
7 me a little bit, frankly. This is not some abstract  
8 kind of scientific study. You don't want to just know  
9 what happens. If there's some possibility of a  
10 management decision being made to influence the  
11 evolution of the scenario, you want to be able to be  
12 able to pass that kind of information on. So, it  
13 sounded to me as if either there isn't any work going  
14 on in that or that that's -- I'm just uncomfortable  
15 about your answer on that one because -- maybe I  
16 misunderstood it, but it didn't seem to me that you  
17 can pull out of this what would be ultimately the  
18 ultimate most useful result, namely not what has  
19 happened, but how do you see that the worst thing  
20 doesn't happen when you're adding water. The rate at  
21 which you add it and when you add it.

22 DOCTOR THADANI: If I may comment on that.  
23 I think this is very valuable information as part of  
24 accident management considerations. In fact, this is  
25 the kind of information that the industry would be

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1 looking at and in fact they are looking at today as  
2 part of their accident management program to see what  
3 kind of strategies they need to develop and what kind  
4 of information would be needed in the development of  
5 that strategy and the information that one needs is  
6 what comes out of an activity like this. There is a  
7 program in place that the industry has. They expect  
8 to implement the accident management program. They  
9 expect to implement by the middle of 1997. I mean  
10 there's a lot more to it, including the completion of  
11 IPEs and so on, but this is very useful information  
12 that goes into that program and assessment of what  
13 actions should be taken given one understands the  
14 state of conditions.

15 COMMISSIONER ROGERS: Yes, but I would  
16 hope that it wouldn't be just an open loop feedback  
17 system, that somehow you'd close that loop so that  
18 whatever studies are being done also consider what the  
19 management actions might possibly be and then the  
20 consequences of those.

21 DOCTOR THADANI: I was being very  
22 simplistic, I admit.

23 COMMISSIONER ROGERS: Okay. All right.

24 DOCTOR THADANI: But yes, indeed. In  
25 fact, including what kind of instrumentation and

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1 capability you need to be able to feed back and  
2 assess.

3 COMMISSIONER ROGERS: All right. Okay.  
4 That is part of your objective here.

5 DOCTOR THADANI: Yes, and also the  
6 decision making process. This is --

7 COMMISSIONER ROGERS: Now I hear NRR  
8 talking, but my problem was with an RES response. So,  
9 I would hope that you would be closing the loop  
10 internally here.

11 DOCTOR BECKJORD: The conclusion of my  
12 paper dealt with this at the Boston meeting last week  
13 and I think there is a very clear lesson from TMI-2 as  
14 to how you handle the scenario and the pressurized  
15 water reactor that's following that way.

16 There are still some questions that have  
17 to be answered and Doctor Eltawila is talking now  
18 about the fuel coolant interaction and that's one of  
19 the questions that needs to be dealt with. In  
20 particular, it's clear that you want to put water in  
21 the vessel. It's almost as important for the vessel  
22 as it is for cooling the core. If the vessel was  
23 overheated, and I think we can conclude now that the  
24 vessel will be overheated if the core melts and falls  
25 to the bottom, you also want to limit the pressure and

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1 bring the pressure down. The question is how far to  
2 bring the pressure down and that's still an  
3 outstanding question that he is dealing with.

4 COMMISSIONER ROGERS: Okay.

5 DOCTOR BECKJORD: And then when you know  
6 that the core has been quenched, then you're free and  
7 clear. You just keep the water in there, keep the  
8 cooling going.

9 COMMISSIONER ROGERS: Sure. Okay.

10 DOCTOR ELTAWILA: (Slide) If I may jump  
11 to a viewgraph on page 23 just to try to describe the  
12 phenomena of fuel coolant interaction and I just would  
13 like to emphasize that this schematic here is a very  
14 old and does not represent our understanding right  
15 now, but I put it in totality here to see how far we  
16 came in understanding the issue of fuel coolant  
17 interaction as a result of the research.

18 When the molten core material is  
19 accumulated on the lower core plate, it was assumed in  
20 WASH-1400 that would be a catastrophic failure of the  
21 lower core plate and the material will enter into the  
22 water pool in the lower plenum. It will fragment and  
23 interact with water produced large quantities of  
24 steam. If an explosion occur as a result, for  
25 example, of the material impacting the lower plenum or

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1 any of the plates located in the lower plenum and that  
2 shock wave propagates through the system, additional  
3 fragmentation will happen which provides more surface  
4 area which will interact with the steam and accelerate  
5 a slug of liquid material upward and impacting on the  
6 upper head of the vessel, dislodging it and impacting  
7 the containment and penetrating the containment. That  
8 was the WASH-1400 assessment.

9 Since then there was some other research  
10 here that indicated if we have enough energy to impact  
11 the upper head and dislodging, that same energy would  
12 be able to fill the lower head and that will reduce  
13 the amount of energy available to impact on the upper  
14 head and that was the reason for concluding that the  
15 alpha mode failure is a low probability.

16 Again, right now, our research result,  
17 which I will discuss it in detail, indicate now there  
18 is not enough energy in the system to fill either the  
19 lower head or the upper head. So, instead of relying  
20 on a failure in the system to eliminate another  
21 failure, we believe that the failure mode of the  
22 vessel has been under control right now.

23 (Slide) Just to put our approach -- I'll  
24 go back to page 22 -- our approach in perspective, in  
25 1985 the NRC formed the steam explosion review group

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1 and that group concluded that the occurrence of a  
2 steam explosion was sufficient energy to fail  
3 containment has a very low probability. At that time  
4 the steam explosion review group used engineering  
5 judgment, used probabilistic approach and used  
6 subjective assessment about uncertain phenomena. They  
7 did not have enough database to help them put this  
8 issue to rest and they recommended additional research  
9 to try to explore the certain key energetic generic  
10 phenomenological aspect of fuel coolant interaction to  
11 address the complex variation in core melt  
12 progression, whether we have a large coherent pour, as  
13 they assume in the WASH-1400, or we can have a slender  
14 slow pour as happened at TMI and in accident  
15 management whether you add water early, in the early  
16 stage of core melt progression or at advanced stage of  
17 core melt progression.

18 So, we devised our research program based  
19 on the recommendation of the steam explosion review  
20 group and we performed a small scale experiment to  
21 look at the fundamental of the phenomena itself, which  
22 mainly the premixing and this is a hypothesis that  
23 when the material located into the lower head, the  
24 largest steam that occurred as a result of that  
25 relocation would pull the water out of the mixing zone

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1 and will result in depletion of water in that region.  
2 So, you have a physical limit on the amount of  
3 material that can participate in fuel coolant  
4 interaction.

5 That was a hypothesis in 1989. We ran  
6 experimental program and we proved that the issue of  
7 water depletion is a real issue and now we have  
8 confidence in our assessment of these loads.

9 The second issue about additional  
10 fragmentation that can happen as a result of being in  
11 an explosion zone and we have completed our research  
12 in that area too. We have used the research result  
13 and developed analytical tools which have been  
14 validated using this experimental result and other  
15 results from other countries too.

16 (Slide) May I have page 24, please?

17 As Doctor Sheron indicated, that we are  
18 performing a large scale experiment with prototypic  
19 material,  $UO_2$ ,  $ZrO_2$ , and Zirconium. And under  
20 prototypic conditions representative of accident in  
21 the in-vessel at the FARO facility, we hopefully will  
22 run a test later on this year to investigate the melt  
23 jet fragmentation, the quenching, the vapor  
24 generation, the hydrogen generation, any thermal load  
25 on the lower head and any erosion in the lower head.

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1           By using our analytical tool that we  
2 developed based on separate effect tests to prepredict  
3 that experiment and then try to compare the result  
4 between preprediction and after the experimental  
5 result, we'll be able to have additional confidence in  
6 our analytical tool.

7           Our approach to resolve fuel coolant  
8 interaction, like any other issue in severe accident,  
9 is using a probabilistic framework. Since there are  
10 too many variations of the accident scenario, we have  
11 to rely on developing a probabilistic framework like  
12 the one we did for DCH or the Mark I liner issue and  
13 we used the same approach, fuel coolant interaction  
14 issue.

15           The result from our fuel coolant  
16 interaction research so far indicated that the  
17 assumption, for example, that was made in WASH-1400  
18 about a massive catastrophic failure of the coil  
19 support plate is unrealistic and that came from our  
20 core melt progression research. We've seen in the TMI  
21 that you get very minor break and relocation process.  
22 The fact of the water depletion phenomena again  
23 reduced the amount of material that can participate in  
24 fuel coolant interaction and reduce the energy that  
25 will be dissipated in the system either on the lower

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1 head and the upper head. And as a result of that  
2 work, we reassess the alpha mode containment failure  
3 probability and will confirm the conclusion that we  
4 reached in 1985. That's indeed a low probability, but  
5 in addition to that we have concluded too that lower  
6 head failure is not expected to occur as a result of  
7 fuel coolant interaction.

8 We feel that our analytical code are  
9 adequate right now for doing fuel coolant interaction  
10 loads for in-vessel as well as ex-vessel. The issue  
11 of premixing and the fragmentation phenomena, which  
12 are the key for fuel coolant interaction phenomena,  
13 are really well understood right now. For ex-vessel  
14 phenomena we might need -- we're waiting for the FARO  
15 test program to see if any variation in the hole size  
16 or in the fall high, the water depth and so on might  
17 affect our perception about ex-vessel. But right now  
18 we have confidence that it might not change that much.

19 Our plan right now is to complete the  
20 ongoing research program which is mainly at FARO and  
21 at the University of Wisconsin. At the conclusion of  
22 that work we will convene a group of experts to  
23 identify the need for and the value of any additional  
24 research in that area.

25 COMMISSIONER REMICK: What do you foresee

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1 as a schedule for convening that group?

2 DOCTOR ELTAWILA: Of course we're not  
3 going to wait until the end of the FARO program  
4 because that will take maybe about two or three years.  
5 What we expect to see after running one FARO  
6 experiment this year and finish the University of  
7 Wisconsin work, sometimes maybe by March, April of  
8 next year we can convene the group immediately after  
9 that.

10 COMMISSIONER REMICK: '94?

11 DOCTOR ELTAWILA: '94, yes.

12 (Slide) The second issue that I would  
13 like to discuss here is the issue of the debris  
14 coolability and what our interest is try to understand  
15 what is the effect on containment performance from  
16 debris-structure-water interaction. If we have core  
17 concrete interaction and add water as a result of  
18 accident management or as a result of design  
19 specification, like an advanced light water reactor,  
20 we want to see the effect on how much can the debris  
21 be cooled enough to arrest the core concrete  
22 interaction and further erosion and reduce the amount  
23 of non-condensable that enter in the containment. And  
24 at the same time we'll try to understand the mechanism  
25 that can lead into sustained coolable configuration.

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1           We have run several experiments in the  
2 past at Sandia National Laboratory and we are a member  
3 of the MACE project which is run by EPRI and include,  
4 in addition to NRC, DOE, EPRI and other foreign  
5 countries.

6           The results from the past testing  
7 performed at the small scale showed that there are  
8 some potential for coolability. Immediately after  
9 adding water there are significant amount of energy  
10 released or removed from the melt. However, because  
11 of the configuration that we test -- run this  
12 experiment which are very small experiment, usually  
13 about 20 by 20 centimeter or 50 by 50 centimeter, the  
14 maximum that we ran, sustained debris coolability  
15 appears to be encumbered by the insulating crust  
16 formed on the debris surface that attached to the  
17 wall.

18           (Slide) If I may go to the figure on page  
19 28 and try to explain that slide in details here.

20           In the left-hand side you see the crucible  
21 which you have the concrete at the bottom and on top  
22 of it we have a charge of uranium oxide, zirconium  
23 oxide and some concrete material. It's heated  
24 electrically and when the melt is complete the charge  
25 is melted and the core concrete interactions start.

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1 Water is added on top of it to cool the debris. What  
2 happened in the experiment, if you look at the right-  
3 hand side, that you see that the dark line on the top,  
4 a crust formed and as the core concrete interaction  
5 continuing, that the surface of the melt keep receding  
6 down, which caused creating a void between the actual  
7 melt and the water on top of it. So, we were not able  
8 to remove heat from that.

9 COMMISSIONER REMICK: Just intuitively, it  
10 would seem like when you had the melt concrete  
11 interaction you'd be producing a lot of gases which  
12 would agitate the melt and break up the crust, but  
13 that does not happen?

14 DOCTOR ELTAWILA: Absolutely. That's  
15 exactly what should have happened. But unfortunately  
16 the crust is formed and because of the size of the  
17 crucible is so small it attached itself to that wall  
18 and will not be able to penetrate it.

19 COMMISSIONER REMICK: So, in the actual  
20 case, one might expect that the gases coming off from  
21 the concrete interaction would agitate and allow water  
22 to get into the melt, I would think.

23 DOCTOR ELTAWILA: In fact, in some of  
24 these tests we see some burst of material coming out,  
25 gases pumping out of that void, breaking the crust and

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1 disputing material on top of the water and causing it  
2 to quench.

3 (Slide) Now I'll go back to page 27 and  
4 again that there are some believe among the  
5 researchers, as Commissioner Remick indicated, that  
6 the crust may be fractured by thermal mechanical loads  
7 and might be fractured by just the aspersion of the  
8 gases from the melt.

9 So, what the MACE project is planning for  
10 the next integral test, M3, is to run it as large a  
11 scale as possible and we are planning right now to run  
12 it at 1.2 meters by 1.2 meters. It's going to have a  
13 charge of 2000 kilogram of reactor melt material and  
14 20 centimeter of debris bed.

15 We're currently assessing the usefulness  
16 of any additional testing versus accepting the current  
17 uncertainty if we can live with the fact that  
18 containment will not be pressurized beyond its  
19 capability within certain time as a result of core  
20 concrete interaction. That might be an acceptable  
21 answer to us.

22 (Slide) I'd like now to return back to  
23 Doctor Sheron.

24 DOCTOR SHERON: Okay. I would just point  
25 out that Ashok had told you -- you asked a question

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1 about what kind of concrete they were using in  
2 advanced designs and you could argue that in one  
3 scenario you want to have a low gas content concrete  
4 that doesn't put a lot of non-condensable gas into the  
5 containment. But from the standpoint of breaking up  
6 across and allowing water ingress, you would like a  
7 lot of gas. So, it's not clear what's the best way.

8 I'd like to finish up here by talking  
9 about utilization of our research results and then  
10 talk a little bit about our future plans.

11 With regard to the results from all this  
12 research we've been doing, when we talked about the  
13 source term research we intend to modify 10 CFR Part  
14 100 based on the new information. We've updated the  
15 source term for the advanced light water reactor which  
16 was documented in NUREG-1465. It's improved all of  
17 this research we've done and the area of severe  
18 accidents has, I think, significantly improved our  
19 understanding of containment performance. This has  
20 been reflected in our evaluation of the IPes, the  
21 individual plant examinations, containment performance  
22 improvements as well as our reviews of the accident  
23 management programs being developed by the industry.

24 We've also used these results to close, as  
25 I said, on some of the severe accident issues that

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1 were dominating the risk uncertainty, namely those  
2 that resulted in early containment failure. As I said  
3 before, we've already closed on the Mark I liner issue  
4 and put that one to bed and hopefully within a year we  
5 will have direct containment heating resolved for all  
6 of the PWRs.

7 COMMISSIONER REMICK: What's the  
8 anticipated schedule for Part 100? Not surprisingly,  
9 when I was in Taiwan and Korea recently there was a  
10 lot of interest in knowing the status of that. What  
11 is the schedule for sending that back up to the  
12 Commission?

13 MR. TAYLOR: I'm supposed to see  
14 something, an options paper, by November 19th, I  
15 believe, and that will then be coming up to the  
16 Commission before we receive -- this will provide the  
17 options. I think that's right.

18 DOCTOR SHERON: (Slide) Slide 30, please.  
19 The other areas we utilized research  
20 results. One is obviously, I think as Tom said  
21 before, we're providing NRR with a database that they  
22 can use for evaluating the advanced light water  
23 reactor's performance against severe accidents. The  
24 areas that are being evaluated were documented in  
25 SECY-90-016 and also, as you know, we had an advanced

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1 notice of proposed rulemaking on Part 50 to deal with  
2 severe accidents for future reactors.

3 Both of these specifically require  
4 technical basis for assessing the capability of the  
5 containment to withstand the severe accident loads and  
6 these loads, as I said before, they're just listed  
7 right here, the DCH, the FCI, direct melt attack on  
8 the concrete, the hydrogen and then the slow  
9 pressurization due to steam and non-condensibles.

10 And then lastly, understanding severe  
11 accident phenomena and their range of behavior is  
12 important for taking advantage of existing reactor and  
13 containment capabilities. This is primarily in  
14 exploring accident management strategies for the  
15 different containment types and developing plant  
16 performance criteria for future light water reactors  
17 against severe accident challenges.

18 So, I think in summary all of this  
19 research is being utilized rather extensively in  
20 various facets of the whole regulatory process.

21 (Slide) This will get to Commissioner  
22 Remick's concern from before with our future plans.

23 First is we would like to -- if all goes  
24 well, we'll complete our research on these major  
25 issues that we're still working on by 1996. That's

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1 sort of a goal that we've set for ourselves. However,  
2 1996 is not when we turn out the lights, close the  
3 door and walk away. We intend to maintain a level,  
4 albeit reduced, capability for the agency, for the  
5 staff to be able to evaluate and predict severe  
6 accident behavior. In order to do this we're going to  
7 need to identify the necessary disciplines for which  
8 expertise should be maintained. We need to identify  
9 the minimum suite of analysis codes that we will need  
10 to maintain. Once we've done that, then we will  
11 identify future efforts needed to maintain this  
12 expertise.

13 I think I said at the thermal hydraulic  
14 briefing you can't maintain the expertise by just  
15 keeping your researchers sitting around on their hands  
16 waiting to run a code or something. The way we would  
17 plan on doing this would be to continue our  
18 involvement in international programs, participate in  
19 international standard problems, participate in  
20 cooperative research with international partners and  
21 so forth. We would maintain a code development and  
22 assessment effort. I think this will provide the  
23 impetus for the researchers to want to improve the  
24 codes the same way as I said in the thermal hydraulic  
25 area. There may be a need to continue to run small

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1 scale experiments, although we don't really under --  
2 we don't see a need right now for any large major  
3 experimental facilities for severe accidents.

4 COMMISSIONER ROGERS: Before you leave  
5 that, just on this whole code question, I know  
6 Commissioner Remick is very interested in it. I'm  
7 interested in it too. But I'll tell you, I would be  
8 a little uncomfortable about developing codes to  
9 pursue code development unless there is a really  
10 important reason to do that other than to maintain the  
11 expertise of the people. I think that's a separate  
12 question of how to maintain expertise and whether  
13 codes need further development or not.

14 I think -- I wouldn't mix those two  
15 together automatically just to pursue code  
16 development, for fine tuning it a little bit more, I  
17 know, to keep people alive, their interest alive. I'd  
18 be very concerned about that because it seems to me at  
19 some point these things ought to stabilize and not  
20 change. Unless there is a good solid technical reason  
21 to pursue additional code development, I wouldn't --  
22 I mean there are some systems that once you get --  
23 once they're complete, they have to be complete. If  
24 you keep tweaking them, you're going to drive  
25 everybody crazy.

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1           So, it's just an issue there, a bit of a  
2 concern that I have with respect to continued code  
3 development. I'm not opposed to it if there's a  
4 really important technical reason why codes need to be  
5 further developed, but just linking that with the  
6 necessity of maintaining expertise is a connection  
7 that to me is a doubtful one.

8           DOCTOR SHERON: Yes, I apologize. I  
9 didn't mean to leave the impression that we were just  
10 going to do this just to keep expertise.

11           COMMISSIONER ROGERS: It's sort of a  
12 gratuitous comment, but --

13           DOCTOR SHERON: Yes, I think on the areas  
14 where we feel very comfortable we're certainly not  
15 going to pursue any major code development just for  
16 the sake of it. But I think that in the area of  
17 severe accidents there's always going to be some areas  
18 where we're just not really totally comfortable and we  
19 could always feel we could do a little better. I  
20 think I said in the thermal hydraulic briefing that  
21 the area I see is going to be in the numerics. With  
22 the computer environment changing the way it is with  
23 these new machines coming on, with much more  
24 capabilities, as you saw the other day we can now run  
25 these large codes right here from NRC, whereas five

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1 years ago that was a dream.

2 COMMISSIONER REMICK: I think that will  
3 help maintain the codes too since we have now  
4 capability in Research and in NRR to run some of these  
5 on work stations. Our own people will realize where  
6 there is a need for improving.

7 CHAIRMAN SELIN: Underground code testing.

8 DOCTOR MURLEY: Mr. Chairman, could I be  
9 excused?

10 CHAIRMAN SELIN: Yes, of course. Thank  
11 you, Doctor Murley.

12 Before you go on, Commissioner Remick, did  
13 you get your questions answered?

14 COMMISSIONER REMICK: Yes. I'm very  
15 pleased with that answer.

16 DOCTOR SHERON: And our long-term planning  
17 is needed right now to determine the requisite funding  
18 level to maintain this capability and that's something  
19 we're going to take an IOU because that's something we  
20 have to do.

21 (Slide) Just a last slide. I just wanted  
22 to touch on very quickly some of the international  
23 programs that we are involved in.

24 We have bilateral agreements with, as you  
25 see, that list the countries who have joined our

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1 Cooperative Severe Accident Research Program. What  
2 joining our Cooperative Research Program means is that  
3 the participants will receive the NRC severe accident  
4 research results, our computer codes that we've  
5 developed and any other information that comes out of  
6 our program. In return, what we usually ask is that  
7 we receive some cash and, depending upon the size of  
8 the country, perhaps some in-kind contribution from  
9 that country. If they're doing research, then we  
10 would like to see their research results.

11 Just as our thermal hydraulic codes, our  
12 severe accident codes, I think, set the standard for  
13 the world. Most of the Europeans and even in Asia are  
14 relying extensively on our severe accident codes to  
15 analyze their designs.

16 That concludes our presentation. I see  
17 it's 11:30, which was the scheduled completion time,  
18 so I don't -- unless you would like, we won't propose  
19 to discuss anymore issues.

20 CHAIRMAN SELIN: I do have a couple of  
21 questions.

22 I was quite impressed with the  
23 presentation and in particular how you were able to  
24 tie the research work to needs in NRR and in the  
25 regulatory program. That's very positive and deserves

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1 commendation.

2 I want to make sure I understand a remark  
3 that Doctor Eltawila made, your discussion of our  
4 databases being more effected by experimental work and  
5 therefore not having to have such large margins of  
6 computational -- well, just large computational  
7 margins. Is the implication that we use experimental  
8 results more than some of our more -- the other  
9 advanced colleagues overseas in doing the codes and in  
10 doing the regulatory work?

11 DOCTOR ELTAWILA: We're using the  
12 experimental result in assessing our code and try to  
13 expand the database to a large full-scale facility and  
14 we are using it more than our colleague overseas  
15 because we had that database available to us as a  
16 result of that research program that we have over the  
17 past ten years.

18 Our colleague overseas, they just start  
19 the process itself. They are developing their own  
20 code. Even the most advanced one, you know, they are  
21 in the beginning of developing their own code or  
22 performing their own experiments, so that's mainly the  
23 reason for the big difference.

24 CHAIRMAN SELIN: I must be missing  
25 something. I understand there's quite a bit of

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1 communication about the experimental results and that  
2 our programs are available. Are people slow to pick  
3 them up or do they disagree with the way we're using  
4 them?

5 DOCTOR ELTAWILA: I don't see disagreement  
6 about the way we use them, but I think it's a matter  
7 of timing that they start developing their own  
8 capability over there. They have been participating  
9 in this program. They see the data. They have been  
10 using our codes, but they mainly in the past,  
11 especially in smaller countries, relied on the NRC for  
12 using the code, developing the database and try to  
13 just develop the code to a state of maturity that they  
14 can use them themselves. Nowadays they are using the  
15 code themselves. In addition to that, they are trying  
16 to assess it against either their own developed data  
17 or data that develop internationally. I don't know if  
18 I answered your question.

19 CHAIRMAN SELIN: You answered the  
20 question. I have to tell you that your answer is not  
21 consistent with my general view of the sophistication  
22 of some of these regulatory areas. I do believe that  
23 we invest more and run a larger regulatory research  
24 program than our colleagues, but I don't have the  
25 sense that the Germans or the French or even the

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1 Swedes are slow to use the results and to integrate  
2 them.

3 COMMISSIONER de PLANQUE: Maybe what we're  
4 looking here for as an answer, are they repeating some  
5 of these experiments, duplicating them, or are they  
6 doing additional or variants on the experimental work  
7 that's been done here?

8 DOCTOR ELTAWILA: For example, the alpha  
9 program that Commissioner Remick mentioned is  
10 duplicating everything we have done in the past. They  
11 have done only one -- they have only one unique  
12 program about reactivity insertion accident. That's  
13 the only difference between their program and our  
14 previous program.

15 The German, we relied a lot on the German  
16 data, and there was, for example -- their research  
17 program is not as comprehensive as ours. They focus  
18 on the particular issue and they address it.

19 For example, if you look at the French,  
20 they have a major program ongoing right now. Most of  
21 that program, we have information about this result  
22 and it's sort of duplication of ours.

23 CHAIRMAN SELIN: We can leave this for  
24 future discussion.

25 I'm concerned about the image of a lot of

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1 chauvinistic duplication of results rather than just  
2 accepting this as an international database and each  
3 one building on the other's results, but that's a big  
4 topic and I'd be interested in your insights at some  
5 future point as to what you think is happening in this  
6 international program.

7 I've had the image of a rather seamless  
8 international research program where we do some things  
9 and other people do some things but the answers are  
10 used sort of regardless of source and the image that  
11 you present is a little more nationalistic and  
12 chauvinistic than that.

13 DOCTOR BECKJORD: My sense, Mr. Chairman,  
14 is that they take some time to incorporate results,  
15 but I don't think they're duplicating in every case.  
16 Maybe the Japanese --

17 CHAIRMAN SELIN: This is not a good topic  
18 to enter in at 11:35 without some concrete example,  
19 but perhaps in the future we could have a little  
20 discussion about that.

21 MR. TAYLOR: Let's take a look at it.

22 CHAIRMAN SELIN: Commissioner Rogers?

23 COMMISSIONER ROGERS: Yes. We've had  
24 quite an extensive presentation and I've enjoyed it  
25 very much. I think that it was very helpful and there

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1 are a lot of things we could talk about and go on all  
2 day, so I'll just touch on two things that I thought  
3 I might like to hear just a little bit about.

4 The scaling methodology, to what extent  
5 have those results been published or are going to be  
6 published in peer review journals that would be of  
7 interest to a broader community? I'm kind of  
8 interested perhaps along the way that Commissioner  
9 Remick started to touch on. It seems to me these are  
10 very fundamental kinds of problems, scaling of these  
11 phenomena experiments up to larger applications. And  
12 I don't know where they might be useful aside from the  
13 nuclear industry, but they might very well be in  
14 certain other applications and it would seem to me  
15 that it would be a good idea to try to see that that  
16 methodology gets published in a peer review journal  
17 that is widely read by interested people of different  
18 technologies, not just nuclear.

19 Excuse me?

20 DOCTOR SHERON: The scaling report, the  
21 NUREG report that was done, had not been published in  
22 any peer review journals. I think one of the reasons  
23 is that we kind of considered the whole development of  
24 it was a peer review process because we had 17 experts  
25 and --

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1                   COMMISSIONER ROGERS: I'm not thinking of  
2 it from the point of view of questioning the quality  
3 of it. I'm just saying that I think the dissemination  
4 of it will only be meaningful in peer review journals,  
5 not in internal documents, and for that reason I'm  
6 talking about peer review journals because those are  
7 the ones that everybody reads that looks at it from  
8 outside of this industry and that's the reason I'm  
9 stressing that.

10                   DOCTOR SHERON: Well, let us take a look  
11 and see if there's a way we can get this published.

12                   COMMISSIONER ROGERS: Because I think  
13 these scaling questions are very sticky questions and  
14 when people are grappling with them I'm sure that they  
15 would love to be able to use something that has the  
16 attention of a large collection of experts that our  
17 work has had.

18                   DOCTOR SHERON: The information is  
19 available. It's published in NUREG reports, NUREG CR  
20 reports, but I don't think it's been really -- yes,  
21 I'm saying it's not available in peer and we're going  
22 to take a look and see if we can --

23                   COMMISSIONER ROGERS: I'm saying, if  
24 somebody has got a problem and they're doing a  
25 literature search, they're not going to be looking in

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1 NUREG reports if they're outside the nuclear industry.

2 DOCTOR SHERON: We will see if we can find  
3 a way to get these published in peer review journals.

4 COMMISSIONER ROGERS: I'd like to see  
5 that. I think that's very important.

6 The other thing is just on the codes, the  
7 international aspects of codes. Are we getting codes?  
8 I mean, our codes are being used and we're providing  
9 them to others internationally. What is the  
10 reciprocity on that? Are we getting codes from other  
11 cooperating bodies?

12 DOCTOR ELTAWILA: We have recently  
13 requested our colleague from CE to give us their ECAR  
14 II code and we have received it and given it to our  
15 contractor at Idaho National Laboratory to try to run  
16 it and benchmark it against our code.

17 In addition to that, we've received an  
18 older version of the Russian code, RASPLAV, but we  
19 have not received any update since about two years ago  
20 and we're looking for other updates in that area.

21 The other codes that are available, most  
22 of the other countries are using our codes so we rely  
23 on them, if they have for example an international  
24 center problem and things like that, to participate  
25 and we'll get feedback about user input, the effect of

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1 user on the analyses and so on, but we have been  
2 getting these codes.

3 Some of the Japanese codes, we have not  
4 received them yet because they have not released them  
5 out to the public because they are not complete.

6 COMMISSIONER ROGERS: Thank you.

7 COMMISSIONER REMICK: I had not intended  
8 to raise it, but, since you mentioned thermal  
9 hydraulic codes and he talked about international  
10 sharing, anything new on CATHARE?

11 DOCTOR SHERON: I made a note here to find  
12 out if we've sent the request over.

13 COMMISSIONER REMICK: Okay.

14 DOCTOR SHERON: Let me take a commitment  
15 to get back to you on that.

16 COMMISSIONER REMICK: Fine. I just want  
17 to say that I'm very pleased with the presentation.  
18 I congratulate the staff on what they've done in the  
19 severe accident program area.

20 I think the refocusing that went on in  
21 1988, and I think, Brian, you played a major role in  
22 that, was a significant development in bringing a  
23 chance of closure on many of these issues. It's  
24 obvious we've come a long way and I agree that  
25 internationally people look to these because it's

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1 setting the pace throughout the world on severe  
2 accident programs and it seems to be now that,  
3 although even five years ago some countries didn't  
4 want to talk about the possibility of severe  
5 accidents, there seems to be a general consensus that  
6 one must look at severe accidents.

7 The work that has been done here I think  
8 has been quite significant. In preparing for your  
9 presentation, I went back and read an ACRS letter of  
10 about a year ago and I found it quite interesting  
11 because they were quite complimentary and ACRS doesn't  
12 tend to always complimentary. They say, "In general,  
13 the presentations were well organized and well  
14 presented and our questions were dealt with patiently  
15 and with good humor," and I thought, gee, that's a  
16 good idea to provide it with ice cream and make them  
17 happy.

18 CHAIRMAN SELIN: Commissioner de Planque?

19 COMMISSIONER de PLANQUE: I have no  
20 further questions, just to commend you on excellent  
21 work and an excellent presentation.

22 DOCTOR SHERON: Thank you.

23 CHAIRMAN SELIN: Thank you very much.

24 (Whereupon, at 11:43 a.m., the above-  
25 entitled matter was adjourned.)

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CERTIFICATE OF TRANSCRIBER

This is to certify that the attached events of a meeting  
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TITLE OF MEETING: BRIEFING ON SEVERE ACCIDENT RESEARCH PROGRAM

PLACE OF MEETING: ROCKVILLE, MARYLAND

DATE OF MEETING: OCTOBER 26, 1993

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**SEVERE ACCIDENT RESEARCH STATUS**  
**BRIEFING TO THE COMMISSION**

**Presented by**

**Eric S. Beckjord  
Brian W. Sheron  
Farouk Eltawila  
Office of Nuclear Regulatory Research**

**October 26, 1993**

Contact: F. Eltawila  
492-3525

# **SEVERE ACCIDENT RESEARCH PROGRAM**

## **OUTLINE**

- **Background**
- **Revised Severe Accident Research Program**
  - **Issues and Results**
- **Severe Accident Research Program Update since September 1992**
  - **Issues and Results**
- **Detailed Presentations on:**
  - **Fuel coolant interactions**
  - **Debris coolability**
- **Utilization of Research Results**
- **Future Plan**
- **International Programs**
- **Additional Information**
  - **Core melt progression**
  - **Hydrogen Combustion**

# **SEVERE ACCIDENT RESEARCH PROGRAM BACKGROUND**

- **Severe Accident Considerations: WASH-1400, other PRAs, TMI-2 and Chernobyl accidents, all tell us that severe accidents represent major contribution to risk from commercial nuclear power plants**
- **Margins (for severe accident challenges) in existing plants**
- **Even before the Chernobyl accident, importance of containment was recognized**
- **Source terms (accident sequences/phenomena)**
- **Severe Accident Research Program (SARP)**
- **Severe Accident Policy Statement**
- **NUREG - 1150**
- **SECY 88-147 (IPE, CPI, AM,SARP)**
- **NUREG-1365**

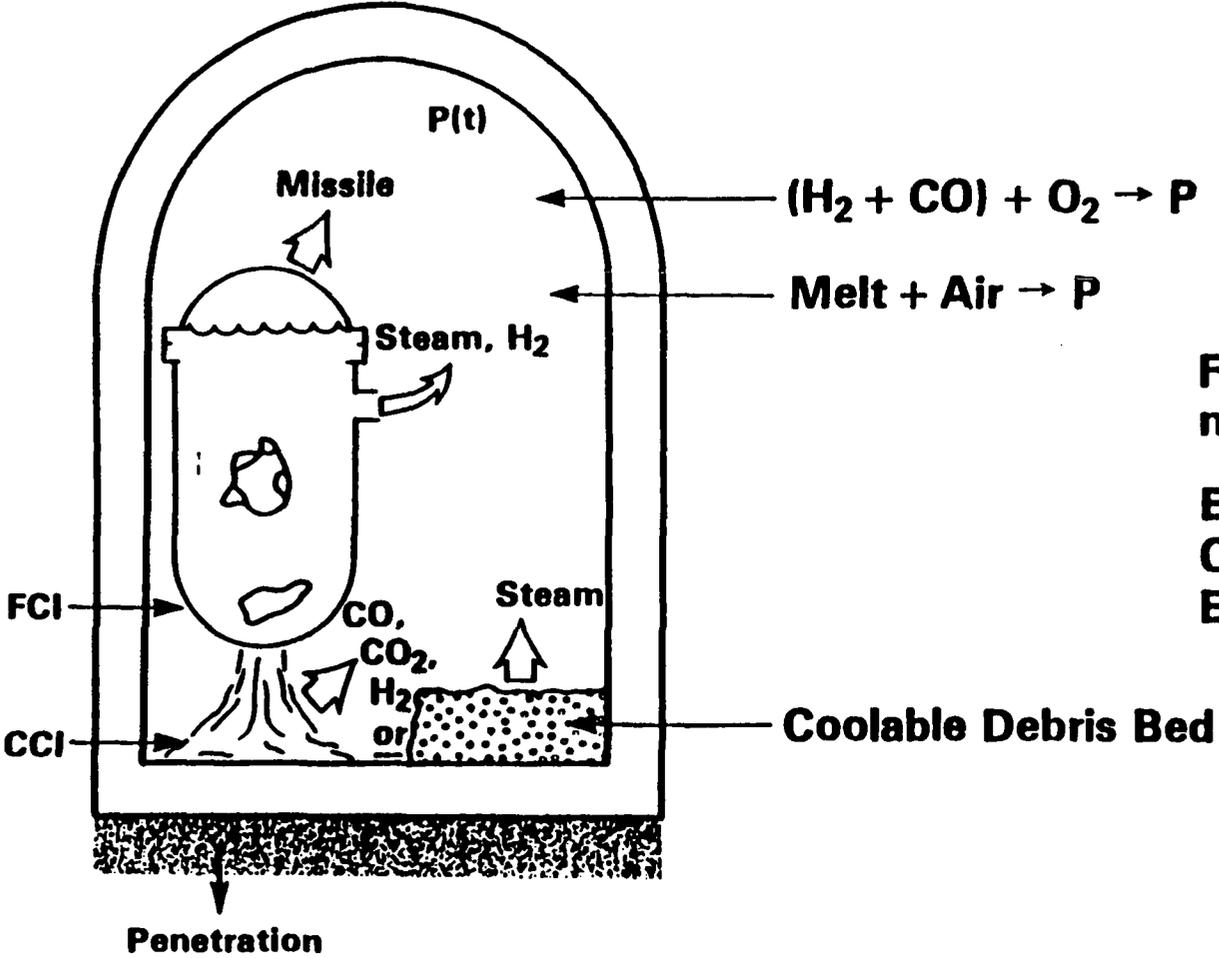
## **REVISED SEVERE ACCIDENT RESEARCH PROGRAM**

- **In 1988, the staff undertook a complete re-examination of the severe accident research program. The objective of this re-examination was to refocus the research on those areas where remaining uncertainties still had a potentially large influence on risk, and where important residual phenomenological uncertainties still remained high.**
- **This re-examination of the severe accident program was documented as NUREG-1365, and was issued in August 1989. The program was extensively reviewed both internally as well as externally. Supportive letters were received from the ACRS and NSRRC.**

## **REVISED SEVERE ACCIDENT RESEARCH PROGRAM (CONTINUED)**

- **The major elements of NUREG-1365 were:**
  - **Emphasis on resolving uncertainties associated with scenarios that produced early containment failure (Specific issues: Mark I containment liner failure, direct containment heating, source term update, core concrete interaction, H<sub>2</sub> combustion)**
  - **Eliminating duplication of analytical codes**
  - **Developing a scaling rationale for severe accident experiments**
  - **Refocusing research in selected areas (i.e., core melt progression, fuel coolant interactions and debris coolability, hydrogen combustion)**

# CONTAINMENT LOADS



Fuel Path is not Unique

Energetic vs. Quasi-Static Events

# **REVISED SEVERE ACCIDENT RESEARCH PROGRAM RESULTS**

- **In the intervening period from 1988 to 1992, the staff completed research on a number of these issues:**
  - **BWR Mark I liner failure**
    - **Demonstrated integrity of Mark I containments under core melt conditions provided water can be added to cover the core debris (NUREG/CR-5423) -- follow up work is complete. NUREG/CR-6025 was peer reviewed and issued in October 1993.**

# **REVISED SEVERE ACCIDENT RESEARCH PROGRAM RESULTS (CONTINUED)**

- **Severe Accident Scaling Methodology**
  - **Effort was completed (NUREG/CR-5809) -- application to DCH by SNL and ANL**
  - **Developed method for applying scaled experimental results to full size plants**
  
- **Source Term Issues**
  - **Research program completed (source term, quantity, timing, chemistry)**
  - **We are participating in the Phebus project**
  - **Source term update is imminent [SECY-92-127], NUREG-1465 Final report to be published end of 1993**

# **REVISED SEVERE ACCIDENT RESEARCH PROGRAM RESULTS (CONTINUED)**

- **Core Concrete Interaction**
  - **Completed all dry core concrete interaction experimental research**
  - **Validated models are available for assessing plants' response**
  - **Additional validation (against experiments conducted worldwide) is ongoing in USA and Russia**
  
- **Hydrogen Transport and Combustion**
  - **Major effort completed (deflagration-detonation criteria under variety of conditions).**
  - **Research on residual issues related to high-temperature hydrogen- combustion -- Joint NRC-NUPEC effort continues**

## **REVISED SEVERE ACCIDENT RESEARCH PROGRAM RESULTS (CONTINUED)**

- **TMI-2 Vessel Investigation Project (OECD)**
  - **Program completed in October 1993**
  - **Provided information to benchmark some aspects of core melt progression and RV integrity**
  - **Evaluated margin to failure of reactor vessel**
  - **Insights on accident management**

## **SARP UPDATE**

- **A SARP update (SECY-92-329; NUREG-1365 Rev. 1) was issued in September 1992:**
  - **Identifies issues that have been completed or are near completion**
  - **Describes the progress in our understanding of important severe accident phenomena**
  - **Defines the research that would lead to closure of core melt progression, direct containment heating (potential early containment failure mode) and fuel-coolant interactions**
  - **Includes research on issues applicable to ALWRs, especially the containment performance criteria during severe accidents**

## **SARP MAJOR ACTIVITIES AND RECENT RESULTS**

- **Focus research on three phenomenological issues and code development and assessment**
- **An important aspect of the Code Development Program is the Peer Review. Each of our major codes has undergone a peer review to identify deficiencies and any necessary further work.**
- **Direct containment heating closure**
  - **New insights and improved data base allowed quantification of DCH loads for Zion and Surry.**
  - **Developed generic criteria for other types of containments and assess the need for any additional work**
  - **Peer review of the closure reports ongoing**

## **SARP MAJOR ACTIVITIES AND RECENT RESULTS (CONTINUED)**

- **Core Melt Progression**
  - **Early-phase core melt progression is well understood**
  - **Remaining uncertainty related to**
    - **Blockage vs. drainage**
    - **Melt pool formation, growth and failure**
- **Fuel-Coolant Interactions and Debris Coolability**
  - **Completed most of the research on the fundamentals of FCI**
  - **Work at FARO, (Italy) involving large scale integral test**
  - **Ex-vessel debris coolability research results remain inconclusive**

## **SARP MAJOR ACTIVITIES AND RECENT RESULTS (CONTINUED)**

- **Severe Accident Codes**
  - **MELCOR** - risk assessment code -- peer review complete; program to address high priority peer reviewers comments is complete
  - **SCDAP/RELAP** - detailed core melt progression code -- peer review complete; program to address peer reviewers comments is underway
    - **CONTAIN** - detailed containment analysis code, peer review started April 1993 and will be completed March 1994
  - **Other special codes for specific functions include HMS (H<sub>2</sub> transport) and COMMIX (AP600)**

# SEVERE ACCIDENT RESEARCH

- **Facilities**

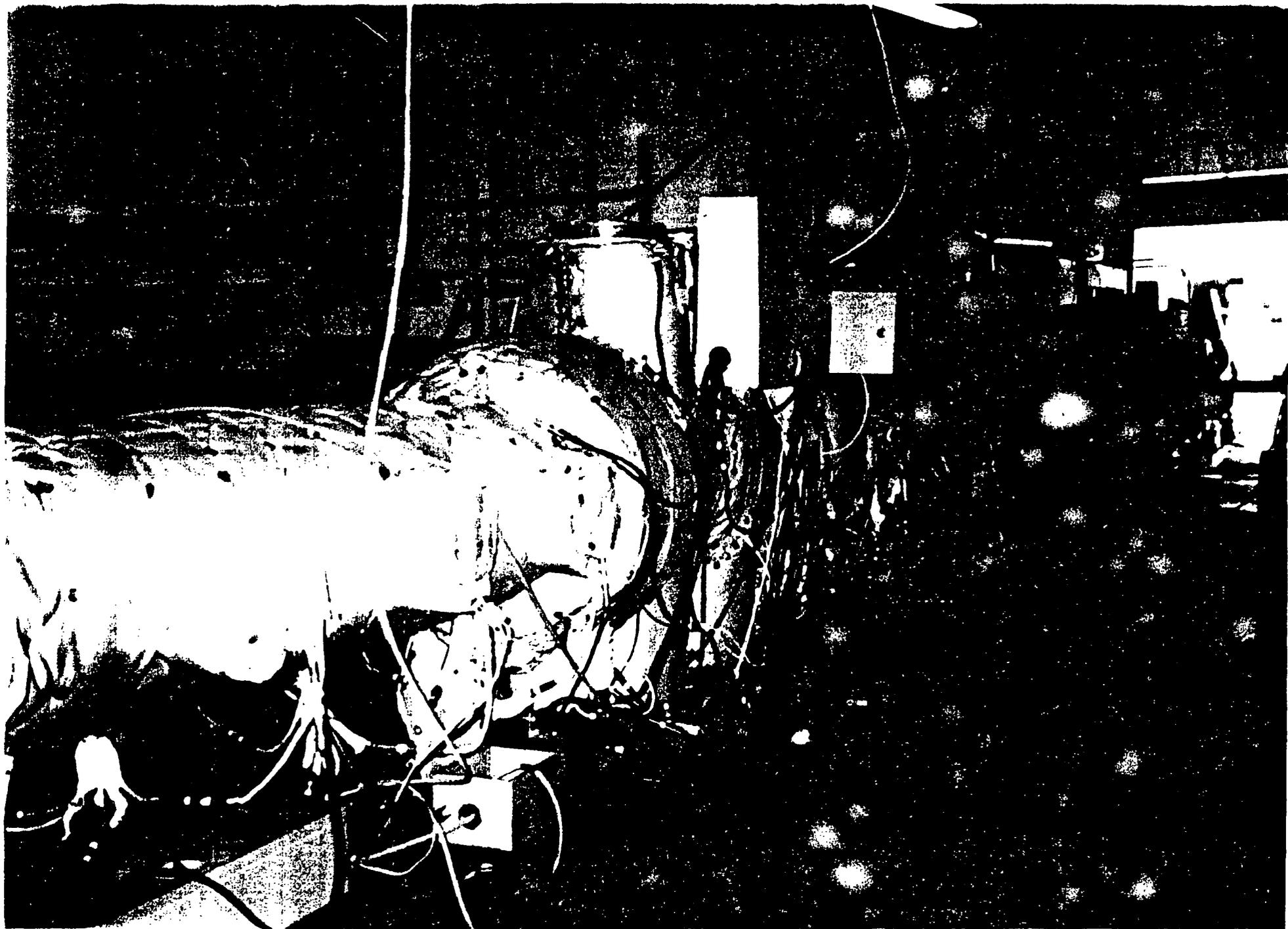
- **The staff has funded significant experimental research in facilities both in the U.S. as well as around the world.**
  - **In-vessel crust behavior studies in Annular Core Research Reactor (SNL)**
  - **Ex-reactor experiments to study blockage vs drainage issue (SNL)**
  - **Full length core melt experiment in the Canadian NRU reactor**
  - **Fuel Coolant interaction experiments in the FARO facility (Ispra, Italy)**
  - **Lower vessel head coolability in the RASPLAV facility (Moscow)**

## **SEVERE ACCIDENT RESEARCH (CONTINUED)**

- **DCH testing in SURTSEY facility, CTT facility (SNL), and the COREXIT facility (ANL)**
- **Debris coolability experiments (MACE test at ANL)**
- **Hydrogen detonation testing at BNL (cooperative with Japanese); and Russia (Kurchatov)**
- **Fission Product transport in the core region, RCS, and containment (Phebus reactor, France)**



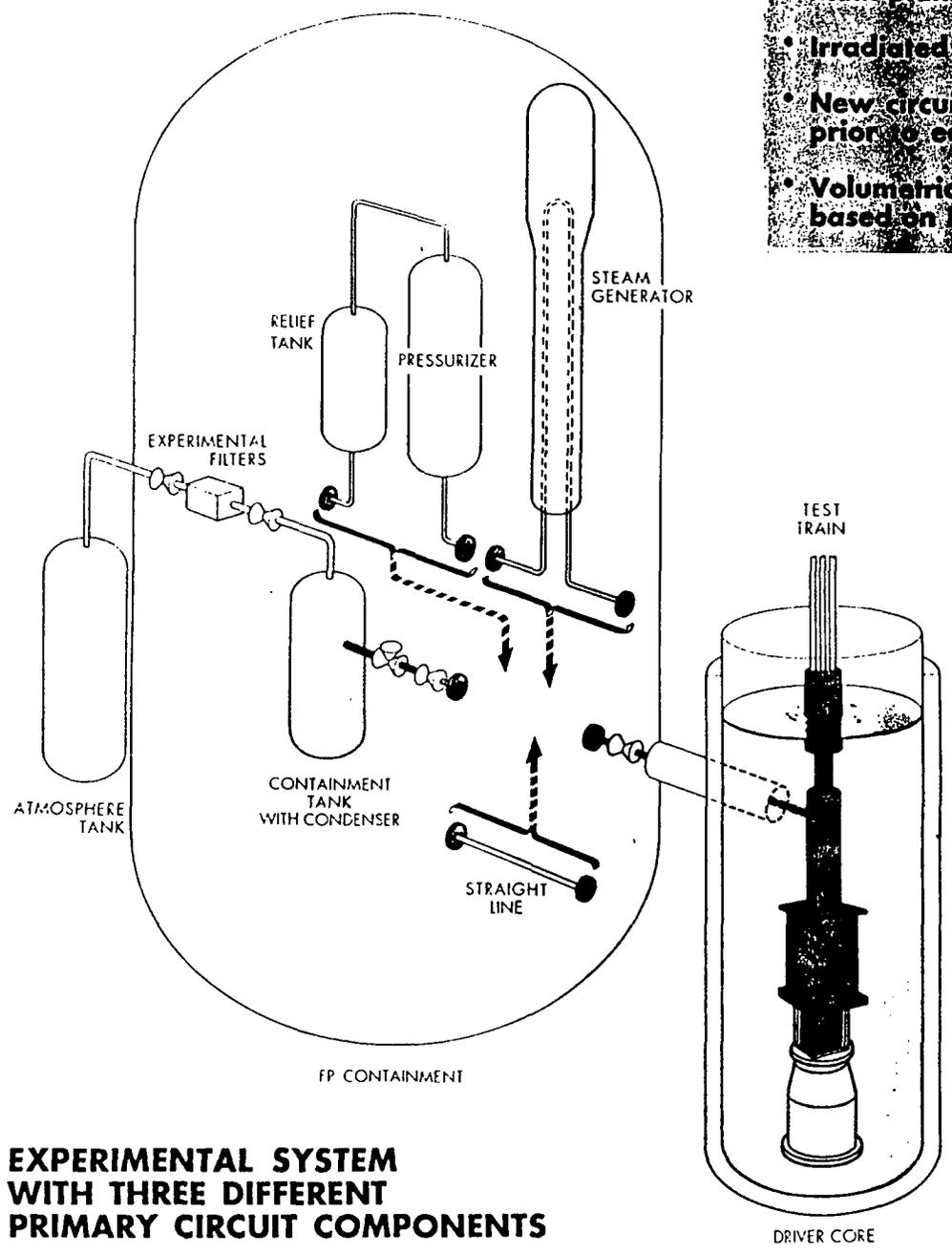




**GENERAL CHARACTERISTICS OF THE FACILITY**

**In pile test**

- Main plant components simulated
- Irradiated fuel - re-irradiation
- New circuits and/or decontamination prior to each test
- Volumetric scaling down factor 1/5000, based on Fission Product Inventory



**EXPERIMENTAL SYSTEM WITH THREE DIFFERENT PRIMARY CIRCUIT COMPONENTS**

□ removable components

# FUEL COOLANT INTERACTIONS

Fuel coolant interactions do not imply only steam explosions ( $\alpha$ -mode containment failure); TMI-2 event exhibits another, in this case, beneficial, example of effects of FCI on melt quenching

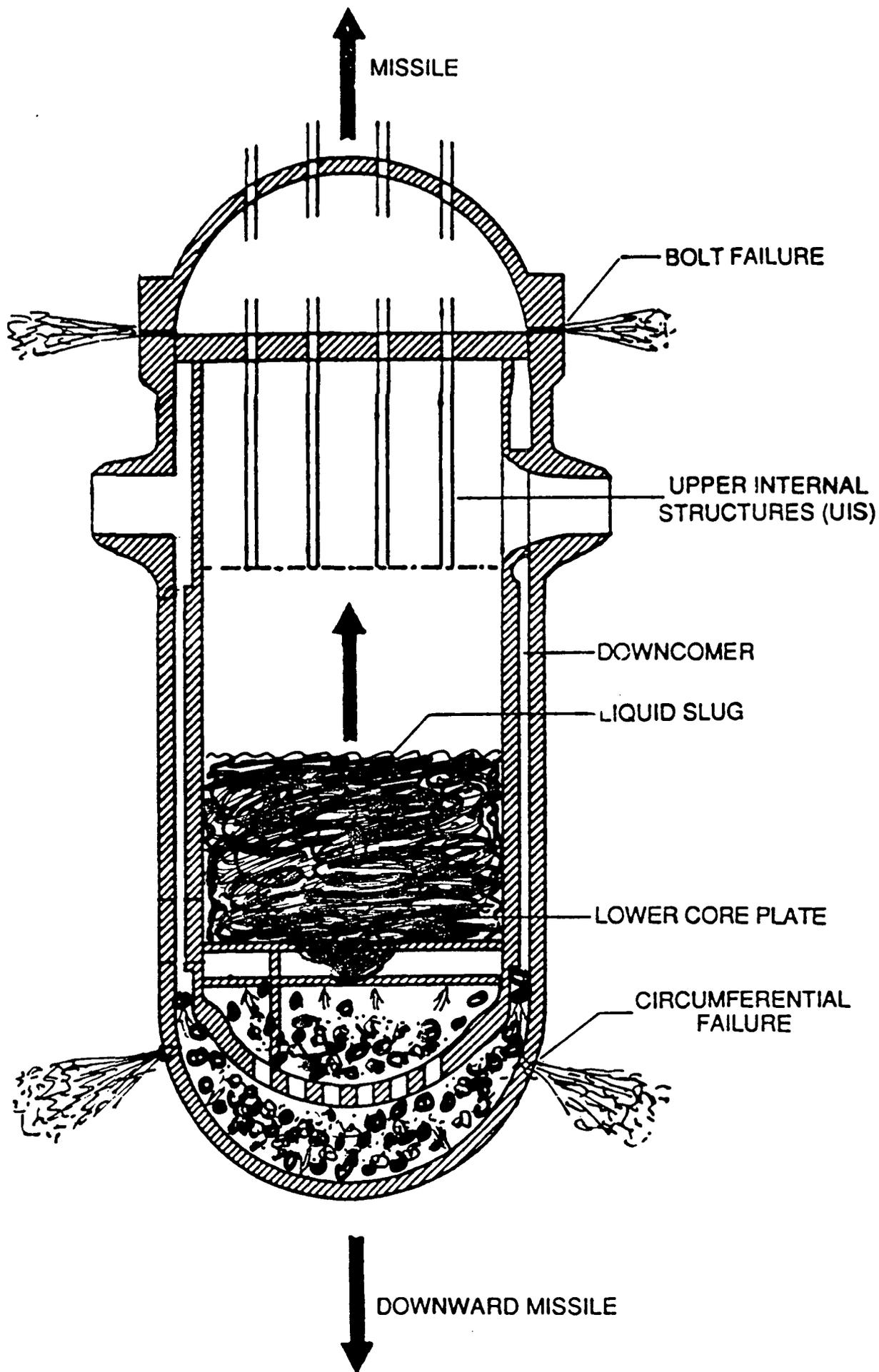
## Issues:

- What are the relocation scenarios likely to lead to coolable configuration?
- What are the effects of FCI on lower head integrity and cavity/pedestal integrity?
- What is the likely energy release and resulting load on containment?

# **FUEL COOLANT INTERACTIONS FCI (CONTINUED)**

## **Approach:**

- **Explore certain key, generic phenomenological aspects of FCI to address the complex variations found in core melt progression and accident management.**
- **Small-scale experiments to explore the fundamentals of FCI (premixing, propagation/fragmentation, yield)**
- **Develop/assess analytical models**



# **FUEL-COOLANT INTERACTIONS**

## **FCI (CONTINUED)**

- **Large-scale experiments with prototypic melt and prototypic conditions to investigate melt jet fragmentation, quenching, vapor generation, thermal load and possible erosion on the lower head -- FARO (Ispra)**
- **Use probabilistic framework to couple the different stages of FCI -- used to quantify the  $\alpha$ -mode failure**

# **FUEL-COOLANT INTERACTIONS**

## **FCI (CONTINUED)**

### **Results:**

- **$\alpha$ -mode of containment failure is low probability**
- **Initial assessment of loads due to FCI is possible**
- **Premixing and fragmentation phenomena are adequately understood**
- **More research may be needed on ex-vessel fuel coolant interactions and to establish accident management options**

### **Plan:**

- **Complete the ongoing programs**
- **Convene a group of experts to identify the need for and value of any additional research**

# DEBRIS COOLABILITY PROGRAM

## Issue:

- What is the effect on containment performance from debris-structure-water interactions?
- What are the mechanisms, if any, by which molten corium, released from the RPV, may be maintained as a coolable debris bed?

## Approach:

- Limited number of ex-vessel coolability tests conducted at small scales

## Results:

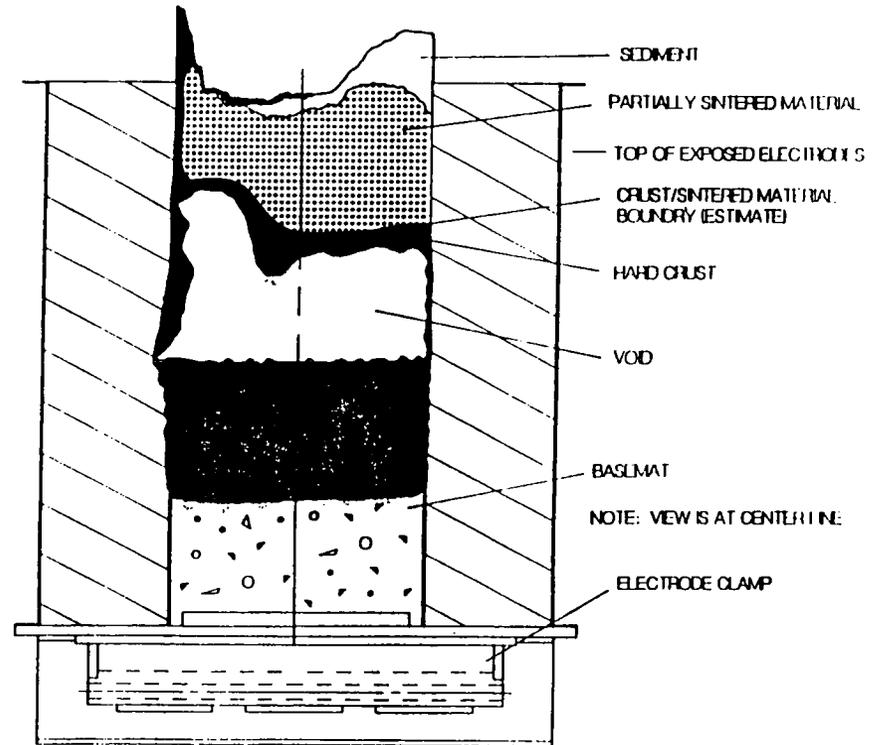
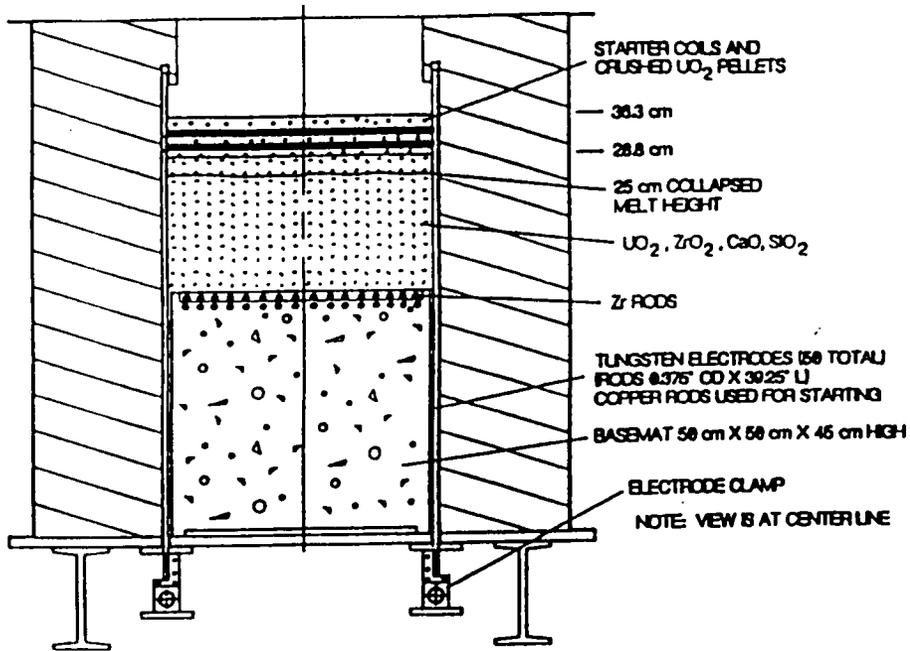
- Following water addition, significant amount of energy was extracted from the melt
- No firm demonstration of yet long-term coolability, and results still inconclusive

## **DEBRIS COOLABILITY PROGRAM (CONTINUED)**

- **Demonstration of debris coolability may be hampered by physical scale of test apparatus; at larger scale any top crust more likely to be fractured by thermal/mechanical stresses**

### **Plan:**

- **MACE project planning for next integral test (M3) (February 1994)**
  - **Large scale 1.2m x 1.2m (2000 Kg reactor melt, 20 cm deep debris bed)**
- **Currently assessing usefulness of additional testing versus accepting current uncertainty**



**Test Section Before and After the Test**

# UTILIZATION OF THE RESEARCH RESULTS

- **Source Term Research**
  - **Modification to 10CFR Part 100**
  - **Updated source term for ALWR (NUREG-1465)**
- **Improved understanding of containment performance**
  - **Individual Plant Examinations, Containment Performance Improvements, and Accident Management**
- **Closure of severe accident issues that could potentially lead to early containment failure (Mark I liner failure and direct containment heating)**

## **UTILIZATION OF RESEARCH RESULTS (CONTINUED)**

- **Provide data for severe accident plant performance criteria for ALWRs**
  - **SECY 90-016**
  - **Advance Notice of Proposed Rulemaking (Part 50)**
  
- **Specifically SECY 90-016 and ANPR require technical basis for assessing capability of the containment to withstand the severe accident loads:**
  - **Direct containment heating**
  - **Energetic fuel coolant interactions**
  - **Direct melt attack**
  - **Hydrogen combustion and detonation**
  - **Slow pressurization (steam, non-condensibles)**

## **UTILIZATION OF RESEARCH RESULTS (CONTINUED)**

- **Understanding the severe accident phenomena and their range of behavior is important for taking advantage of existing reactor and containment capabilities; exploring accident management strategies for different containment types; developing plant performance criteria for future LWRs against severe accident challenges**

## **FUTURE PLANS**

- **We plan to complete research needed to close on major remaining issues by 1996**
- **However, staff intends to maintain reduced level of capability to evaluate and predict severe accident behavior beyond 1996**
  - **staff will identify necessary disciplines for which expertise should be maintained**
  - **staff will identify minimum suite of analysis codes to be maintained**
  - **future efforts will involve moderate level of continuing research to maintain expertise (involvement in international programs, maintain code development and assessment efforts, possible small scale experiments)**

## **FUTURE PLANS (CONTINUED)**

- **Staff will continue to address issues as they arise**
- **Plan to maintain cooperation with foreign participants**
  
- **Long term planning needed to determine requisite funding level to maintain capability - in progress**

## **INTERNATIONAL PROGRAMS**

- **NRC has bilateral agreements with the following countries who have joined the Cooperative Severe Accident Research Program:**

<b>Bulgaria</b>	<b>Czech Republic</b>	<b>Finland</b>
<b>France</b>	<b>Germany</b>	<b>Hungary</b>
<b>Italy</b>	<b>Japan</b>	<b>JRC</b>
<b>Korea</b>	<b>Lithuania</b>	<b>Netherlands</b>
<b>NUPEC</b>	<b>Russia</b>	<b>Slovak Republic</b>
<b>Spain</b>	<b>Sweden</b>	<b>Switzerland</b>
<b>Taiwan</b>	<b>UK</b>	

- **Participants receive NRC Severe Accident Research Results, codes, etc.**
- **NRC receives some cash and in-kind contribution**
- **NRC codes are used extensively internationally**

# **ADDITIONAL INFORMATION**

# **CORE MELT PROGRESSION**

## **Issue:**

- **What are the characteristics of the melt released from the core and the vessel?**
  - **Need melt mass, temperature composition (Metallic or ceramic), and rate and time of release**
  - **Used as input for assessment of vessel integrity, containment loads, hydrogen production, fission products.**
- **What are threshold and location of ceramic pool meltthrough from a blocked core?**
- **Does metallic melt drainage form a core blockage in BWR dry core accidents?**

## **Approach:**

- **Ex-reactor experiments (blockage vs. drainage)**
- **In-reactor experiments (ceramic pool meltthrough)**
- **Analysis**

## **CORE MELT PROGRESSION (CONTINUED)**

### **Results:**

- **Blocked core gives large ceramic melt release like TMI-2; very low metal content (~ 1% at TMI-2)**
- **Ceramic melt release occurs on failure of the growing ceramic crust that contains the melt pool.**
- **If metallic melt drains from the reactor core, the later release from the lower head (following dry out) is lower temperature metallic melt**

## **CORE MELT PROGRESSION (CONTINUED)**

### **Plan:**

- **Metallic melt drainage or core blockage**
  - **Plan two simplified XR1 tests and four XR2 experiments within the next year**
- **Meltthrough from a blocked core**
  - **Performed MP-1 and MP-2 experiments in ACRR**
- **Analysis of the data from experiments is ongoing**
- **In late 1993, review group will consider current results and the adequacy of understanding, and the need for and likely benefits of further research**

# **HYDROGEN COMBUSTION**

## **Issue:**

- **At high temperature the limiting concentration for detonability may approach the deflagration limit (for downward propagation)**
- **High-temperature high-speed hydrogen combustion phenomena:**
  - **Effect of elevated temperatures on inherent detonability and on deflagration to detonation transition**

## **Results:**

- **Higher temperatures increase the mixture sensitivity**
- **Steam addition to hydrogen-air mixture decreases the mixture sensitivity**
- **Detonations observed to propagate in hydrogen-air mixtures with 10% hydrogen at 650K (no steam)**

# **HIGH-SPEED HIGH-SPEED HYDROGEN COMBUSTION PROGRAM**

## **Plans**

- **Complete construction of the high-temperature combustion facility (HTCF)**
- **Use the HTCF to perform:**
  - **Inherent detonability experiments,**
  - **Deflagration to detonation transition experiments with and without venting,**
- **Experiments will start in January 1994**
- **Program will be completed in April 1996**