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

July 28, 1988

Project No. 675

50-470

APPLICANT: Combustion Engineering, Inc.

FACILITY: CESSAR-DC, System 80+ Design

SUBJECT: SUMMARY OF MEETING WITH COMBUSTION ENGINEERING/IT CORP. TO DISCUSS ARSAP TOPIC PAPERS SET NO. 1 AND SET NO. 2

INTRODUCTION

A meeting of the staff with representatives of Combustion Engineering (CE) and International Technology (IT) Corporation was held a the NRC offices in Rockville, Maryland, on June 21, 1988. The purpose o the meeting was to discuss the staff's comments on the ARSAP Topic Papers, Set No. 1, and to review and discuss the issues of ARSAP Topic Papers, Set No. 2. ARSAP Topic Papers, Set No. 2, were submitted by letters dated June 6 and 17, 1988. Enclosure 1 provides the list of attendees to the meeting. Enclosure 2 provides the agenda for the meeting. Enclosure 3 provides the viewgraphs which IT Corporation used during their presentation. Enclosure 4 provides our Review Status Report on the ARSAP Topic Papers. This report identifies reviewers and tentative review schedules.

DISCUSSION

CE indicated that the development of ARSAP Topic Papers are closely coordinated with the EPRI ALWR Requirements Document effort. The ARSAP Topic Papers are on the CESSAR-DC, System 80+ docket but are handled in a generic scene. However, there are no BWR issues involved in the ARSAP Topic Papers.

There was another concern about the concept of resolution. CE would want the resolution to be an agreement. For any particular issues, they would like an agreement on the assumptions presented. If there could be no agreement, they would like guidance on reaching an agreement.

Th e was another concern about where the review effort to the ARSAP topic ers fits in the priority scheme of NRR. The review of ARSAP topic papers e category 2 in a priority scheme of 4 of the review effort within NRR.

It was noted that the topic papers do make reference to the use of the industry's MAAP code. The staff is troubled by the use of the MAAP code since it has not been reviewed and accepted. The MAAP code is a changing code and the staff does not know in detail what is in the code. The industry response was to invite questions concerning the MAAP code where ever there was a concern in a particular application. The staff requested a brief summary of what the MAAP code is and what it will do.

The staff emphasized that the resolution of these issues should ultimately be in the designs. The designs should be such that the issues can be accommodated,

DF01
1/1

such that the issues will not be applicable or so conservative that the issues would be insignificant.

General comments on each of the topic papers of Set No. 1 follow:

1. Fission Product Release Prior to Vessel Failure - IDCOR Issue 1.

This issue was considered as to be resolved.

2. Reactor Coolant System Natural Circulation - IDCOR Issue 2.

The proposed resolution of this issue is through design for depressurization. The staff considered depressurization to be acceptable provided it can be shown that it works. If the industry is dependent upon the MAAP code to justify the acceptance of the resolution, the staff could not accept it. The NRC does not have the complete MAAP code. Also, from what is known about the MAAP code, the MAAP code does not have the capability to handle the dynamics of the transient. The staff suggested the use of NRC approved codes.

3. Release Model for Control Rod Materials - IDCOR Issue 3.

Since the agreed-upon resolution there has been new data. The staff must look at this new data.

4. Fission Product and Aerosol Deposition in RCS and Containment - IDCOR Issues 4 and 12.

In order to continue our review on this issue, we need Reference 10, (P. G. Ellison and M. Epstein, "Nuclear Fission Product Aerosol Transport and Deposition", which is soon to be published).

5. In-vessel Steam Explosion and Alpha Mode of Containment Failure - IDCOR Issue 7.

The staff agrees that this issue is resolved.

6. Ex-vessel Fission Product Release - IDCOR Issue 9 and Ex-vessel Heat Transfer Models from Molten Core to Containment - IDCOR Issue 10.

This issue is not resolved within NRC or the industry. The staff has no difficulty with the proposed model. The problem is in the great uncertainties of the inputs. There is no agreement on what happens when the core hits the concrete. The importance of concrete was not adequately flagged in the early days. The fission product release, flow rate and coolability must be analyzed. Heat Transfer models vary by a factor of 5 to 6.

7. Revaporization of Fission Products - IDCOR Issue 11.

Indicate the method of analysis to be used and provide more detail concerning the analysis.

8. Modeling of Emergency Response - IDCOR Issue 14

The staff agrees with the industry resolution.

9. Secondary Containment Performance - IDCOR Issue 16.

For the application of resolution of this issue to the System 80+ design provide the following information:

A. Provide qualifications of ARSAP relevant to NRC reliance on ARSAP evaluation and conclusion that the NRC/IDCOR issue identified is valid for ALWRs.

B. Provide the basis and rational for the ARSAP conclusions.

C. Provide the basis and rational for the CE conclusions regarding the applicability of the identified NRC/IDCOR resolution to the System 80+ design.

D. Describe the extent and depth of the CESSAR 80+ system commitment to the NRC/IDCOR resolution, including the scope of applicability among the System 80+ safety systems.

IT Corporation presented the ARSAP Topic Papers, Set No. 2, as provided in Enclosure 3. For IDCOR Issue 5, In-Vessel Hydrogen Generation, the staff indicated that the industry interpretation of the modeling of the PBF-SFD experiment design is not acceptable to the staff. The NRC does not confirm that the maximum hydrogen produced is that produced by 75% of the active core zirconium oxidizing. Experiments to date do not confirm this. For IDCOR Issue 8, Direct Containment Heating, the staff indicated that we will have significant comments. For IDCOR Issue 17, Hydrogen Ignition and Burning, the staff indicated that recent data indicates that the minimum hydrogen concentration of 13% by volume for detonation may not be proper. The data, Enclosure 5, indicates that the minimum concentration for hydrogen detonation should be 9.5% by volume at higher temperatures. For containment design, the lower minimum concentration would be more applicable.

CE suggested that we have meetings like this meeting for each submittal of topic papers. It is CE's goal to submit topic papers for staff review at monthly intervals until all topic papers are submitted. The staff's goal is to provide draft SERs or letters of agreement, as appropriate, according to the schedule of Enclosure 4.

Guy S. Vissing

Guy S. Vissing, Project Manager
Standardization and Non-Power
Reactor Project Directorate
Division of Reactor Projects - III, IV,
V and Special Projects

Enclosure:
As stated

8. Modeling of Emergency Response - IDCOR Issue 14

The staff agrees with the industry resolution.

9. Secondary Containment Performance - IDCOR Issue 16.

For the application of resolution of this issue to the System 80+ design provide the following information:

A. Provide qualifications of ARSAP relevant to NRC reliance on ARSAP evaluation and conclusion that the NRC/IDCOR issue identified is valid for ALWRs.

B. Provide the basis and rational for the ARSAP conclusions.

C. Provide the basis and rational for the CE conclusions regarding the applicability of the identified NRC/IDCOR resolution to the System 80+ design.

D. Describe the extent and depth of the CESSAR 80+ system commitment to the NRC/IDCOR resolution, including the scope of applicability among the System 80+ safety systems.

IT Corporation presented the ARSAP Topic Papers, Set No. 2, as provided in Enclosure 3. For IDCOR Issue 5, In-Vessel Hydrogen Generation, the staff indicated that the industry interpretation of the modeling of the PBF-SFD experiment design is not acceptable to the staff. The NRC does not confirm that the maximum hydrogen produced is that produced by 75% of the active core zirconium oxidizing. Experiments to date do not confirm this. For IDCOR Issue 8, Direct Containment Heating, the staff indicated that we will have significant comments. For IDCOR Issue 17, Hydrogen Ignition and Burning, the staff indicated that recent data indicates that the minimum hydrogen concentration of 13% by volume for detonation may not be proper. The data, Enclosure 5, indicates that the minimum concentration for hydrogen detonation should be 9.5% by volume at higher temperatures. For containment design, the lower minimum concentration would be more applicable.

CE suggested that we have meetings like this meeting for each submittal of topic papers. It is CE's goal to submit topic papers for staff review at monthly intervals until all topic papers are submitted. The staff's goal is to provide draft SERs or letters of agreement, as appropriate, according to the schedule of Enclosure 4.

original signed by

Guy S. Vissing, Project Manager
Standardization and Non-Power
Reactor Project Directorate
Division of Reactor Projects - III, IV,
V and Special Projects

Enclosure:
As stated

PDSNP	PDSNP	AD:PDSNP
EHylton	GVissing:cw	CMiller
07/28/88	07/25/88	07/28/88

Enclosure 1

C. E. SYSTEMS 80+
MEETING - JUNE 21, 1988

NAME	ORGANIZATION	PHONE NO.
Charles Ferrell	SAIB/RES/NRC	301-492-3978
Tony Buhl	IT Corp/ARSAP	615-481-3300
Stephen Additon	IT Corp/ARSAP	202-463-0550
Robert E. Henry	FAI/ARSAP	312-323-8750
Bob Capp	EG&G Idaho/ARSAP	208-526-1715
Chang Park	BNL	FTS 666-2788
John Lehner	BNL	516-282-3921
Len Soffer	NRC/RES	301-492-3916
Robert J. Hammersley	FAI/ARSAP	312-323-8750
George A. Davis	Combustion Engineering	203-285-5207
Stan Ritterbusch	Combustion Engineering	203-285-5206
Mario Fontana	IT/ARSAP	615-481-3300
Guy S. Vissing	NRR/PDSNP	301-492-1101
Thomas J. Walker	RES/AEB	301-492-3908
James T. Han	NRC/RES/AEB	301-492-3939
Brad Burson	NRC/RES/AEB	301-492-3909
J. H. Raval	NRR/SPLB	301-492-0857
E. S. Chelliah	RES/PRAB	301-492-3948
R. Van Houten	NRC/RES/AEB	301-492-3936
R. W. Houston	NRC/RES/DRAA	301-492-3900
Mark W. Crump	Combustion Engineering	203-285-4537
Brad Hardin	NRC/RES/DRA	301-492-3733
Pat Worthington	NRC/RES/AEB	301-492-3911
Bob Wright	NRC/RES/AEB	301-492-3906

NRC/C-E/ARSAP MEETING ON SEVERE ACCIDENT ISSUES

TOPIC SETS 1 AND 2

White Flint, Md
(Nicholson Lane South, Room 14)

June 21, 1988

10:00	Introduction	S. E. Ritterbusch
10:05	Review of NRC Questions and Comments on Topic Set 1	G. S. Vissing
	o Fission Product Release	NRC Staff
	o Release of Control Rod Material	
	o In-Vessel Steam Explosion	
	o Ex-Vessel Heat Transfer	
	o Emergency Responses	
	o Secondary Containment	
	o RCS Natural Circulation	
	o Fission Product Release	
	o Revaporization	
11:30	Lunch	

12:00	Summary of Topic Set 2 o Hydrogen Generation o Core Melt Progression o Containment Heating o Containment Performance o Hydrogen Ignition o Debris Coolability	ARSAP
1:30	Summary of Program for Submittal of Remaining Topic Sets	ARSAP
1:45	Summary of Program for Reviews of Remaining Topic Sets	NRC Staff
2:00	Closing	S. E. Ritterbusch

NRC-ARSAP MTG. JUNE 21, 1988

R.J. HAMMERSLEY

2.1 IN-VESSEL HYDROGEN GENERATION (IDCOR ISSUE 5) ISSUE DEFINITION

CONTAINMENT PRESSURIZATION FROM HYDROGEN COMBUSTION IS A MAJOR CONCERN IN SEVERE ACCIDENT RISK ASSESSMENT

- CONTAINMENT IS DESIGNED FOR DESIGN BASIS EVENTS, BUT EVALUATED FOR MARGINS TO FAILURE UNDER SEVERE ACCIDENT CONDITIONS

- MELT PROGRESSION PHENOMENA GOVERN THE AMOUNT OF HYDROGEN GENERATED

- THE CONTAINMENT FREE VOLUME AND THE AMOUNT OF HYDROGEN GENERATED AS WELL AS THE MASS OF STEAM IN THE ATMOSPHERE GOVERN BOTH THE POTENTIAL FOR DEFLAGRATION OR DETONATION AND THE CAPABILITY TO TOLERATE COMBUSTION

2.1 IN-VESSEL HYDROGEN GENERATION HISTORIC PERSPECTIVE (IDCOR)

IDCOR EFFORTS FOCUSED ON THE DEVELOPMENT OF MAAP MODELS, BENCHMARKED AGAINST HYDROGEN GENERATION EXPERIMENTS PROTOTYPIC OF REACTOR CONDITIONS

- o PRINCIPAL BENCHMARKS ARE LOFT LP-FP-2 AND TMI-2; BOTH ARE CONSISTENT WITH A DECREASING POTENTIAL FOR OXIDATION DUE TO RELOCATED MATERIAL

- o PBF-SFD HAS ALSO BEEN MODELLED, THOUGH THE EXPERIMENT DESIGN APPEARS TO PRECLUDE THE INFLUENCE OF RELOCATED MATERIAL EXPECTED FOR REACTOR CONDITIONS

- o INITIAL TMI-2 ANALYSES USED MAAP 2.0, BUT UPDATED ANALYSES WITH MAAP 3.0B ARE CURRENTLY UNDERWAY

- o ALL OF THE ABOVE CONFIRM MAXIMUM HYDROGEN GENERATION BELOW AN AMOUNT EQUIVALENT TO THAT PRODUCED BY 75% OF THE ACTIVE CORE ZIRCONIUM OXIDIZING

2.1 IN-VESSEL HYDROGEN GENERATION HISTORICAL PERSPECTIVE (NRC)

NRC HAS CONDUCTED MAJOR EXPERIMENTS AND ANALYTICAL PROGRAMS TO ADDRESS THIS ISSUE

- o EXPERIMENTS INCLUDE PBF-SFD, ACRR, NRU, AND LOFT-FP-2
- o ANALYSES HAVE BEEN PERFORMED WITH MARCH 2.0, MARCH 3.0 IN THE SOURCE TERM CODE PACKAGE, SCDAP, AND MELPROG
- o ONE SENSITIVITY STUDY DEMONSTRATED TWICE THE AMOUNT OF HYDROGEN GENERATED (I.E. 60% EQUIVALENT VS. 31%) WITH MELT RELOCATION DELAYED TO 2500·K FROM 2200·K
- o THE NRC POSITION, BASED ON UNCERTAINTIES IN THE MELT PROGRESSION PHENOMENA, WAS THAT A RANGE OF HYDROGEN PRODUCTION ESTIMATES, EXTENDING TO AMOUNTS SIGNIFICANTLY GREATER THAN PREDICTED BY MAAP, SHOULD BE CONSIDERED IN BOUNDING SEVERE ACCIDENT RISK

2.1 IN-VESSEL HYDROGEN GENERATION APPROACH TO RESOLUTION

1. ENSURE THAT THE CONTAINMENT IS DESIGNED TO WITHSTAND A BURN OF HYDROGEN IN THE AMOUNT PRODUCED BY OXIDATION OF 75% OF THE ZIRCONIUM CLADDING IN THE ACTIVE CORE (EPRI REQUIREMENTS DOCUMENT)

2. PROVIDE TECHNICAL JUSTIFICATION THAT THE AMOUNT OF HYDROGEN GENERATED BY OXIDATION OF 75% OF THE ZIRCONIUM CLADDING IN THE ACTIVE CORE IS A SUITABLE UPPER BOUND FOR THE ADVANCED PWR CONTAINMENT CAPABILITY

   - ADDRESS THE CURRENT LICENSING BASIS

   - ADDRESS THE AVAILABLE EXPERIMENTAL DATA, INCLUDING NRC TESTS

   - ADDRESS THE RESULTS OF ANALYSES WITH NRC CODES

   - PERFORM MAAP ANALYSES, WITH AND WITHOUT THE INFLUENCE OF CORE DEFORMATION, USING UPDATED MODELS BELOW

2.1 <u>IN-VESSEL HYDROGEN GENERATION APPROACH TO RESOLUTION</u> (CONTINUED)

3. IMPLEMENT MAAP IMPROVEMENTS TO MODEL MOLTEN ZIRCALOY-FUEL EUTECTIC FORMATION, RELOCATION, AND REFREEZING; INCLUDE THE EFFECTS OF RELOCATED MASS ACCUMULATION ON COOLANT CHANNEL GEOMETRY

2.2 CORE MELT PROGRESSION AND VESSEL FAILURE (IDCOR ISSUE 6) ISSUE DEFINITION

COMPLEX CORE MELT PROGRESSION PHENOMENA DETERMINE THE STATE OF THE REACTOR IN A SEVERE ACCIDENT, THE STATE OF CORE DEBRIS AT VESSEL FAILURE, EARLY CHALLENGES TO CONTAINMENT INTEGRITY, AND THE STATE OF MANY FISSION PRODUCTS

- UNCERTAIN PHENOMENA INCLUDE RELOCATION OF MOLTEN MATERIAL (BOTH THRESHOLD AND MECHANISMS), CRUST AND RUBBLE BED FORMATIONS, THERMAL ATTACK ON STRUCTURES AND DEBRIS, DEBRIS-COOLANT INTERACTIONS IN THE LOWER PLENUM, AND REACTOR VESSEL FAILURE

- THE REACTOR VESSEL FAILURE MODE (INCLUDING TIMING, LOCATION, SIZE AND PRESSURE) AND THE CORRESPONDING COMPOSITION, AMOUNT, AND TEMPERATURE OF RELEASED CORE DEBRIS DETERMINE CONTAINMENT CHALLENGES THROUGH DIRECT CONTAINMENT HEATING (TOPIC 2.3), OXIDATION OF RELEASED MATERIALS, THE INITIATION OF CORE-CONCRETE INTERACTIONS, AND THE RELATED COOLABILITY OF THE DEBRIS (TOPIC 2.6)

2.2 CORE MELT PROGRESSION AND VESSEL FAILURE HISTORICAL PERSPECTIVE

IDCOR DEVELOPED CORE MELT PROGRESSION MODELS IN MAAP 3.0, INCLUDING:

- o CANDLE-LIKE RELOCATION OF MOLTEN MATERIAL AND FORMATION OF BLOCKAGE

- o ACCUMULATION OF MOLTEN MATERIAL TRIGGERING SUDDEN LOWER PLENUM ENTRY AND THERMAL ATTACK ON THE VESSEL LOWER HEAD

- o WELD FAILURE, INSTRUMENT TUBE EXPULSION (AT HIGH PRESSURE), STEEL ABLATION, AND COMPLETE BLOWDOWN WITHIN 4-80 SECONDS

NRC APPROACHES INVOLVED DIFFERENCES

- o THE NRC POSITION WAS THAT RELEASES OF LARGER AMOUNTS OF DEBRIS (THAN IDCOR PREDICTED) WITH VARYING STEEL COMPOSITION SHOULD BE TREATED PARAMETRICALLY IN SEVERE ACCIDENT ANALYSES

2.2 CORE MELT PROGRESSION AND VESSEL FAILURE APPROACH TO RESOLUTION

1. DEVELOP MORE MECHANISTIC MAAP MELT PROGRESSION MODELS INCLUDING EUTECTIC FORMATION, A THRESHOLD BREAKOUT TEMPERATURE, EUTECTIC FLOW AND HEAT TRANSFER, MOLTEN CORE DEBRIS BEHAVIOR, AND ATTACK ON THE LOWER CRUST

2. PERFORM SENSITIVITY STUDIES OF DEBRIS BEHAVIOR IN THE LOWER PLENUM WITH AN OPERATIONAL SAFETY DEPRESSURIZATION SYSTEM TO CONFIRM DEPRESSURIZATION PRIOR TO VESSEL FAILURE AT A PENETRATION

3. PERFORM SENSITIVITY STUDIES OF IMPORTANT PARAMETERS IN THE NEW MODELS TO CONFIRM THAT CORE MELT PROGRESSION UNCERTAINTIES DO NOT SIGNIFICANTLY AFFECT THE SEVERE ACCIDENT PERFORMANCE OF AN ALWR CONTAINMENT

2.3 DIRECT CONTAINMENT HEATING (IDCOR ISSUE 8) ISSUE DEFINITION

POTENTIAL FOR CONTAINMENT PRESSURIZATION FOLLOWING HIGH PRESSURE DISCHARGE OF FINELY FRAGMENTED CORE DEBRIS FROM THE REACTOR VESSEL DUE TO:

- RAPID HEAT TRANSFER FROM DEBRIS TO ATMOSPHERE
- OXIDATION OF UNREACTED METALLIC MATERIALS PRODUCING HYDROGEN AND ADDITIONAL HEATING
- POTENTIAL HYDROGEN COMBUSTION
- RAPID STEAM GENERATION FROM WATER IN CAVITY AIDING TRANSPORT OF CORE DEBRIS, HYDROGEN, AND ENERGY TO THE UPPER CONTAINMENT VOLUME

2.3 DIRECT CONTAINMENT HEATING HISTORICAL PERSPECTIVE

IDCOR CONCLUDED THAT MOST CURRENT PWR CAVITY CONFIGURATIONS MAKE DCH CONTRIBUTION TO CONTAINMENT PRESSURIZATION SMALL

- CAVITY GEOMETRY AND ASSOCIATED STRUCTURES ARE SIGNIFICANT
- "BUILDING BLOCK" SIMULANT MATERIAL TESTS DEMONSTRATED RETENTION EFFECTS
- BOUNDING ANALYSES FOR SEVEN METRIC TONS OF DEBRIS INTO CONTAINMENT WERE ACCEPTABLE FOR LARGE DRY PWR DESIGN (12 PSI PRESSURE RISE)

NRC REQUIRED SENSITIVITY ANALYSES FOR AN UNCERTAINTY RANGE BETWEEN IDCOR POSITION AND THAT OF THEIR OWN CONTAINMENT LOADING WORKING GROUP (CLWG)

- SANDIA EXPERIMENTS DEMONSTRATED POTENTIALLY LARGER EFFECTS FOR SIMPLIFIED GEOMETRIES
- EFFECTS OF WATER NOT INCLUDED IN NRC EXPERIMENTS AT THAT TIME

2.3 DIRECT CONTAINMENT HEATING HISTORICAL PERSPECTIVE (CONTINUED)

- EXPERIMENTS ONGOING AT SURTSEY AND BROOKHAVEN
- RECENT SANDIA CALCULATIONS WITH CONTAIN INDICATE THE POTENTIAL FOR SIGNIFICANT ADDITIONAL HYDROGEN GENERATION WHEN WATER IS PRESENT

2.3 DIRECT CONTAINMENT HEATING APPROACH TO RESOLUTION

1. ADDRESS THE ISSUE WITH DESIGN FEATURES INCLUDING A CAVITY CONFIGURATION THAT LIMITS DEBRIS DISPERSAL (EPRI REQUIREMENTS DOCUMENT, CHAPTER 5)

   - DESIGNS INCLUDE CAPABILITY FOR PRIMARY SYSTEM DEPRESSURIZATION UNDER SEVERE ACCIDENT CONDITIONS.

   - DISPLACED CAVITY EXIT AREA TO SEPARATE DEBRIS FROM THE GAS

   - CAVITY COLLECTION VOLUME OF TWICE THE CORE VOLUME

2. SENSITIVITY ANALYSES OVER REASONABLE RANGES IN PRA ADDRESSING DEBRIS MASS, HYDROGEN GENERATION, AND EFFECTS OF PRESENCE OF WATER

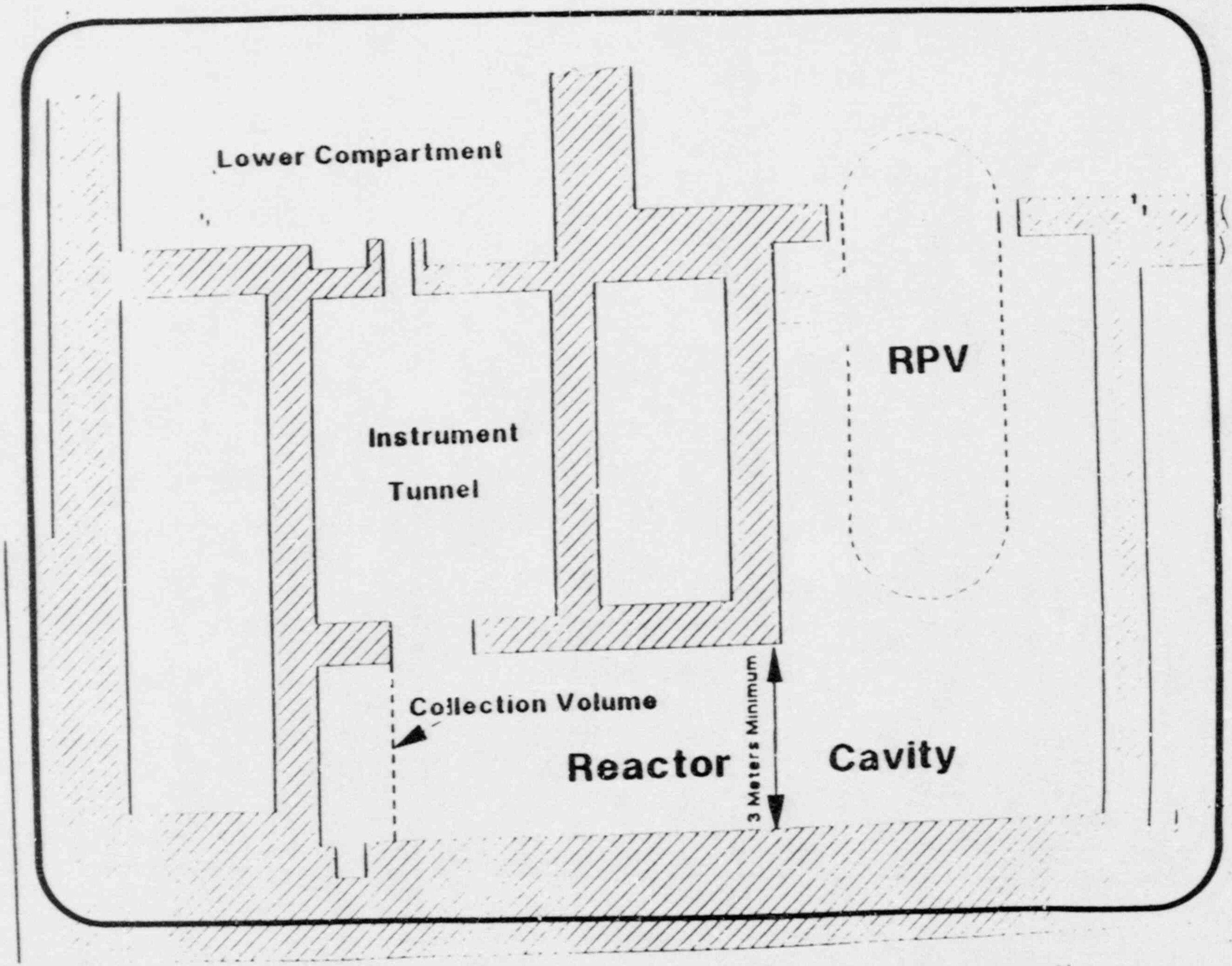

Figure 1. Millstone 3 type lower reactor cavity configuration

2.4 CONTAINMENT PERFORMANCE (IDCOR ISSUE 15) ISSUE DEFINITION

SEVERE ACCIDENT ASSESSMENT OF CONTAINMENT PERFORMANCE INVOLVES THE POTENTIAL FOR CONTAINMENT FAILURE DUE TO:

- OVERTEMPERATURE (NOT SIGNIFICANT FOR A PWR, GIVEN THAT DIRECT CONTACT WITH CORE MATERIAL CAN BE PRECLUDED BY DESIGN)

- OVERPRESSURIZATION RESULTING IN GROSS RUPTURE (A LARGE FAILURE ALLOWING RAPID DEPRESSURIZATION)

- OVERPRESSURIZATION RESULTING IN LEAK-BEFORE-BREAK (INCREASING LEAKAGE UNTIL PRESSURIZATION IS TERMINATED)

2.4 CONTAINMENT PERFORMANCE HISTORICAL PERSPECTIVE

IDCOR CONSIDERED THE DOMINANT FAILURE MODE TO BE LEAK-BEFORE-BREAK

- LINER FAILURE AT PENETRATIONS PREDICTED AT HIGH CONTAINMENT STRAINS

- MAAP MODEL DEVELOPED AND BENCHMARKED TO PREDICT STRAIN FAILURE FOR CONCRETE OR STEEL CONTAINMENTS; FAILURE AT ULTIMATE STRESS ALSO MODELLED

NRC REQUIRED SENSITIVITY STUDIES FOR A SPECTRUM OF CONTAINMENT FAILURE MODES FOR VARIOUS CONTAINMENT DESIGNS

- FAILURE PRESSURE WAS PREDICTABLE FOR STEEL CONTAINMENTS, BUT LOCATION AND MODE OF FAILURE WERE UNCERTAIN; THE NRC SPECTRUM INCLUDES A THRESHOLD MODEL WITH NO LEAKAGE BEFORE FAILURES OF VARIOUS SIZES

- FAILURE MODE WAS PREDICTABLE FOR CONCRETE CONTAINMENTS, BUT FAILURE LOCATION AND PRESSURE WERE UNCERTAIN; THE NRC SPECTRUM AGAIN INCLUDED LARGE CONTAINMENT FAILURE SIZES AT THRESHOLDS BASED ON REINFORCEMENT YIELD OR PRESTRESSED TENDON STRAIN

2.4 CONTAINMENT PERFORMANCE APPROACH TO RESOLUTION

1. PERFORM DETAILED, REALISTIC ANALYSIS TO ASSESS THE POTENTIAL FOR LEAKAGE AT PENETRATIONS PRIOR TO REACHING ULTIMATE CONTAINMENT FAILURE CONDITIONS (LEAK-BEFORE-BREAK)

2. INCLUDE A SENSITIVITY ANALYSIS IN THE PRA TO ASSESS THE IMPACT OF VARIOUS CONTAINMENT LEAK SIZES AND LOCATIONS

3. DEVELOP CONTAINMENT DESIGNS THAT PREVENT DIRECT CONTACT OF CORE DEBRIS WITH THE CONTAINMENT BOUNDARY

2.5 HYDROGEN IGNITION AND BURNING (MAJOR ISSUE 17) ISSUE DEFINITION

POTENTIAL FOR EARLY CONTAINMENT FAILURE DUE TO THE TEMPERATURE AND PRESSURE LOADS IMPOSED BY HYDROGEN COMBUSTION

- GLOBAL HYDROGEN BURN CAN PRODUCE SIGNIFICANT LOADS, BUT THEY ARE LOADS THAT CAN BE ACCOMMODATED BY CONTAINMENT DESIGN

- THE MAGNITUDE AND TIMING OF HYDROGEN BURN LOADS, IF NOT ALSO PRECLUDED, MUST BE DETERMINED BY ANALYSES USING HYDROGEN COMBUSTION MODELS

2.5 HYDROGEN IGNITION AND BURNING HISTORICAL PERSPECTIVE

IDCOR'S RESPONSE TO THIS ISSUE INCLUDED:

- o BENCHMARKING OF THE IDCOR BURN MODELS (GLOBAL AND IGNITER BURNS) AGAINST A VARIETY OF EXPERIMENTAL CONFIGURATIONS
- o FLAME TEMPERATURE IGNITION CRITERION WAS CHECKED FOR CONSISTENCY WITH BURN COMPLETENESS
- o AGREED TO STANDARD PROBLEM EXERCISE. MAAP RESULTS WERE GENERATED AND SUBMITTED.

NRC'S RESPONSE TO THIS ISSUE INCLUDED:

- o COMPLETION OF ONGOING RESEARCH IN LARGE-SCALE HYDROGEN BURNS
- o AGREED TO STANDARD PROBLEM EXERCISE. HECTR PROGRAM RESULTS TO BE PROVIDED.

2.5 HYDROGEN IGNITION AND BURNING APPROACH TO RESOLUTION

1. THE ADVANCED PWR CONTAINMENT WILL BE DESIGNED IN A MANNER THAT PRECLUDES GLOBAL HYDROGEN DETONATION AND ACCOMMODATES GLOBAL BURNS, AS STIPULATED IN THE EPRI REQUIREMENTS DOCUMENT, CHAPTER 5

   - THE CONTAINMENT DESIGN WILL ENSURE THAT THE UNIFORMLY DISTRIBUTED CONCENTRATION OF HYDROGEN DOES NOT EXCEED 13% UNDER REALISTIC SEVERE ACCIDENT CONTAINMENT CONDITIONS

   - THE CONTAINMENT DESIGN WILL ENSURE EFFECTIVE MIXING SO THAT LOCAL DETONATIONS ARE UNLIKELY; AREAS IN WHICH HYDROGEN COULD BE INTRODUCED WILL BE INVESTIGATED AND REQUIRED TO ACCOMMODATE DETONATION, IF IT IS NOT SO UNLIKELY

2.5 HYDROGEN IGNITION AND BURNING APPROACH TO RESOLUTION (CONTINUED)

- o A STRUCTURAL ANALYSIS VERIFYING THAT THE CONTAINMENT CAN WITHSTAND PRESSURES RESULTING FROM GLOBAL HYDROGEN BURNS OF UP TO 13% HYDROGEN CONCENTRATION WILL BE PERFORMED; THIS ANALYSIS WILL BE PART OF A BEST ESTIMATE ASSESSMENT OF CONTAINMENT PERFORMANCE FOR PRA SEQUENCES

- o THE TECHNICAL BASIS FOR THE 13% CONCENTRATION PRECLUDING DETONATION WILL BE PROVIDED

2. THE MAAP HYDROGEN BURN MODEL WILL BE REVIEWED AND UPDATED TO ADDRESS THE NRC CONCERNS; UPDATES WILL INCLUDE MODELS FOR IGNITION, BURN COMPLETENESS, AND TRANSITION BETWEEN INCOMPLETE AND COMPLETE BURNS

2.6 DEBRIS COOLABILITY (IDCOR ISSUE 10) ISSUE DEFINITION

ALWRS ARE DESIGNED TO ESTABLISH A SAFE STABLE STATE FOR THOSE SCENARIOS IN WHICH THE REACTOR VESSEL FAILS WITH CORE DEBRIS FALLING INTO THE REACTOR CAVITY

- IDCOR ISSUE 10 INVOLVED ALL ASPECTS OF CORE DEBRIS IN THE REACTOR CAVITY INTERACTING THERMALLY AND CHEMICALLY WITH THE STRUCTURAL CONCRETE

- THE SUB-ISSUE OF THERMAL AND PRESSURE LOADINGS ON THE CONTAINMENT WAS RESOLVED, SUBJECT TO CONTINUING COMPARISON OF MODELS WITH EXPERIMENTAL DATA AS IT BECOMES AVAILABLE (AN ELEMENT OF ARSAP)

- THE SUB-ISSUE OF DEBRIS COOLABILITY (I.E. QUENCHING OF THE DEBRIS AND THE ESTABLISHMENT OF A HEAT TRANSPORT PATH TO THE ULTIMATE HEAT SINK) WAS NOT RESOLVED

2.6 DEBRIS COOLABILITY HISTORICAL PERSPECTIVE

IDCOR ASSESSED DEBRIS COOLABILITY BASED ON TMI-2 QUENCHING AND ON EXPERIMENTS CONDUCTED BY SANDIA AND EPRI

- o A CRITICAL HEAT FLUX REPRESENTATION OF QUENCHING WAS FOUND TO BE ADEQUATE
- o LAVA BED QUENCHING EXPERIMENTS DEMONSTRATE SUFFICIENT CRACKING TO ENSURE THAT CONDUCTION WILL NOT BE LIMITING
- o MAAP MODELS REFLECT THESE CONCEPTS

THE NRC CONSIDERED THE AVAILABLE DATA INSUFFICIENT TO SUBSTANTIATE THE IDCOR POSITION

- o EARLY EXPERIMENTS AT SANDIA FOCUSED ON CORE-CONCRETE ATTACK THOUGH AVAILABLE HEAT FLUX RESULTS WERE CONSISTENT WITH THE IDCOR APPROACH
- o ON-GOING SURC TESTS WERE EXPECTED TO PROVIDE DATA TO TEST THE VALIDITY OF THE IDCOR MODELS FOR DEBRIS COOLABILITY

2.6 DEBRIS COOLABILITY APPROACH TO RESOLUTION

1. PROVIDE DESIGN REQUIREMENTS ASSURING AN APPROPRIATELY SIZED CAVITY AND THE AVAILABILITY OF WATER (EPRI REQUIREMENTS DOCUMENT)

   - SUFFICIENT CAVITY SURFACE AREA TO AFFORD 0.02 M^2 PER RATED MEGAWATT OF THERMAL POWER

   - FLOW PATHS, AREAS, CURBS AND DRAINS TO ENSURE CAVITY FLOODING

   - IRWST CONFIGURED TO OVERFLOW TO CAVITY AT APPROPRIATE EXCESS ABOVE NORMAL OPERATING VOLUME

   - CONTAINMENT ARRANGED TO AFFORD HEAT TRANSPORT PATHS AND ALTERNATIVE MEANS TO PROVIDE ADDITIONAL WATER

2. PROVIDE THE TECHNICAL BASIS TO ESTABLISH DEBRIS COOLABILITY GIVEN THE ABOVE REQUIREMENTS

REVIEW STATUS REPORT
ON ARSAP TOPIC PAPERS

SET NUMBER	TOPIC PAPER SET	TOPIC PAPER	SUBMITTAL DATE	NRR RESPONSIBLE BRANCH CHIEF	RES REVIEWER	SECONDARY REVIEWER (NRR)	RAI	RAI RESPONSE	SER TO PM	SER TO ACRS
1	RESOLVED IDCOR/NRC ISSUES APPLICABILITY TO ALWRS	REACTOR COOLANT SYSTEM NATURAL CIRCULATION (IDCOR ISSUE 2)	11/24/87	W. HODGES	C. FERRELL J. HAN	L. KOPP	06/15/88T	08/15/88T	10/15/88T	11/15/88T
1	RESOLVED IDCOR/NRC ISSUES APPLIABLE TO ALWRS	IN-VESSEL STEAM EXPLOSIONS AND ALPHA MODE FAILURE (IDCOR ISSUE 7)	11/24/87	W. HODGES	C. FERRELL B. WRIGHT	L. KOPP	06/15/88T	08/15/88T	10/15/88T	11/15/88T
1	RESOLVED IDCOR/NRC ISSUES APPLICABLE TO ALWRS	EX-VESSEL HEAT TRANSFER MODELS FROM MOLTEN CORE TO CONCRETE (IDCOR ISSUE 10)	11/24/87	W. HODGES	C. FERRELL B. BURSON	L. KOPP	06/15/88T	08/15/88T	10/15/88T	11/15/88T
1	RESOLVED IDCOR/NRC ISSUES APPLICABLE TO ALWRS	FISSION PRODUCT RELEASE PRIOR TO VESSEL FAILURE (IDCOR ISSUE 1)	11/24/87	L. CUNNINGHAM	C. FERRELL L. CHAN	T. ESSIG	06/15/88T	08/15/88T	10/15/88T	11/15/88T
1	RESOLVED IDCOR/NRC ISSUES APPLICABLE TO ALWRS	RELEASE MODEL FOR CONTROL ROD MATERIALS (IDCOR ISSUE 3)	11/24/87	L. CUNNINGHAM	C. FERRELL L. CHAN	T. ESSIG	06/15/88T	08/15/88T	10/15/88T	11/15/88T
1	RESOLVED IDCOR/NRC ISSUES APPLICABILE TO ALWRS	FISSION PRODUCT AND AEROSO. DEPOSITION IN RCS AND CONTAINMENT (IDCOR ISSUES 4 & 12)	11/24/87	L. CUNNINGHAM	C. FERRELL P. WORTHINGTON	T. ESSIG	06/15/88T	08/15/88T	10/15/88T	11/15/88T
1	RESOLVED IDCOR/NRC ISSUES APPLICABLE TO ALWRS	EX-VESSEL FISSION PRODUCT RELEASE (DURING CORE - CONCRETE INTERACTIONS) (IDCOR ISSUE 8)	11/24/87	L. CUNNINGHAM	C. FERREL B. BURSON	T. ESSIG	06/15/88T	08/15/88T	10/15/88T	11/15/88T
1	RESOLVED IDCOR/NRC ISSUES APPLICABLE TO ALWRS	REVAPORIZATION OF FISSION PRODUCTS (IDCOR ISSUE 11)	11/24/87	L. CUNNINGHAM	C. FERRELL L. CHAN	T. ESSIG	06/15/88T	18/15/88T	10/15/88T	11/15/88T

REVIEW STATUS REPORT
ON ARSAP TOPIC PAPERS

SET NUMBER	TOPIC PAPER SET	TOPIC PAPER	SUBMITTAL DATE	NRR RESPONSIBLE BRANCH CHIEF	RES REVIEWER	SECONDARY REVIEWER (NRR)	RAI	RAI RESPONSE	SER TO PM	SER TO ACRS
1	RESOLVED IDCOR/NRC ISSUES APPLICABLE TO ALWRS	SECONDARY CONTAINMENT PERFORMANCE (IDCOR ISSUE 16)	11/24/87	J. CRAIG	C. FERRELL T. WALKER	J. RAVAL	06/15/88T	08/15/88T	10/15/88T	11/15/88T
1	RESOLVED IDCOR/NRC ISSUES APPLICABLE TO ALWRS	MODELING OF EMERGENCY RESPONSE (IDCOR ISSUE 14)	11/24/87	W. HODGES	C. FERRELL	L. KOPP	06/15/88T	08/15/88T	10/15/88T	11/15/88T
2	PLANT RESPONSE UNDER SEVER ACCIDENT CONDITIONS	IN-VESSEL HYDROGEN GENERATION (IDCOR ISSUE 5)	06/06/88	W. HODGES	R. VAN HOUTEN	L. LOIS	08/30/88T	10/30/88T	12/30/88T	01/30/88T
2	PLANT RESPONSE UNDER SEVERE ACCIDENT CONDITIONS	CORE MELT PROGRESSION AND VESSEL FAILURE (IDCOR ISSUE 6)	06/06/88	W. HODGES	R. WRIGHT	L. KOPP	08/30/88T	10/30/88T	12/30/88T	01/30/89T
2	PLANT RESPONSE UNDER SEVERE ACCIDENT CONDITIONS	DIRECT CONTAINMENT HEATING BY EJECTED CORE MATERIALS (IDCOR ISSUE 8)	06/30/88	J. CRAIG	P. WORTHINGTON	J. RAVAL	08/30/88T	10/30/88T	12/30/88T	01/30/89T
2	PLANT RESPONSE UNDER SEVERE ACCIDENT CONDITIONS	CONTAINMENT PERFORMANCE (IDCOR ISSUE 15)	06/06/88	J. CRAIG	T. WALKER	J. RAVAL	8/30/88T	10/30/88T	12/30/88T	01/30/88T
2	RESPONSE UNDER SEVERE ACCIDENT CONDITIONS	CONTAINMENT PERFORMANCE (IDCOR ISSUE 17)	06/06/88	J. CRAIG	P. WORTHINGTON	J. RAVAL	08/30/88T	10/30/88T	12/30/88T	01/30/88T
2	PLANT RESPONSE UNDER SEVERE ACCIDENT CONDITIONS	DEBRIS COOLABILITY (IDCOR ISSUE 10)	06/30/88	W. HODGES	B. BURSON	L. KOPP	08/30/88T	10/30/88T	12/30/88T	01/30/89T
3	METHODOLOGY PRA	EXTERNAL EVENTS	07/30/88	R. BARRETT		G. KELLY	09/30/88T	11/30/88T	01/30/89T	02/30/89T
3	METHODOLOGY PRA	SUCCESS CRITERIAL	07/30/88	R. BARRETT		G. KELLY	09/30/88T	11/30/88T	01/30/89T	02/28/89T
3	METHODOLOGY PRA	ACCIDENT SEQUENCE SELECTION	07/30/88	L. CUNNINGHAM		T. ESSIG	09/30/88T	11/30/88T	01/30/88T	02/28/88T

REVIEW STATUS REPORT
ON ARSAP TOPIC PAPERS

SET NUMBER	TOPIC PAPER SET	TOPIC PAPER	SUBMITTAL DATE	NRR RESPONSIBLE BRANCH CHIEF	RES REVIEWER	SECONDARY REVIEWER (NRR)	RAI	RAI RESPONSE	SER TO PM	SER TO ACRS
3	METHODOLOGY PRA	HUMAN RELIABILITY ANALYSIS	07/30/88	W. REGAN		G. LAPINSKY	09/30/88T	11/30/88T	01/30/89T	02/28/89T
3	METHODOLOGY PRA	COMMON CAUSE FAILURE	07/30/88	R. BARRETT		G. KELLY	09/30/88T	11/30/88T	01/30/89T	02/28/89T
4	SEVERE ACCIDENT PERFORMANCE	ESSENTIAL EQUIPMENT PERFORMANCE (IDCOR ISSUE 18)	07/30/88	J. CRAIG		J. RAVAL	09/30/88T	11/30/88T	01/30/89T	02/28/89T
4	SEVERE ACCIDENT PERFORMANCE	CRITERIAL FOR SAFE STABLE STATES	05/30/88	W. HODGES		L. KOPP	09/30/88T	11/30/88T	01/30/89T	02/28/89T
5	SAFETY GOALS EVALUATION	SAFETY GOAL IMPLEMENTATION - INTERPRETATION OF GOALS AND USAGE OF PRA RESULTS IN COMPARISON WITH GOALS, INCLUDING INTERPRETATION OF UNCERTAINTIES	09/30/88	R. BARRETT		R. KELLY	11/30/88T	01/30/89T	03/30/89T	04/30/89T
5	SAFETY GOALS EVALUATIONS	UNCERTAINTIES IN PLANT RISK ANALYSIS	09/30/88	R. BARRETT		G. KELLY	11/30/88T	01/30/89T	03/30/89T	04/30/89T
5	SAFETY GOALS EVALUATION	MAAP-DOR CODE VALIDATION	09/30/88	R. BARRETT		G. KELLY	11/30/88T	01/30/89T	03/30/89T	04/30/89T
6	SEVERE ACCIDENT ACCIDENT MANAGEMENT	S/A MANAGEMENT PLANNING	10/30/88	L. CUNNINGHAM		T. ESSIG	12/20/88T	02/28/89T	04/30/89T	05/30/89T
6	SEVERE ACCIDENT MANAGEMENT	S/A MANAGEMENT - EQUIPMENT CAPABILITY AND OPERATIONAL REQUIREMENTS	10/30/88	J. CRAIG		J. RAVAL	12/30/88T	02/28/89T	04/30/89T	05/30/89T

*** Total ***
72

COMPARISON OF THE LIMITS OF VARIOUS COMBUSTION MODES

COMPOSITION	THERMODYNAMIC STATE	FLAMMABILITY LIMITS	FLAME ACCELERATION LIMITS	DETONATION LIMITS
Lean H_2-Air	T=20°C, P=1 atm	4-9% H_2(1)	10% H_2(3)	11.7% H_2(7)
Lean H_2-Air	T=100°C, P=1 atm	4.5% H_2(2)		9.5% H_2(7)
Rich H_2-Air	T=20°C, P=1 atm	74.2% H_2(1)	73% H_2(3)	75% H_2(7)
Rich H_2-Air	T=100°C, P=1 atm	78.5% H_2(2) (extrapol.)		77% H_2(7)
Steam-Diluted Stoichiometric H_2-Air	T=100°C, P=1 atm	>52% H_2O(2) (to inert)	>35% H_2O(4) (to inert)	>35% H_2O(7) (to inert)
Helium-Diluted Stoichiometric H_2-O_2	T=22°C, P=1 atm	>86.5% He(5) (to inert)		>86.5% He(6) (to inert)

1. Coward, H. F. and Jones, G. W., "Limits of Flammability of Gases and Vapor," U.S. Bureau of Mines Bulletin 503, 1952. (4% H_2 is the upward propagation limit and 9% H_2 is the downward propagation limit.)
2. Marshall, B. W., "Hydrogen:Air:Steam Flammability Limits and Combustion Characteristics in the FITS Vessel," SAND84-0383.
3. Peraldi, O., Knystautas, R., Lee, J. H., "Criteria for Transition to Detonation in Tubes," 21st International Combustion Symposium.
4. Brehm, unpublished data obtained at Technical University Munich.
5. Kumar, R. K., "Flammability Limits of Hydrogen-Oxygen-Diluent Mixtures," J. Fire Sciences, V3, pp 245-262, 1985.
6. Kumar, recent unpublished data obtained at Whiteshell Nuclear Research Establishment.
7. Stamps, D. W., recent unpublished data obtained in the HDT at Sandia National Laboratories.

\+ Acceleration of flame to the isobaric sound speed.

July 28, 1988

DISTRIBUTION:
Central File
NRC PRDR
PDSNP Reading
LRubenstein
EHylton
GVissing
OGC-Rockville
EJordan
BGrimes
NRC Participants
ACRS (10)