UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MAY 6 1987

MEMORANDUM TO: DISTRIBUTION

FROM: L. G. Hulman, Chief
Severe Accident Issues Branch
Division of Reactor Accident
Analysis Office of Nuclear Regulatory Research

SUBJECT: SUMMARY OF MARCH 27, 1987 MEETING WITH BWR OWNERS GROUP/IDCOR ON MARK I CONTAINMENTS

The meeting was opened by Messrs. Denton and Bernero, who discussed the background and the nature of the 15 questions addressed to the BWR Owners Group. A previous meeting with representatives of the research community was referenced. The summary of that meeting was identified as available through the Public Document Room. Enclosure 1 is the attendance list for the meeting. Enclosure 2 contains the proposed meeting schedule and lists the 15 questions.

V. Boyer, Philadelphia Electric Co. (PECo), indicated that the Owners Group/IDCOR were requested to respond to the 15 questions. The responses were coordinated through the NUMARC Containment Issues Working Group of which he is chairman. He indicated that other NUMARC efforts were being delayed to respond to the request for information on the 15 questions, and that the NUMARC working group draft report to the steering committee was not expected until mid-May as a result. He suggested that NUMARC would probably not be able to report on their study to the Commission before this summer. He indicated that the IDCOR (Industry Degraded Core Rulemaking) effort was going our of business. He then introduced the responses, and summarized his views on the most critical issues and information available (Enclosure 3, p 2-4). The critical issues identified were 1) the progress of core failure, 2) cooling of a core on the floor, and 3) core concrete interaction.

R. Diedrich, PECo, described the industry evaluations (Enclosure 2, p 5-8). He indicated that they were evaluating both overall risks (referred to as bottom line), and conditional failures. He indicated their conclusion that conditional failure is sequence and plant dependent, thereby making it difficult to compare plants in a meaningful way. He also stated a conclusion that the Chicago Bridge and Iron Company containment study is indicating that the ultimate MK I pressure capability is higher than generally assumed, and that the torus airspace is the most likely failure location. He compared the IDCOR and NUREG-1150 efforts, including the conclusions from both that modifications were not justified. He concluded with a summary that indicated the NUMARC working group is studying MK I containments, that he believed sufficient technical bases exist for NUMARC to make decisions, and that cost/benefit comparisons will be made of potential modifications. He indicated studies to date have shown no modifications to be cost beneficial.

RD-10-1
BWR
X RD-9-A
MARK I

E. Burns, Delian Corp., discussed the responses to questions 1 and 2 (Enclosure 3, pg-10). He indicated there were four or five PRA's for MK I plants available that indicate no specific accident type dominates for all MK I's. He, therefore, concluded that the spectrum of potential sequences was important. He also concluded that there was no mechanistic coupling of containment failure to inducing coremelt. (See Enclosure 5)

R. Henry, FAI, discussed the responses to questions 3 through 10 (Enclosure 3, p 11-20). The conclusions presented with respect to containment failure were in large measure based upon evaluations of heat transfer in which the containment shell was not postulated to fail by perforation (Enclosure 4). This evaluation was noted as significantly different from those of the NRC staff and contractors. The significant points of his analysis were: 1) a 12 cm debris bed depth, 2) water above the debris bed acts as a heat sink with nucleate boiling at the shell surface, 3) the concrete below the debris acts as a heat sink, and 4) the debris bed was assumed to be near the melt temperature. His other main points were:

(Q4) high pressure melts have no significant effect on core melt progression, but the distribution of material in the containment is influenced;

(Q5) there are no significant differences between BWRs and PWRs in meltdown or melt through times;

(Q6) the debris properties of a "core-on-the-floor" are different, but the behavior is not. BWR's would have more metal with less oxidation;

(Q7) water on the drywell floor is beneficial, but requires replenishment. (Note that use of the IDCOR heat transfer model results in no prediction of steel containment liner or downcomer melt through);

(Q8) drywell sprays would reduce containment challenge, sufficient water to remove decay heat would be adequate, and sprays can help remove airborne fission products. Spray rates in the range of 500 - 1500 gpm appear adequate. Enclosure 4 was again referred to for a discussion of heat transfer and related conduction. It was noted that the IDCOR heat transfer methodology was included in submittals to the staff, but little feedback had resulted;

(Q9) a debris barrier would not be useful, and could result in negative effects; and

(Q10) a debris barrier to contain debris in the pedestal area under the vessel was considered detrimental. He suggested that if something was done, it would be to allow a coremelt the maximum expansion area and attempt to stabilize it with water.

Comments on a draft summary were solicited by memo date March 31, 1987. Several informal comments and three sets of formal comments were received. All were considered in this final summary. The formal comments by Messrs. J. C. Carter, A. R. Diederich and G. A. Greene are enclosed (Enclosure 6). Copies of this summary are being furnished to those participants of the March 27 and February 3, 1987 meetings.

L. G. Hulman, Chief
Severe Accidents Issues Branch
Division of Reactor Accident Analysis
Office of Nuclear Regulatory Research

Enclosures:
1. Attendance List
2. Proposed Meeting Schedule and Question List
3. Owner Group/IDCOR Slides
4. IDCOR Heat Transfer Model
5. [illegible] Accident Sequence Classes

R. Diederich discussed Q 11. He indicated no analysis was made of the gap between the drywell and the biological shield. However, if the drywell were breached, some fission products might be trapped in the gap in the path to the reactor building through penetrations in the biological shield. (See Enclosure 3, pg 21) The calculations were characterized as conservative because no credit for fission product attenuation was taken for the biological shield area.

E. Burns discussed venting (Q 12). He indicated venting was a means of preventing uncontrolled releases and establishing a heat removal path as a last resort. Further, venting can be used to prevent coremelts in such sequences as TW. However, he indicated large costs were not justified generally, but plant specific analyses may indicate differently. (See Enclosure 3, p 22)

R. Diederich discussed noble gas venting (Q 13). He indicated such venting as a last resort can reduce the impacts of some sequences, but that negative effects must be considered. (See Enclosure 3, p 23) He presented a backup slide which showed substantial reductions in doses if releases of noble gases were delayed about 18 hours.

R. Henry discussed the use of containment sprays for station blackout sequences in response to Q 14. He indicated several benefits (debris cooling, delay of containment failure, and fission product removal), but eventually containment heat removal is required. (See Enclosure 3, pg 24). He also discussed debris coolability referring to pages 25-35 of Enclosure 3 using inferences from TMI, experimental evidence and analytical assessments. Analogies were also made to debris coolability in coal fired power plants and experience in the steel industry with electric furnaces by several participants.

R. Diederich discussed Q 15 (See Enclosure 3, p 25). He indicated that the NUMARC evaluation is not complete, but that to date no cost beneficial modifications have been identified.

R. Bernero asked whether modifications such as a more reliable ADS system could help. R. Henry indicated he did not consider such modifications cost beneficial.

The issue of steel shell perforation was again raised. R. Henry again summarized the IDCOR view that the carbon steel and heat transfer capabilities as modeled precluded such as occurrence.

V. Boyer concluded by indicating the NUMARC working group report was expected in mid-May, followed by a review by a supervising technical committee. He indicated no firm dates had been established for briefing the Commission or the staff, but any briefings would likely not be before summer.

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5. BWR Severe Accident Sequence Classes
6. Formal Comments

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/s/

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OFC	:DRAA:SAI	:	:	:	:	:
NAME	:LHulman/vgt	:	:	:	:	:
DATE	:5/7/87	:	:	:	:	:

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J. Carter, International Technologies Corp.
R. Henry, Fauske & Associates, Inc.
E. Burns, Delian Corp.
J. Lang, EPRI
W. C. Ham, House Subcommittee on Energy & Power Staff
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C. Wright, GE
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B. Sheron, NRC
G. Lainas, NRC
C. E. Rossi, NRC
J. Kudrick, NRC
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ENCLOSURE 1

ATTENDANCE LIST

NAME	BUSINESS ADDRESS	TELEPHONE NO.	INDICATE IF YOU WANT THE PREVIOUS SUMMARY, AND CHECK IF YOU WANT TO COMMENT ON MTG. SUMMARY
L. G. Hulman	U. S. NRC NL - 007 Washington, DC. 20555	301-492-7941	X
M. C. Thadani	NRC	301-492-8649	X
Tom Murley	NRC		No
Eric Beckjord	NRC		No
T. P. Speis	NRC		No
Z. R. Rosztoczy	NRC		No
Farouk Eltawila	NRC		Yes
Matt Chiramal	NRC		Yes
R. W. Houston	NRC		No
Ashok Thadani	NRC		No
Stephen D. FLoyd	Carolina Power & Light Co. 411 Fayetville Street Raleigh, NC 27602		X
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Terry Pickens	Northern States Power Co. 414 Nicollet Mall Minneapolis, MN 55401	(612) 337-2037	X
Dick Diederich	Philadelphia Electric Co. 2301 Market Street Philadelphia, PA 19101	(215) 841-4516	X
VS Boyer	Philadelphia Electric Co. 2301 Market Street Philadelphia, PA 19101	(215) 841-4000	X

NAME	BUSINESS ADDRESS	TELEPHONE NO.	INDICATE IF YOU WANT THE PREVIOUS SUMMARY, AND CHECK IF YOU WANT TO COMMENT ON MTG. SUMMARY
Jim Carter	International Technologies 575 Oak Ridge Turnpike Pak Ridge, TN 37830	(615) 481-3300	X
Bob Henry	Fauske & Associates, Inc. 16 W070 West 83rd Street Burr Ridge, IL 60521	(312) 323-8750	X
E. T. Burns	Delian Corporation 1340 Saratoga-Sunnyvale Road Suite 206 San Jose, CA 95129	(408) 446-4242	X
H. R. Denton	NRC		X
Mark W. Idell	Public Service Electric & Gas Co. P. O. Box 570 Newark, NJ 07101	(609) 339-3073	Yes
Eryk Dluzniewski	GRS 801 18th St. NW Suite 300 Washington, D.C. 20006	293-4200	X
Paul R. Hill	Pennsylvania Power & Light Co. 2N 9th St. Allentown, PA 18101	(215) 770-7949	Yes X
E. A. Hughes	Erin Engineering 1850 Mt. Diablo Blvd. Suite 600 Walnut Creek, CA 94596	(415) 943-7077	Yes
R. A. Cushman	Niagara Mohawk Power Corp. 301 Plunheld Rd. Syracruse, NY 13203	(315) 428-7476	X
A. J. Marie	Philadelphia Electric Co. 2301 Market Street Philadelphia, PA 19101	(215) 841-6378	

NAME	BUSINESS ADDRESS	TELEPHONE NO.	INDICATE IF YOU WANT THE PREVIOUS SUMMARY, AND CHECK IF YOU WANT TO COMMENT ON MTG. SUMMARY
E. R. Schmidt	NUS Corp. 910 Clopper Road Gaithersburg, MD 20878	(301) 258-5831	
P. J. Fulford	NUS Corp. 910 Clopper Road Gaithersburg, MD 20878	(301) 258-8692	X
R. A. Pinelli	GPU Nuclear 1 Upper Pond Rd. Parsippany, NJ 07054	(201) 316-7155	X
K. M. Campe	NRC		No
J. E. Rosenthal	NRC		Yes X
Joe DelMedico	NRC		Copy of this mtg. summary, please
Charles Ader	NRC		Yes X
Roger Huston	AIF 7101 Wisconsin Ave. Bethesda, MD 20814	(301) 654-9260	X
Dennis Fadden	INPO 1100 Circle 75 Pkwy. Atlanta, GA 30339	(404) 980-3219	No
J. F. Lang	EPRI P.O. Box 10412 Palo Alto, CA 94303	(415) 855-2038	Yes
J. A. Murphy	NRC/RES	X37921	Yes
D. R. Muller	NRC/NRR		No
W. C Ham	House Subcommittee on Energy & Power House Annex 2 H2-331 Washington, D.C. 20515		Minutes

NAME	BUSINESS ADDRESS	TELEPHONE NO.	INDICATE IF YOU WANT THE PREVIOUS SUMMARY, AND CHECK IF YOU WANT TO COMMENT ON MTG. SUMMARY
Jack Kudrick	NRC/DBL/PSB		No
C. R. Wright	General Electric Co. Suite 203 7910 Woodmont Avenue Bethesda, MD 20014		No
W. A. Smith	Bechtel 15740 Shady Grove Rd. Gaithersburg, MD 20877		Y
Wayne Hodges	NRC/NRR	492-7483	This mgt., Yes No
L. S. Gifford	General Electric Co. Suite 203 7910 Woodmont Ave. Bethesda, MD 20014	654-0011	Yes X
R. Bernero	NRC		No X
H. Spector	New York Power Authority 123 Main Street White Plains, NY 10601	(914) 681-6994	Please send all material
Jocelyn Mitchell	NRC	(301) 443-7983	No Yes

ENCLOSURE 1

PROPOSED SCHEDULE

MEETING ON MARK I CONTAINMENT

Opening Remarks		1:00 - 1:10
Introduction		1:10 - 1:30
Response to 15 Questions		
A. Accident Sequence Questions 1, 2 and 3		1:30 - 1:50
B. Core Melt Behavior Questions 4, 5 and 6		1:50 - 2:25
C. Effects of Spray Questions 7, 8 and 9		2:25 - 3:00
	Break	3:00 - 3:10
D. Corium Retention Question 10		3:10 - 3:25
E. Drywell Release Path Question 11		3:25 - 3:35
F. Effect of Venting Question 12		3:35 - 3:50
G. Cost Benefit Analysis Questions 13 and 14		3:50 - 4:10
H. Alternatives Question 15		4:10 - 4:20
I. Discussion		4:20 - 5:00

PROPOSED AGENDA AND DISCUSSION LEADERS*

1. What core melt accident sequences may be expected to be significant in BWRs with Mark I containments? (E. Burns)

2. Do current analyses indicate containment failure preceding core melt?...and causing core melt? (E. Burns)

3. What are the approximate time scales for significant sequences? e.g., time to core uncovery, time to core melt, time to melt through, time to containment failure. Is this generic or very plant specific? (R. Henry)

4. Do high pressure melts (ADS failure) have a significant effect on the physical behavior of the core melt in a BWR? (R. Henry)

5. Do current models indicate substantial differences between PWRs and BWRs in meltdown times?...in meltthrough times? (R. Henry)

6. Are the physical properties of the "core-on-the-floor" for a BWR expected to be significantly different than for a PWR? e.g., thermal conductivity, viscosity, etc. (R. Henry)

7. In a typical Mark I, initiation of drywell spray before meltthrough can cover the drywell floor with up to 1 foot of water before core material begins to drop. Is the presence of such a water layer beneficial? (R. Henry)

8. In a typical Mark I the drywell spray can distribute up to 20,000 gpm in the area outside the reactor pedestal area. If this spray is operating at the time of meltthrough, can it inhibit corium movement toward and attack of the outer wall of the drywell? Would success be proportional to water flow rate? (R. Henry)

9. Given the presence of drywell spray, would a short diversion barrier which could double or triple the path length to the outer wall significantly reduce the likelihood of liner meltthrough? (R. Henry)

10. If a substantial barrier of refractory character could be provided to hold most of the corium in the reactor pedestal area, would this be preferred? Would attack of the reactor vessel pedestal be a significant concern? (R. Henry)

11. Is any release attenuation expected from the biological shield surrounding the Mark I drywell?...is it treated in current models? (A. Diederich)

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* Discussion leader is expected to initiate discussion on the topic with a 3-5 minute statement, viewgraphs can be used. Discussion leaders may exchange topics by agreement.

12. In a typical Mark I containment available or practically adaptable vent paths have an effective diameter of about 10-12 inches which is sufficient to pass water vapor at 1 to 1½ times design pressure equivalent to 1-2% decay heat. What effect on significant accident sequences can be expected if there are assured means to open this vent path? (R. Henry)

13. Calculations now available indicate that although noble gas doses can be high (see attached Figure) deliberate release of those gases appears to be better to avoid the far greater releases that might occur with an uncontrolled release. Do present models indicate that deliberate venting of noble gas activity may not be justified? (A. Diederich)

14. To what extent could reliable containment spray alone, without venting, substantially reduce containment failure in the station blackout sequence? (R. Henry)

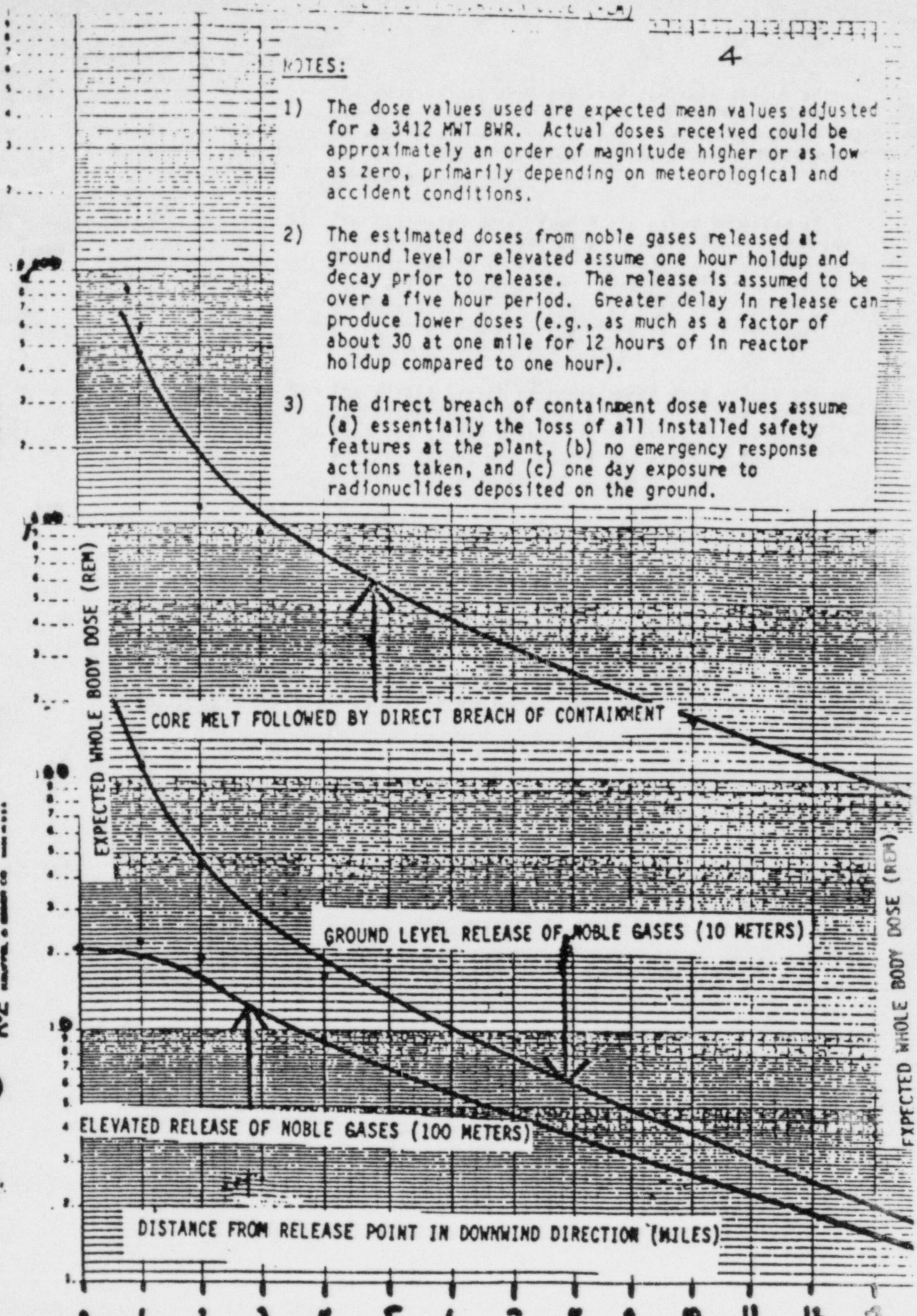
15. Is there any other practical change to the Mark I containment system which can significantly improve its performance in core melt? (R. Bernero and A. Diederich)

NOTES:

1) The dose values used are expected mean values adjusted for a 3412 MWT BWR. Actual doses received could be approximately an order of magnitude higher or as low as zero, primarily depending on meteorological and accident conditions.

2) The estimated doses from noble gases released at ground level or elevated assume one hour holdup and decay prior to release. The release is assumed to be over a five hour period. Greater delay in release can produce lower doses (e.g., as much as a factor of about 30 at one mile for 12 hours of in reactor holdup compared to one hour).

3) The direct breach of containment dose values assume (a) essentially the loss of all installed safety features at the plant, (b) no emergency response actions taken, and (c) one day exposure to radionuclides deposited on the ground.



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K·E SEMI-LOGARITHMIC 3 CYCLES X 70 DIVISIONS

BWR OWNERS GROUP/IDCOR
RESPONSE TO FIFTEEN MARK I CONTAINMENT
RELATED QUESTIONS

PRESENTED TO
NRC STAFF
BETHESDA, MARYLAND
MARCH 27, 1987

INTRODUCTION

- O RESPONSES FROM BWR OWNERS GROUP AND IDCOR WORK, FACILITATED BY NUMARC CIWG

- O NUREG 1150 NOT REVIEWED

- O RESPONSE PREPARATION HAS DELAYED NUMARC EFFORT

- O CONSIDERABLE EPRI, DOE, NRC RESEARCH WORK UNDERWAY TO FURTHER UNDERSTAND CONCERNS AND TO REDUCE UNCERTAINTY

- O MOST CRITICAL ISSUES RELATE TO:
  - o PROGRESS OF CORE FAILURE
  - o COOLING OF CORE ON THE FLOOR
  - o CORE CONCRETE INTERACTION
- O SUFFICIENT WORK DONE BY IDCOR FOR INDEPENDENT PLANT EVALUATION

- O CONTAINMENT INTEGRITY IS RECOGNIZED BY INDUSTRY AS BEING IMPORTANT
- O NUMARC WORKING GROUP FORMED
- O COMPREHENSIVE MARK I EVALUATION BY BWROG (UNDERWAY)
  - SPECTRUM OF CHALLENGES
  - ALTERNATE MODIFICATIONS
  - COST BENEFIT ANALYSIS

PERFORMANCE MEASURES

- O RISK - "BOTTOM LINE"
  - ALLOW COMPARISONS
  - IDENTIFIES OUTLIERS
- O CONDITIONAL FAILURE
  - PLANT SPECIFIC
  - SEQUENCE DEPENDENT
  - COMPARISONS DIFFICULT

MARK I - OBSERVATIONS

- O BWROG/CBI PRESSURE CAPABILITY
  - ULTIMATE CAPABILITY HIGHER THAN GENERALLY ASSUMED
  - TORUS AIRSPACE LIKELY FAILURE
- O NUREG-1150 INDICATES SIMILAR BLACKOUT CDF AT MOST PLANTS
- O HEAT CAPACITY SIMILAR FOR ALL CONTAINMENT TYPES
- O ATWS IMPORTANCE DECLINING
  - IMPROVED DESIGNS (E.G., ATWS RULE)
  - IMPROVED PROCEDURES (BWROG EPG's)
  - OPERATOR TRAINING
  - INCREASED UNDERSTANDING
- O STUDIES GENERALLY INDICATE NO COST-BENEFICIAL IMPROVEMENTS

MARK I STUDY RESULTS

0 IDCOR

- SPECTRUM OF SEQUENCES
- CONTAINMENT FAILURE LATE
- RELEASES SMALL
- RISK LOW
- MODIFICATIONS NOT JUSTIFIED

0 NUREG-1150

- FEWER SEQUENCES
- CONTAINMENT FAILURE VARIES
- RELEASES HIGHER
- RISK LOW
- MODIFICATIONS NOT JUSTIFIED

CONCLUSION

COMPREHENSIVE MARK I EVALUATION

- O UNDERWAY BY BWROG
- O TECHNICAL BASIS FOR NUMARC DECISIONS
- O COST-BENEFIT COMPARISON FOR POTENTIAL MODIFICATIONS

1. WHAT CORE MELT ACCIDENT SEQUENCES MAY BE EXPECTED TO BE SIGNIFICANT IN BWRS WITH MARK I CONTAINMENTS?

RESPONSE:

FACTS ON MARK I PLANTS

O 24 MARK I PLANTS

O INCLUDE BWR - 2 - 3 - 4

O DIFFERENT AEs

O DIFFERENT UTILITIES

O CONSTRUCTED OVER 20 YEAR PERIOD

ANALYSIS

O PRAs SHOW PLANT SPECIFIC DOMINANT ACCIDENT SEQUENCES

GENERIC APPLICABILITY

O IN GENERAL DOMINANT ACCIDENT SEQUENCES ARE NOT APPLICABLE TO ALL MARK I PLANTS BECAUSE OF LARGE DIFFERENCES IN BALANCE OF PLANT AND SUPPORT SYSTEMS

2. DO CURRENT ANALYSES INDICATE CONTAINMENT FAILURE PRECEDING CORE MELT?.....AND CAUSING CORE MELT?

RESPONSE:

ANALYSES

- SOME PROBABILISTIC ANALYSES HAVE POSTULATED SUCH EFFECTS
- TREATMENT CONSERVATIVE IN PUBLISHED PRAs
- NO MECHANISTIC COUPLING OF CONTAINMENT FAILURE TO INDUCING CORE MELT

EXISTING BWR CAPABILITY

- DIVERSE COOLANT INJECTION CAPABILITY FROM MULTIPLE SOURCES
- AFFORDS ASSURANCE OF CONTINUED RPV INJECTION TO PREVENT CORE MELT

3. APPROXIMATE TIME SCALES FOR SIGNIFICANT SEQUENCES? E.G.' TIME TO CORE UNCOVERY, CORE MELT, MELT THROUGH, CONTAINMENT FAILURE. IS THIS GENERIC OR VERY PLANT SPECIFIC?

RESPONSE:

APPROXIMATE TIME SCALES:

- O TIME VARIATION LARGE FOR IMPORTANT SEQUENCES (E.G., CORE MELT 3.3 - 40 HOURS)
- O TIMING OF EARLY MELT SEQUENCES APPROXIMATELY SAME
  - CORE UNCOVERY (1.1 - 2.2 HOURS)
  - CORE MELT START (1.4 - 3.0 HOURS)
  - VESSEL FAILURE (1.9 - 3.8 HOURS)

GENERIC OR PLANT SPECIFIC

- O TIMING THROUGH VESSEL FAILURE SIMILAR FOR SAME SEQUENCES
- O TIMING CAN BE PLANT SPECIFIC AND TYPE SPECIFIC
  - E.Q. ISOLATION CONDENSER
  - BWR VS. PWR STATION BLACKOUT

4. DO HIGH PRESSURE MELTS (ADS FAILURE) HAVE A SIGNIFICANT EFFECT ON THE PHYSICAL BEHAVIOR OF THE CORE MELT IN A BWR?

<u>RESPONSE</u>:

- O NO SIGNIFICANT EFFECT ON CORE MELT PROGRESSION EXPECTED FOR HIGH PRESSURE SEQUENCES COMPARED TO LOW PRESSURE SEQUENCES.

- O DISTRIBUTION OF MATERIAL IN CONTAINMENT AFFECTED BY HIGH PRESSURE VESSEL FAILURE.

5. DO CURRENT MODELS INDICATE SUBSTANTIAL DIFFERENCES BETWEEN PWRs AND BWRs IN MELTDOWN TIMES?...IN MELT THROUGH TIMES?

RESPONSE:

- O NO. SIGNIFICANT DIFFERENCES DO NOT EXIST. MAT'L TYPES, AMOUNTS AND FUEL DESIGN MAY CAUSE MINOR DIFFERENCES.
- O SEQUENCE ASSUMPTIONS CONTRIBUTE MAIN DIFFERENCES IN TIME.

6. ARE THE PHYSICAL PROPERTIES OF THE "CORE-ON-THE-FLOOR" FOR A BWR EXPECTED TO BE SIGNIFICANTLY DIFFERENT THAN FOR A PWR?

RESPONSE:

- DEBRIS PROPERTIES WILL HAVE DIFFERENCES BUT BEHAVIOR NOT SIGNIFICANTLY DIFFERENT.

7. IS THE PRESENCE OF A ONE FOOT WATER LAYER ON THE DRYWELL FLOOR BENEFICIAL?

RESPONSE:

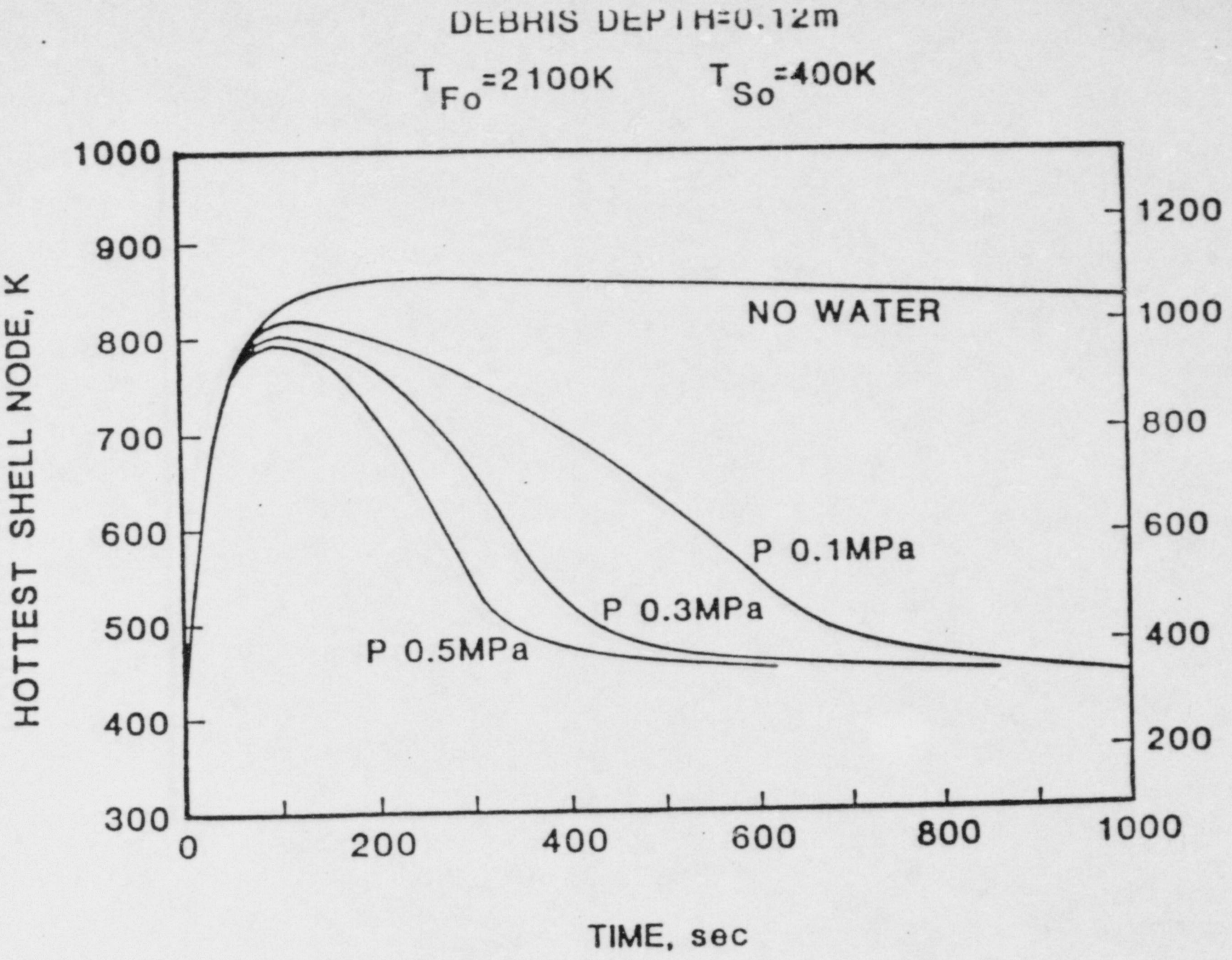
O THE PRESENCE OF WATER WILL REDUCE:

- POTENTIAL FOR DRYWELL WALL CONTACT
- AIRBORN FISSION PRODUCTS THROUGH STEAM CONDENSING

O ONE FOOT LAYER ALONE NOT SUFFICIENT - MUST BE REPLENISHED.

O IDCOR ANALYSIS SHOWS:

- PEAK WALL TEMPERATURE IS WELL BELOW THE STEEL MELT POINT FOLLOWING DEBRIS CONTACT
- WATER LAYER SUBSTANTIALLY LOWERS THE WALL TEMPERATURE AND QUENCHES THE DEBRIS.


DEBRIS DEPTH=0.12m
T_{Fo}=2100K T_{So}=400K
HOTTEST SHELL NODE, K
1000
900
800
700
600
500
400
300
0
200
400
600
800
1000
TIME, sec
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P 0.3MPa
P 0.5MPa

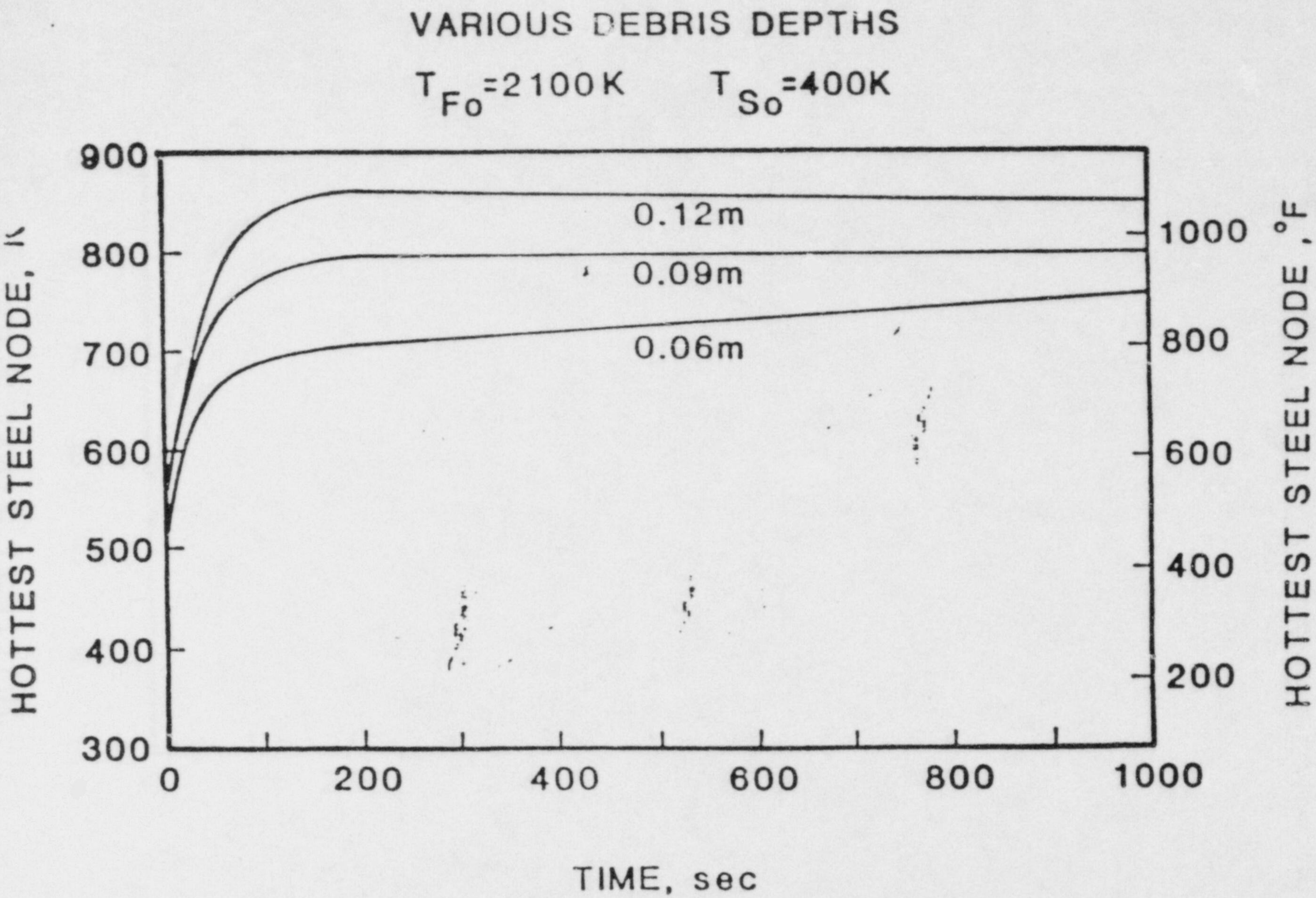


Figure D.4 Thermal history of the hottest shell [illegible]

8. CAN DRYWELL SPRAY INHIBIT CORIUM MOVEMENT TOWARD AND ATTACK OF THE OUTER WALL OF THE DRYWELL? WOULD SUCCESS BE PROPORTIONAL TO WATER FLOW RATE?

<u>RESPONSE</u>:

- O PRESENCE OF WATER OVER THE DEBRIS FROM ANY INJECTION SOURCE WILL REDUCE CONTAINMENT CHALLENGE.
- O A WATER AMOUNT SUFFICIENT TO REMOVE DECAY HEAT OR LARGER WOULD BE ADEQUATE.
- O ALTERNATIVE WATER SOURCES WILL ALSO REMOVE AIRBORN FISSION PRODUCTS.

9. WITH DRYWELL SPRAY, WOULD A SHORT DIVISION BARRIER WHICH COULD DOUBLE OR TRIPLE THE PATH LENGTH TO THE OUTER WALL SIGNIFICANTLY REDUCE THE LIKELIHOOD OF LINER MELT THROUGH?

<u>RESPONSE</u>:

O BARRIERS WOULD CAUSE
- DEBRIS DEPTH INCREASED
- HEAT TRANSFER SURFACE REDUCED
- EXPECT NO IMPROVEMENT; PERHAPS NEGATIVE EFFECT

10. WOULD HOLDING CORE DEBRIS IN REACTOR PEDESTAL BE PREFERRED TO SPREADING OVER DRYWELL FLOOR? VESSEL PEDESTAL A CONCERN?

RESPONSE:

- O DRYWELL SPRAY AND FISSION PRODUCT REMOVAL EFFECTIVENESS WOULD BE REDUCED
- O HEAT REMOVAL EFFECTIVENESS IN PEDESTAL IS MINIMIZED
- O POSSIBLE CONCENTRATED ATTACK OF CONCRETE FLOOR WOULD BE UNDESIRABLE

11. IS A RELEASE ATTENUATION EXPECTED FROM THE BIOLOGICAL SHIELD SURROUNDING THE MARK I DRYWELL?...IS IT TREATED IN CURRENT MODELS?

<u>RESPONSE</u>:

- O BIOLOGICAL SHIELD:
  - ATTENUATES DIRECT SHINE
  - ELIMINATES POSSIBLE DRYWELL FAILURE LOCATIONS
  - MAY PROVIDE SMALL AMOUNT OF FISSION PRODUCT REMOVAL IF DRYWELL FAILURE OCCURRED
- O NO CREDIT CURRENTLY TAKEN
- O NO QUANTIFICATION AND CREDIT FOR POTENTIAL BENEFIT ARE PLANNED

12. WHAT EFFECT ON SIGNIFICANT ACCIDENT SEQUENCES CAN BE EXPECTED IF RELIABLE MARK I VENTING IS UTILIZED

RESPONSE:

O VENTING THROUGH THE MARK I CONTAINMENT WETWELL

- PREVENTS UNCONTROLLABLE RELEASES FROM CONTAINMENT FAILURE

- REDUCES RELEASE TO NOBLE GASES

- ESTABLISHES CONTAINMENT HEAT REMOVAL PATH IN SOME SEQUENCES

O VENTING SIZED FOR DECAY HEAT REMOVAL <u>ONLY</u> CAN BE USED AS A LAST RESORT TO PREVENT LOSS OF CONTAINMENT FUNCTION.

13. DO PRESENT MODELS INDICATE THAT DELIBERATE VENTING OF NOBLE GAS ACTIVITY MAY NOT BE JUSTIFIED?

<u>RESPONSE</u>:

- O VENTING AS A LAST RESORT CAN REDUCE THE RISK IMPACTS OF SOME SEQUENCES
- O A NUMBER OF NEGATIVE EFFECTS MUST BE CONSIDERED FOR VENTING
- O IDCOR AND OTHER STUDIES HAVE SHOWN THAT SIGNIFICANT VENTING MODIFICATIONS ARE NOT COST BENEFICIAL.

14. TO WHAT EXTENT COULD RELIABLE CONTAINMENT SPRAY ALONE, WITHOUT VENTING, SUBSTANTIALLY REDUCE CONTAINMENT FAILURE IN THE STATION BLACKOUT SEQUENCE?

<u>RESPONSE</u>:

- O WATER PROVIDED CAN COOL THE DEBRIS AND SUBSTANTIALLY DELAY CONTAINMENT FAILURE.
- O EVENTUALLY CONTAINMENT HEAT REMOVAL IS NEEDED.
- O FISSION PRODUCT REMOVAL SUBSTANTIAL.

15. IS THERE ANY OTHER PRACTICAL CHANGE TO THE MARK I CONTAINMENT SYSTEM WHICH CAN SIGNIFICANTLY IMPROVE ITS PERFORMANCE IN CORE MELT?

RESPONSE:

O NUMARC IS CURRENTLY EVALUATING CONTAINMENT PERFORMANCE ISSUES

O THIS REVIEW INCLUDES:
- BASIS FOR CONTAINMENT PERFORMANCE
- BERNERO PROPOSED MODIFICATIONS
- ALTERNATIVE MODIFICATIONS

O CURRENTLY NO COST BENEFICIAL MODIFICATIONS IDENTIFIED BUT STUDY NOT COMPLETE

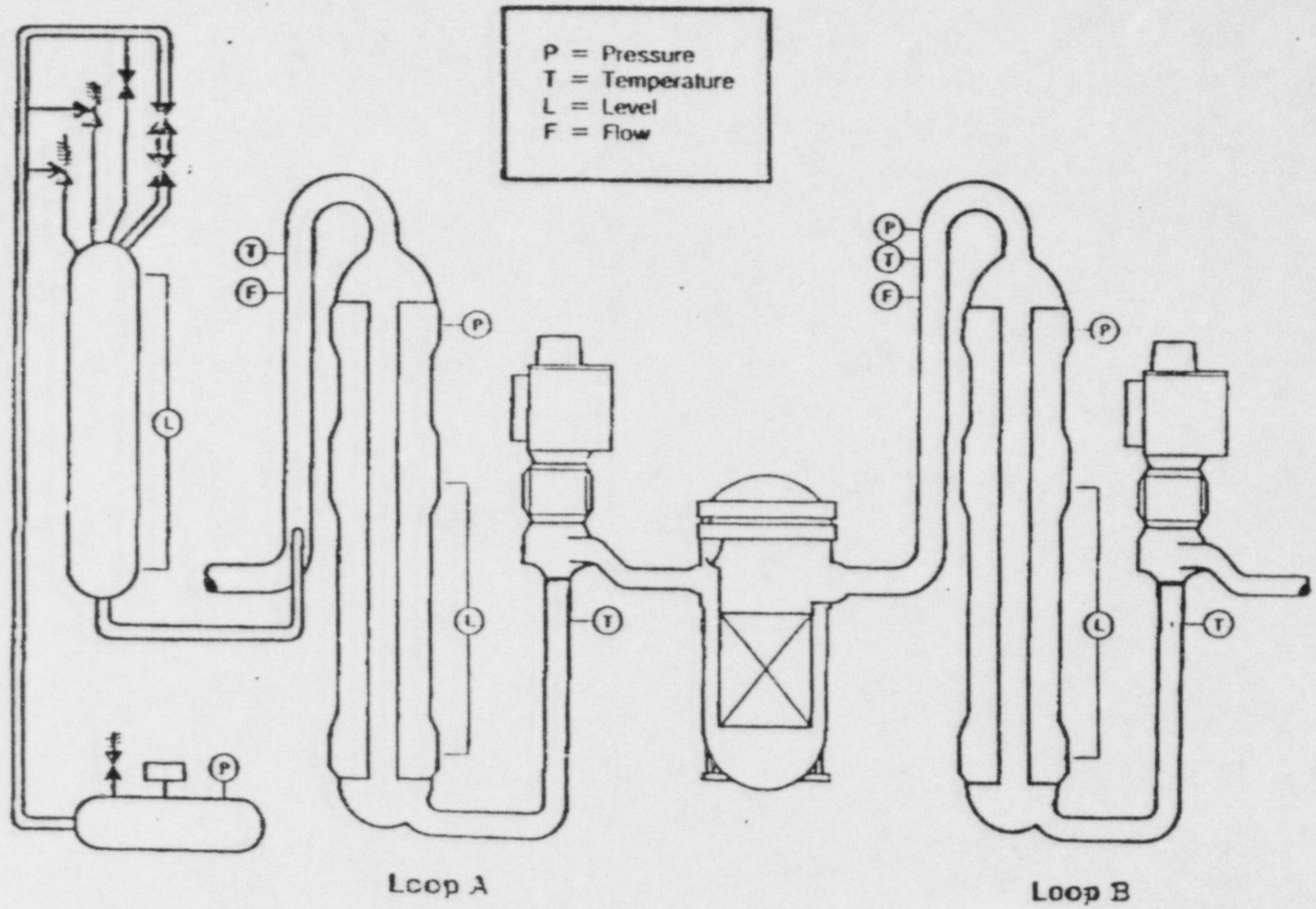
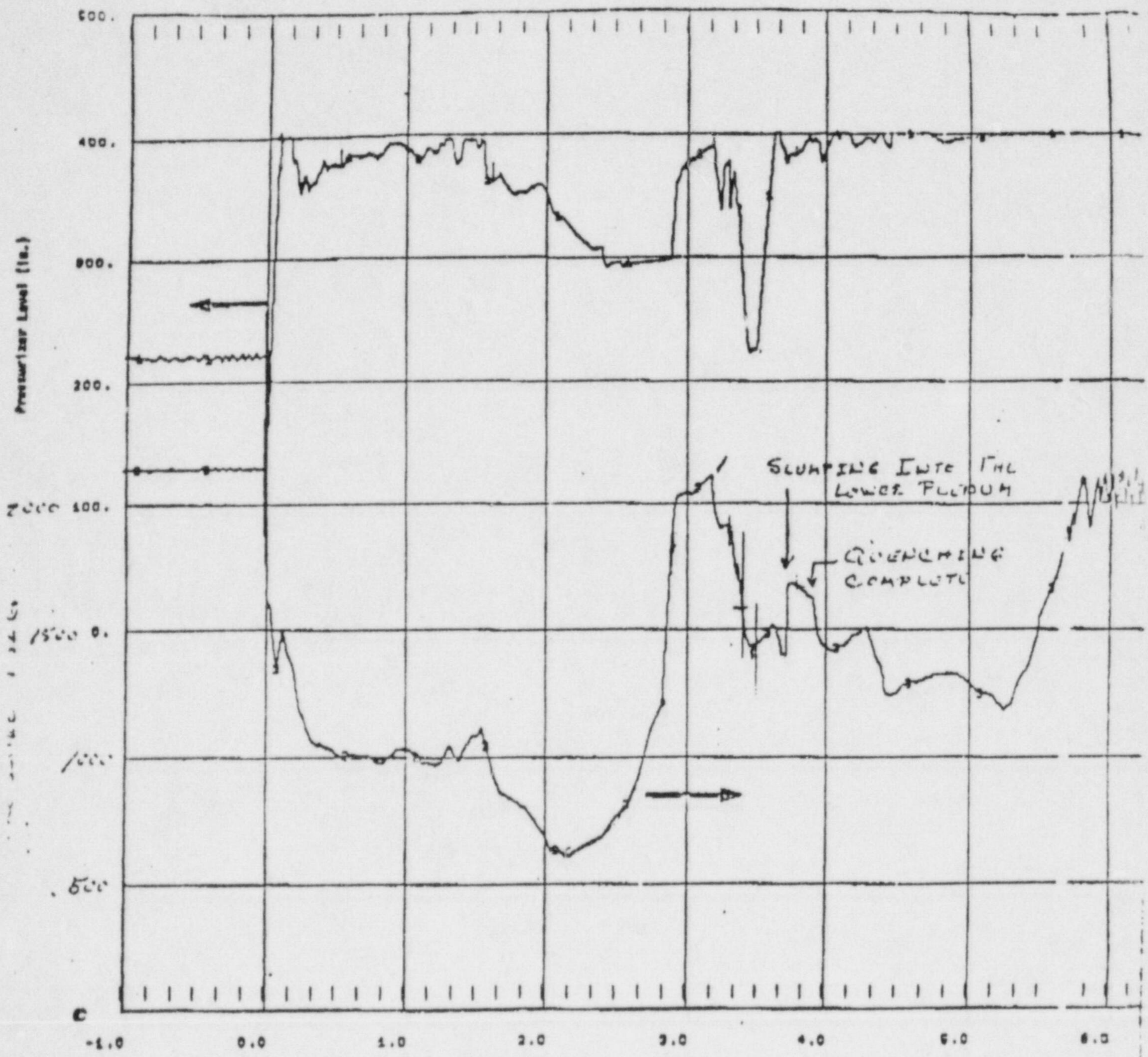


Figure TH3 Primary System Reactimeter Measurement


Pressurizer Level (in.)
500.
400.
300.
200.
2000 100.
1500 0.
1000
500
0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
SLUMPING INTO THE LOWER PLENUM
QUENCHING COMPLETE

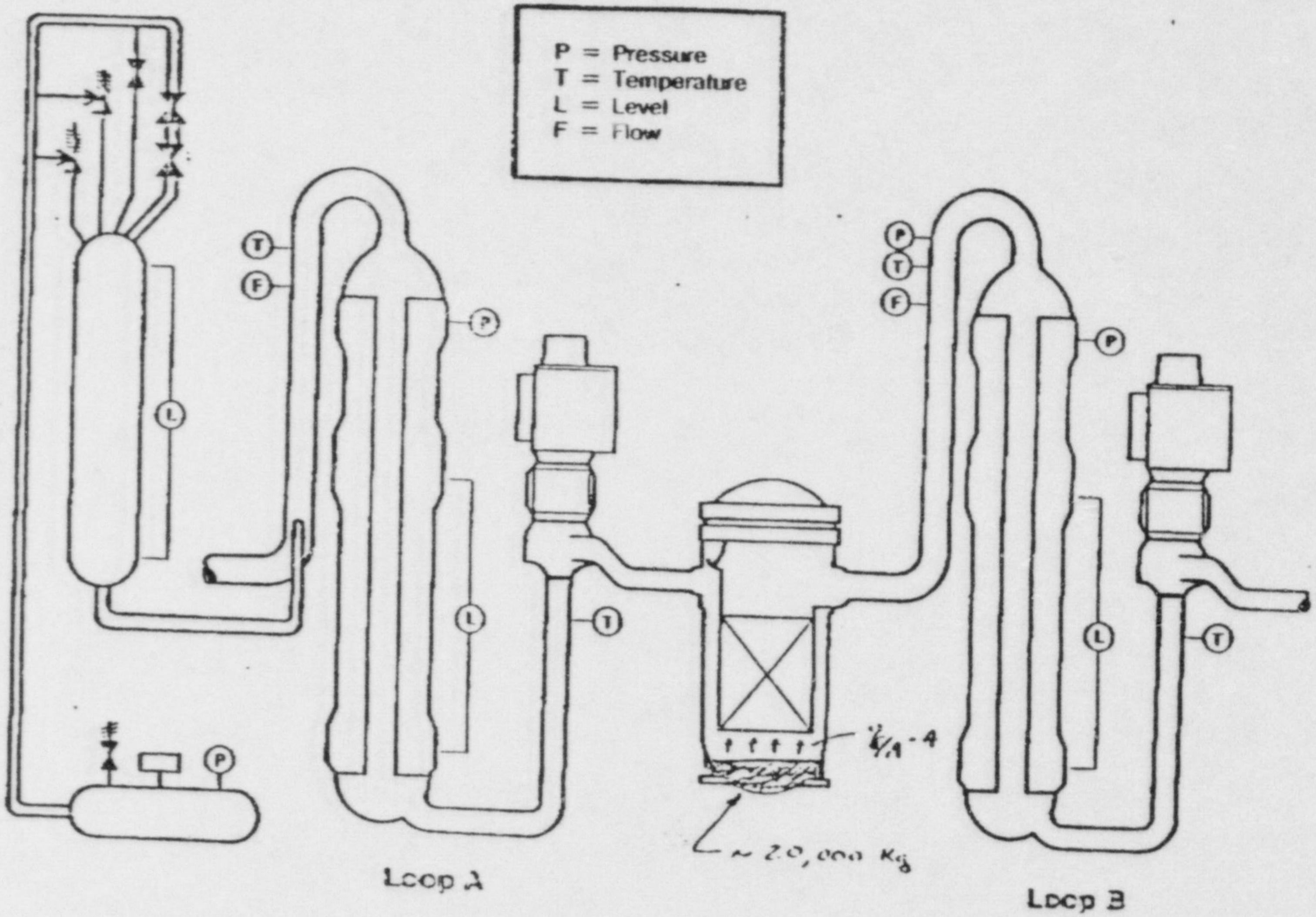


Figure TH9. Primary System Reactimeter Measurement

TMI-2
DEBRIS COOLABILITY IN THE LOWER PLENUM

Mass of Material ~ 20,000 kg

Planar Area ~ 12 m^2

Quenching Heat Flux ~ 3.4 x 10^6 w/m^2

Debris Initial Temperature ~ 2500K

$$\Delta\theta = \frac{mc_p\,(T - T_{sat})}{q/A \cdot A}$$

$\Delta\theta \approx 600$ secs = 10 min

CONCLUSION

COMPREHENSIVE MARK I EVALUATION

- O UNDERWAY BY BWROG
- O TECHNICAL BASIS FOR NUMARC DECISIONS
- O COST-BENEFIT COMPARISON FOR POTENTIAL MODIFICATIONS

ENCLOSURE 4

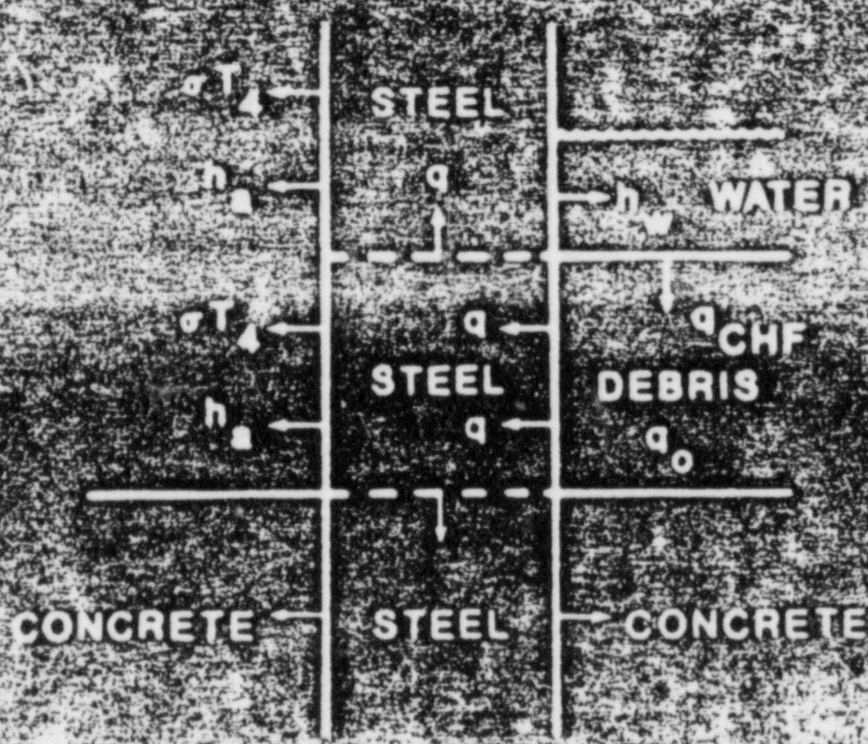


Figure D.1 General nodalization scheme

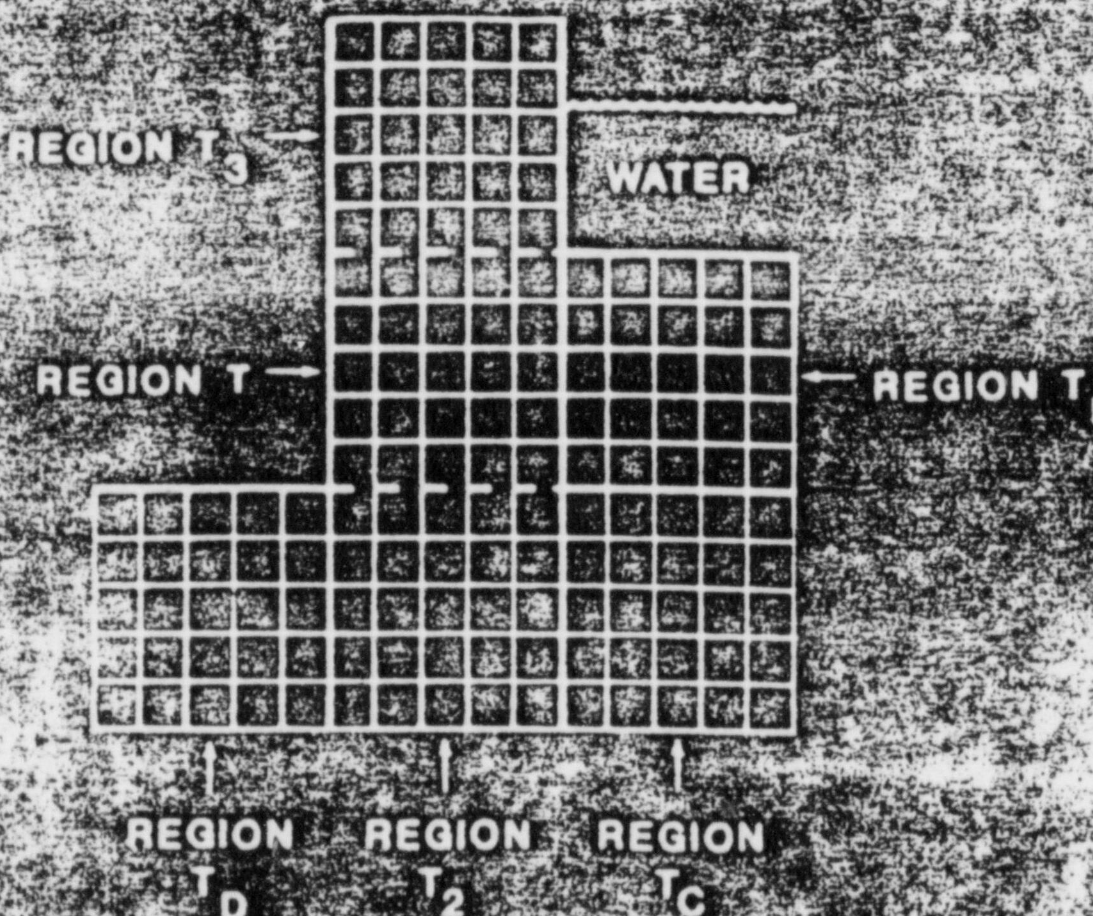
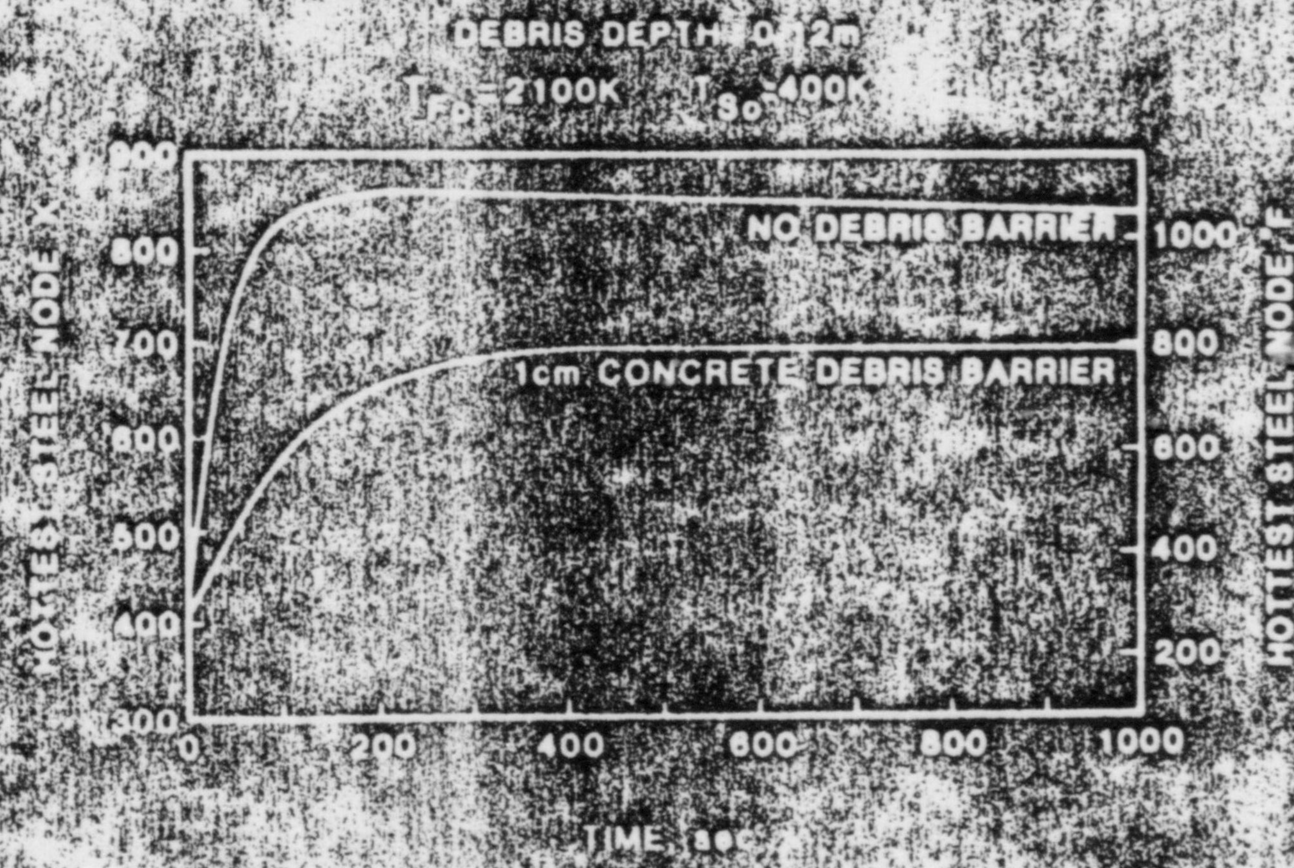


Figure D.2 Subnodalization scheme


DEBRIS DEPTH 0.12m
T Fo = 2100K T So = 400K
NO DEBRIS BARRIER
1cm CONCRETE DEBRIS BARRIER
HOTTEST STEEL NODE K
HOTTEST STEEL NODE °F
TIME sec
300
400
500
600
700
800
900
0
200
400
600
800
1000
200
400
600
800
1000

ENCLOSURE 5

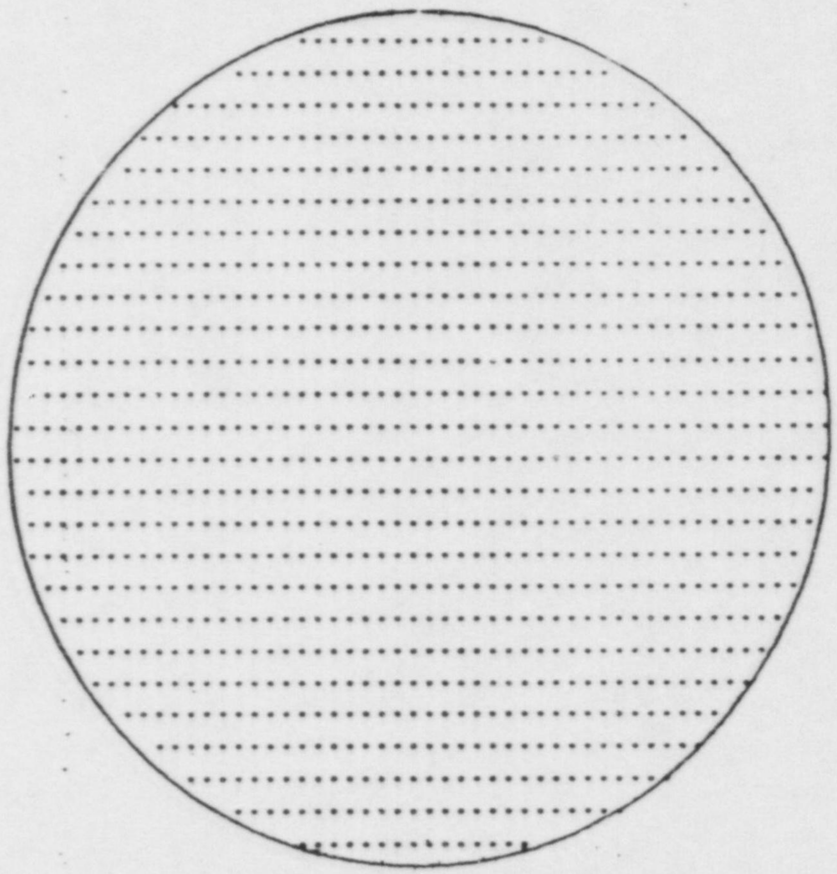
Key

Legend

CLASS	EXAMPLE DESCRIPTION	EXAMPLE
I	- Loss of Inventory - Station Blackout	TQUX, TQUV
II	Loss of Containment Heat Removal	TW
III	LOCAs	AV
IV	ATWS	TC
V	LOCA Outside Containment	A out V

BROWNS FERRY
IREP

2-T-157-002



CLASS I (100%)

NOTE: Most of the Class I Events are in fact induced by postulated failure of the containment Heat Removal system. The analysis had unique scope and boundary limitations that may have limited the problem diversity.

Figure 10 Summary of the Contributors to Core Melt Frequency for Browns Ferry. Total Core Melt Frequency = 2.0 E-4/yr.

2-T-157-002

SHOREHAM

LONG ISLAND LIGHTING COMPANY IPE

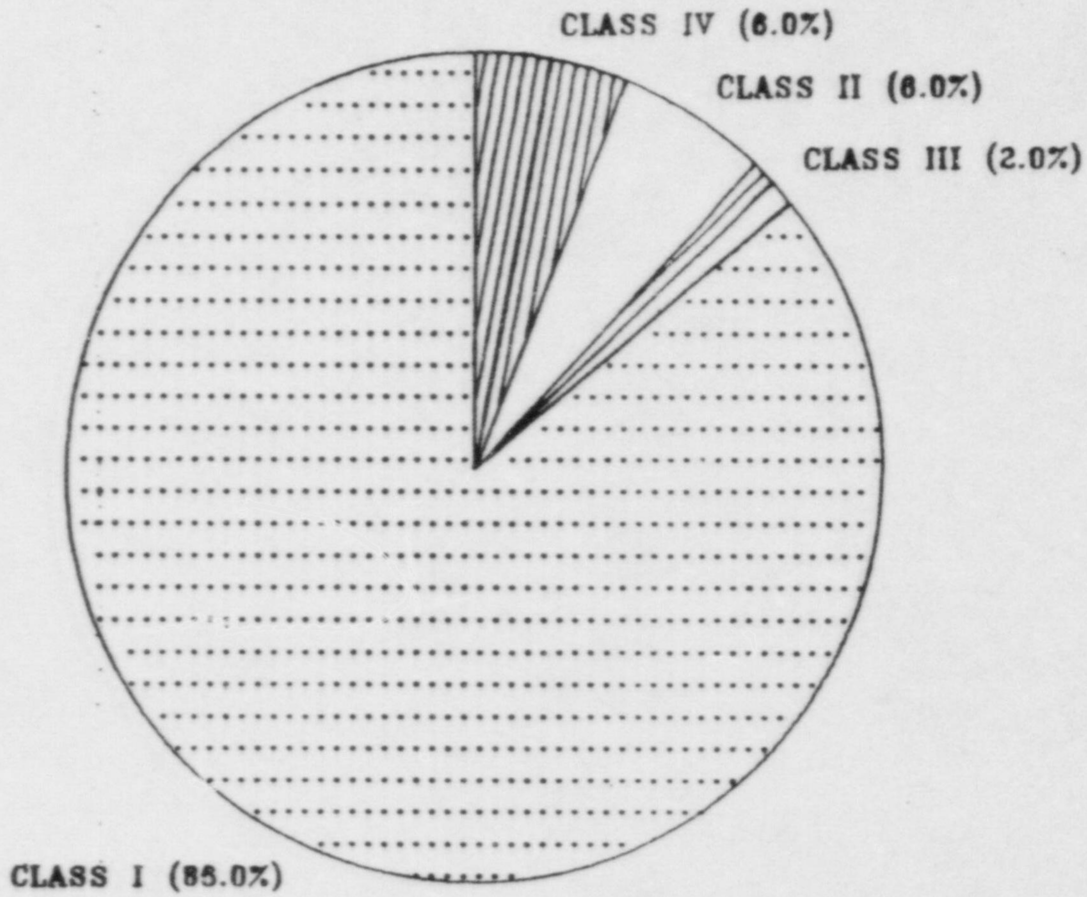


Figure 9 Summary of Contributors to Core Melt Frequency for Shoreham from LILCO. Total Frequency = 8.5 E-5/yr.

ENCLOSURE 6

INTERNATIONAL TECHNOLOGY CORPORATION

April 10, 1987

Mr. L. G. Hulman, Chief
Plant Systems Branch
Division of BWR Licensing
Nuclear Regulatory Commission
Phillips Building
Washington, DC 20555

Dear Mr. Hulman:

DRAFT SUMMARY OF MARCH 27, 1987 MEETING WITH BWR OWNERS GROUP/IDCOR ON MARK I CONTAINMENTS

I have reviewed your draft summary of the subject meeting. My comments on your summary are as follows:

1) In the second paragraph of page 2 you indicate that R. Henry presented the responses to questions 3 through 10. You immediately observe that the conclusions were in large measure based upon evaluation of heat transfer in which the containment shell is not postulated to fail. This is misleading. The heat transfer model of the steel shell has no influence on the answers to questions 4 through 6, 9 and 10 and very little influence on the response to questions 3 and 8.

2) Your note in parentheses in the summary to question 6 is not quite correct. Your note implies that the conclusions are based on the containment shell heat transfer model. This is an incorrect implication.

3) The note in parentheses in the summary response to question 7 refers to the IDCOR heat transfer model as an "assumption". This is misleading. The heat transfer evaluation should be referred to as a model. While certain assumptions are made with any modeling of physical processes, the heat transfer model of the debris-containment wall interface is a simple application of heat transfer laws. The principal assumption present in this model is that debris is molten forming a pool in good heat transfer contact with the shell. Such an assumption represents a worse case condition for evaluating the melt through of the containment wall.

4) The summary provided to question 10 should state that a debris barrier to contain debris in the pedestal area would be detrimental. No discussion of usefulness should be made.

Regional Office
575 Oak Ridge Turnpike • Oak Ridge, Tennessee 37830 • 615-481-3300

Thank you for the opportunity to comment on your summary report. Please call me at (615) 481-3300, if you need to discuss any of my comments.

Sincerely,

Jim Carter

James C. Carter
IDCOR Project Manager

JCC:ks

cc: A. Buhl
A. Deiderich (PECO)
M. Fontana
R. Henry
G. Hughes (ERIN)
J. Raulston

NO 0487-040

PHILADELPHIA ELECTRIC COMPANY

2301 MARKET STREET

P.O. BOX 8699

PHILADELPHIA, PA. 19101

(215) 841-4000

ENGINEERING AND RESEARCH DEPARTMENT

\PR 1 0 1987

Mr. L. G. Hulman, Chief
Plant Systems Branch
Division of BWR Licensing
U.S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: Draft Summary of March 27, 1987 Meeting
on Mark I Containments

Dear Mr. Hulman:

Attached are my comments on the subject meeting summary. These are in the form of mark-ups on your letter of March 31, 1987.

I have limited my comments to areas which I presented.

Sincerely,

AR Diederich

A. Richard Diederich
Supervising Engineer
Environmental Branch

ARD/cb/04108701

Attachment

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MAR 31 1987

MEMORANDUM TO: DISTRIBUTION

FROM: L. G. Hulman, Chief
Plant Systems Branch
Division of BWR Licensing

SUBJECT: DRAFT SUMMARY OF MARCH 27, 1987 MEETING WITH BWR OWNERS GROUP/IDCOR ON MARK I CONTAINMENTS

This draft is being furnished to those participants in the meeting that requested the opportunity to comment on the summary. Please provide comments, including any supplemental material to be incorporated into the final summary, to reach the undersigned by April 10, 1987.

The meeting was opened by Messrs. Denton and Bernero, who discussed the background. A previous meeting with representatives of the research community was referenced. The summary of that meeting was identified as available through the Public Document Room. A copy of that summary is enclosed for those meeting attendees that so requested. Enclosure 1 is the attendance list for the meeting. Enclosure 2 contains the proposed meeting schedule and lists the 15 questions.

V. Boyer, Philadelphia Electric Co. (PECo), indicated that the Owners Group/IDCOR were requested to respond to the 15 questions. The responses were coordinated through the NUMARC Containment Issues Working Group of which he is chairman. He indicated that other NUMARC efforts were being delayed to respond to the request for information on the 15 questions, and that the NUMARC working group draft report to the steering committee was not expected until mid-May as a result. He indicated that the IDCOR (Industry Degraded Core Rulemaking) effort was going out of business. He then introduced the responses, summarized his views on the most critical issues and information available (Enclosure 3, p 2-4). The critical issues identified were 1) the progress of core failure, 2) cooling of a core on the floor, and 3) core concrete interaction.

R. ~~Deterich~~ Dieterich, PECO, described the industry evaluations (Enclosure 3, p 5-8). He indicated that they were evaluating both overall risks (referred to as bottom line), and conditional failures. He indicated their conclusion that ~~risks are~~ conditional failure is sequence and plant dependent, making it difficult to compare different plants in a meaningful way. He also stated a conclusion that the Chicago Bridge and Iron study is indicating that the ultimate MK I pressure capability is higher than generally assumed, and that the torus airspace is the most likely failure location. He compared the IDCOR and NUREG-1150 efforts, including the conclusions from both that modifications were not justified. He concluded with a summary that indicated the NUMARC working group is studying MK I containments, that he believed sufficient technical bases exist for NUMARC to make decisions, and that cost/benefit comparisons ~~will be~~ will be made of potential modifications. He indicated studies to date have shown no modifications to be beneficial.

E. Burns, Delian Corp., discussed the responses to questions 1 and 2 (Enclosure 3, pg-10). He indicated there were four or five PRA's for MK I plants available that indicate no specific accident type dominate for all MK I's. He, therefore, concluded that the spectrum of potential sequences was important. He also concluded that there was no mechanistic coupling of containment failure to inducing coremelt. (See Enclosure 5)

R. Henry, FAI, discussed the responses to questions 3 through 10 (Enclosure 3, p 11-20). The conclusions presented were in large measure based upon evaluations of heat transfer in which the containment shell was not postulated to fail by perforation (Enclosure 4). This evaluation was noted as significantly different from those of the NRC staff and contractors. The significant points of his analysis are: 1) 12 Cm debris bed depth, 2) water above the debris bed acts as a heat sink with nucleate boiling at the Shell surface, 3) concrete below acts as a heat sink, and 4) debris bed assumed to be near the melt temperature. His other main points were:

(Q4) high pressure melts have no significant effect on core melt progression, but the distribution of material in the containment is influenced;

(Q5) there are no significant differences between BWRs and PWRs in meltdown or melt through times;

(Q6) the debris properties of a "core-on-the-floor" are different, but the behavior is not. BWR's would have more metal with less oxidation. (Note that predicted behavior is in large measure a function of heat transfer modeling - see above);

(Q7) water on the drywell floor is beneficial, but requires replenishment. (Note again that the IDCOR heat transfer assumption results in no prediction of steel containment or downcomer melt through);

(Q8) drywell spray would reduce containment challenge, sufficient water to remove decay heat would be adequate, and sprays can help remove airborne fission products. Spray rates in the range of 500 - 1500 gpm appear adequate. Enclosure 4 was again referred to for a discussion of heat transfer and related conduction. It was noted that the IDCOR heat transfer methodology was included in submittals to the staff, but little feedback had resulted;

(Q9) a debris barrier would not be useful, and could result in negative effects; and

(Q10) a debris barrier to contain debris in the pedestal area under the vessel was not considered useful.

R. Dexerich discussed Q 11. He indicated no analysis was made of the gap between the ~~containment~~ drywell and the biological shield. However, if the ~~containment~~ drywell were breached in the biological shield, some fission products ~~would get into other buildings~~ might be trapped in the gap on the pathway to the reactor building through penetrations. (See Enclosure 3, pg 21)

E. Burns discussed venting (Q 12). He indicated venting was a means of preventing uncontrolled releases and establishing a heat removal path as a last resort. Further, venting can be used to prevent coremelts in such sequences as TW. However, he indicated large costs were not justified generally, but plant specific analyses may indicate differently. (See Enclosure 3, p 22)

R. Dieterich discussed noble gas venting (Q 13). He indicated such venting as a last resort can reduce the impacts of some sequences, but that negative effects must be considered. (See Enclosure 3, p 23) He presented a backup slide which showed substantial reduction in dose if ~~venting~~ RELEASE of nobel gases is delayed.

R. Henry discussed the use of containment sprays for station blackout sequences in response to Q 14. He indicated several benefits (debris cooling, delay of containment failure, and fission product removal), but eventually containment heat removal is required. (See Enclosure 3, pg 24). He also discussed debris coolability referring to pages 25-35 of Enclosure 3 using inferences from TMI, experimental evidence and analytical assessments. Analogies were also made to debris coolability in coal fired power plants and experience in the steel industry with electric furnaces by several participants.

R. Dieterich discussed Q 15 (See Enclosure 3, p 25). He indicated that the NUMARC evaluation is not complete, but that to date no cost beneficial modifications has been identified.

R. Bernero asked whether modifications such as a more reliable ADS system could help. R. Henry indicated he did not consider such modifications cost beneficial.

The issue of steel shell perforation was again raised. R. Henry again summarized the IDCOR view that the carbon steel and heat transfer capabilities precluded such as occurrence.

V. Boyer concluded by indicating the NUMARC working group report was expected in mid-May, followed by a review by a supervising technical committee. He indicated no firm dates had been established for briefing the Commission or the staff.

L. G. Hulman, Chief
Plant Systems Branch
Division of BWR Licensing

Enclosures:
As stated

cc w/enclosures:
H. Denton
T. Murley
E. Beckjord
T. Speis
D. Ross
R. Bernero

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

Upton, Long Island, New York 11973

Department of Nuclear Energy

(516) 282
FTS 666 2296

April 13, 1987

Mr. L. G. Hulman
N-007
Severe Accident Issues Branch
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Jerry:

Here is the assessment we did concerning the IDCOR-IPE methodology for BWR's as reported in FAI-86/1. Specifically, this part of the assessment examined the Mark I steel liner response to contact with core debris. Let me remind you that this is somewhat "anonymous" due to the administrative turf battles I alluded to over the phone.

Should you need any follow-up action or wish to discuss this, please give ma a call (FTS-666-2296).

Sincerely,

G. A. Greene
Experimental Modeling Group

kb
Enc.

Thermal Response of Mark I BWR Steel Containment Shell When Contacted by Core Debris During Severe Accident Conditions

It is the stated objective of the IDCOR-IPE program and the NRC Severe Accident Policy Statement to ascertain if there are any potential risk outliers with respect to core-melt frequency or unusual containment vulnerabilities. One such containment vulnerability has been identified for the Mark I BWR containment steel liner, and an analysis of the potential for liner melt-through has been published [1]. Primarily on the basis of Reference 1, the failure of the Mark I liner when contacted by core debris following vessel failure was included by the SARRP program in the NUREG-1150 source term analyses [2]. An average of the eight SARRP analysts' estimates of liner failure probability upon contact with core debris is shown below.

Postulated Accident Conditions	Probability of Liner Failure
High pressure vessel failure	83%
Low pressure vessel failure, dry floor	76%
Low pressure vessel failure, wet floor	61%

The IDCOR analysis in the draft report "Approximate Source Term Methodology for Boiling Water Reactors (FAI/86-1)" [3] recognized this potential containment failure mode and reexamined the liner vulnerability or survivability in a separate analysis. In what was characterized to be a "conservative" analysis, the report indicated that the steel containment liner would not fail under any of the postulated conditions. This conclusion is in disagreement with the analyses presented in Reference 1, as well as with the containment event tree issues in SARRP for the Mark I containment analyses. As such, the models and assumptions inherent in the IDCOR analyses will be assessed.

The IDCOR analysis of the behavior of the Mark I containment shell was based upon numerous assumptions and judgements. It is on the basis of these assumptions and judgements that the initial and boundary conditions, physical properties, and phenomenological models were developed. Those assumptions that could be identified from the text in Reference 3 are discussed below:

IDCOR Model Assumptions

(a) The core debris that escapes the pedestal region of the drywell is assumed to be in a thin layer 6-12 cm deep and to be, by definition, solidified [4]. This debris, for the purpose of the analysis in Reference 3, is assumed to consist only of uranium oxide fuel.

(b) Heat transfer within the core debris is assumed to be by conduction only. There is no allowance for internal convective processes.

(c) Heat generation within the core debris is by decay power heating. There are no provisions for the chemical energy source resulting from metal-gas phase reactions between concrete decomposition gases and metallic core debris.

(d) A pool of water overlying the core debris is assumed to boil at the critical heat flux. The film boiling regime is not modeled.

(e) The steel liner is modeled to transfer heat from its outer surface by thermal radiation to the surrounding concrete shield wall as well as by convection to the gas in the gap. Both the concrete shield wall and the gas in the gap appear to be heat sinks at a constant low temperature. All emissivities are apparently equal to 1.

(f) The area of the steel liner that is in contact with the overlying water pool is assumed to transfer heat to the water at a rate specified by an arbitrary heat transfer coefficient, h_w.

(g) The core debris, consisting of UO_2, is assumed to be at a temperature of only 1800 C and only 12 cm deep. An unspecified "protective layer on the inner steel shell surface" is postulated.

(h) The core debris transfers heat to underlying concrete by conduction. However, the basemat concrete is not allowed to outgas (i.e., dehydrate and decarboxylate) or to ablate. This prevents concrete decomposition gases from entering the debris from below and rules out convective heat transfer and exothermic chemical reactions from occurring in the melt.

There may be other fundamental assumptions inherent in the model for liner response when contacted by core debris. However, assumptions (a) - (h) were those that could be readily identified from Reference 3. Nevertheless, these eight categories of assumptions appear to form the basis for the IDCOR approach to the problem; each will be addressed in the following discussion and compared to representative NRC positions or assumptions.

Discussion of IDCOR Assumptions

IDCOR assumption (a) assumes that the debris is solidified, and consists of UO_2 fuel only. Since the debris is assumed to be pure UO_2, its thermal conductivity is only 3 W/mK. However, IDCOR's own core-concrete interaction model, DECOMP, does not agree with these conditions. DECOMP assumes that the ex-vessel debris is a homogeneous mixture of oxide and metallic core debris phases, not just oxide fuel. This results in a debris pool with a lower melting temperature that can sometimes be molten, a more fluid pool of debris, and a higher debris thermal conductivity, in the range of 10-20 W/mK. NRC analyses rely upon the CORCON code. These analyses allow the debris to be molten or solid, depending upon the calculated conditions, not only assumption. The molten oxide and metallic phases solidify in a mechanistic framework in a manner consistent with prevailing thermal hydraulic conditions in the melt and the boundary conditions experienced by the melt. These analyses show that the liner may be contacted by a deeper pool of core debris ($\geq$ 25 cm) than assumed by Reference 3. Also, this pool can be molten and have a considerable quantity of molten metal phase present, with a thermal conductivity as great as 47 W/mK.

IDCOR assumption (b) assumes categorically that the UO_2 core debris is a solidified mass. This precludes internal convective processes from transferring heat to boundaries, especially to the basemat concrete and the steel liner. In deeper pools, this has been shown not to be the case, and both NRC and EPRI presently have reactor materials experimental programs in progress to examine the molten stage of debris-concrete interactions.

IDCOR assumption (c) allows for internal heat generation in the solidified fuel by decay heating only. However, reactor materials experiments and code analyses have shown that, especially for BWR cases which may have a large inventory of unoxidized Zr in the melt, the internal heat source due to metal-gas phase chemical reactions will in general exceed the decay heat generation by a large margin, in most cases representing the driving heat source for the aggressive melt-concrete interaction stage.

IDCOR assumption (d) considers a pool of water over the debris, boiling at the critical heat flux. At the temperature specified for the debris, 2100 K, clearly this boiling regime would most appropriately be represented by film boiling. For most cases of interest in the NUREG-1150 analyses there would be no water present since containment sprays are assumed to not be available. The availability of fire sprays must be evaluated on a plant-specific basis.

IDCOR assumption (e) models heat transfer from the outer surface of the liner by radiation to the concrete shield wall and by convection to the gas in the narrow gap. The concrete and gas appear to be isothermal heat sinks at 350-400 K and the emissivities representative of blackbody radiation. However, the gap between the liner and concrete shield wall, at least for the Browns Ferry Nuclear Power Station analyses reported in Refetence 1, is not empty but full of fibreglass and polyester foam. Over the time intervals reported in Reference 1 for liner failure, this would be sufficient to insure an adiabatic boundary condition on the outside surface of the liner, not a radiation-convection boundary condition.

IDCOR assumption (f) assumes that an overlying pool of water exists over the core debris and that it cools the exposed surface of the liner with an effective heat transfer coefficient h_w. In most Mark I BWR drywells, the downcomer vents to the torus are only one foot above the drywell floor. If core debris were to accumulate to this depth, the overlying water pool would simply overflow into the suppression pool. This would prevent the water heat rejection mechanisms proposed, both for the liner and melt (debris) surface, and expose the liner to direct radiant heat transfer from the high temperature debris.

IDCOR assumption (g) proposes a debris temperature of 1800 C and a debris depth of, at most, 12 cm. For similar low temperature cases studied in Reference 1, the steel liner was sometimes calculated to survive melt-through. However, the steel was calculated to be at a high enough temperature so as to have greatly reduced mechanical strength, and failure by mechanical deformation would be likely. Furthermore, a simple examination of the ex-vessel debris inventories calculated in recent studies such as BMI-2104, NUREG-1079, NUREG-0956, and NUREG-1150 indicate that debris depths (assuming uniform spreading over the entire drywell floor to minimize the depth) may exceed one foot.

Finally, IDCOR assumption (h) allows for heat transfer to underlying drywell concrete from the core debris by conduction only. By assumption, the concrete is not allowed to decompose or ablate. This is in spite of the fact that concrete needs only to be heated to 100 C to start boiling the free water in the aggregate matrix. By not accounting for debris-concrete interactions, the gases (H_2O, CO_2) which would bubble up through the debris and react with metallic species (if there were any) are eliminated, thus precluding the possibility of exothermic chemical reactions in the melt.

Other issues that may be imbedded in the IDCOR assumptions in Reference 3 but were not apparent to this assessment are the concepts that (1) water overlying molten core debris quenches that debris and (2) water on the floor presents an obstacle to the migration of high temperature melts across the floor. Data from ongoing experimental programs at SNL and BNL exist which contradict these concepts. Instead it is found that water overlying melts engages in film boiling and that melts flow through or under water obstacles as long as the debris is molten. Neither of these two concepts presents a convincing case to argue that core debris cannot flow to the containment liner and still be molten.

It is clear that there are major differences between the assumptions in the IDCOR analyses [3] and the NRC analyses [1] for the Mark I BWR containment liner response to contact with core debris. The IDCOR analyses pertain only to a limited, optimistic set of assumed accident conditions and are not generally applicable to a wide range of accident conditions such as those addressed by NRC in Reference 2. The IDCOR analyses specifically are not applicable under the conditions that (1) the debris pool is hot, molten, and deep, (2) the debris has a significant metallic component, (3) the debris is attacking the drywell basemat concrete, and (4) there are exothermic chemical reactions in the melt. In addition, some of the IDCOR models are suspect and should be reevaluated. In particular, (5) the heat transfer from the outer surface of the steel liner, (6) the existence of an overlying pool of water over the debris when containment sprays are not available, and (7) the mode of boiling of an overlying pool of water when water is available. Finally, some of IDCOR assumptions with respect to physical properties should be assessed, specifically (8) radiative emissivities of steel, core debris, and concrete, and (9) the debris thermal conductivity.

References

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2. Reactor Risk Reference Document, NUREG-1150, Draft for Comment (February 1987).

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