H_2 CONTROL MEASURES

FOR

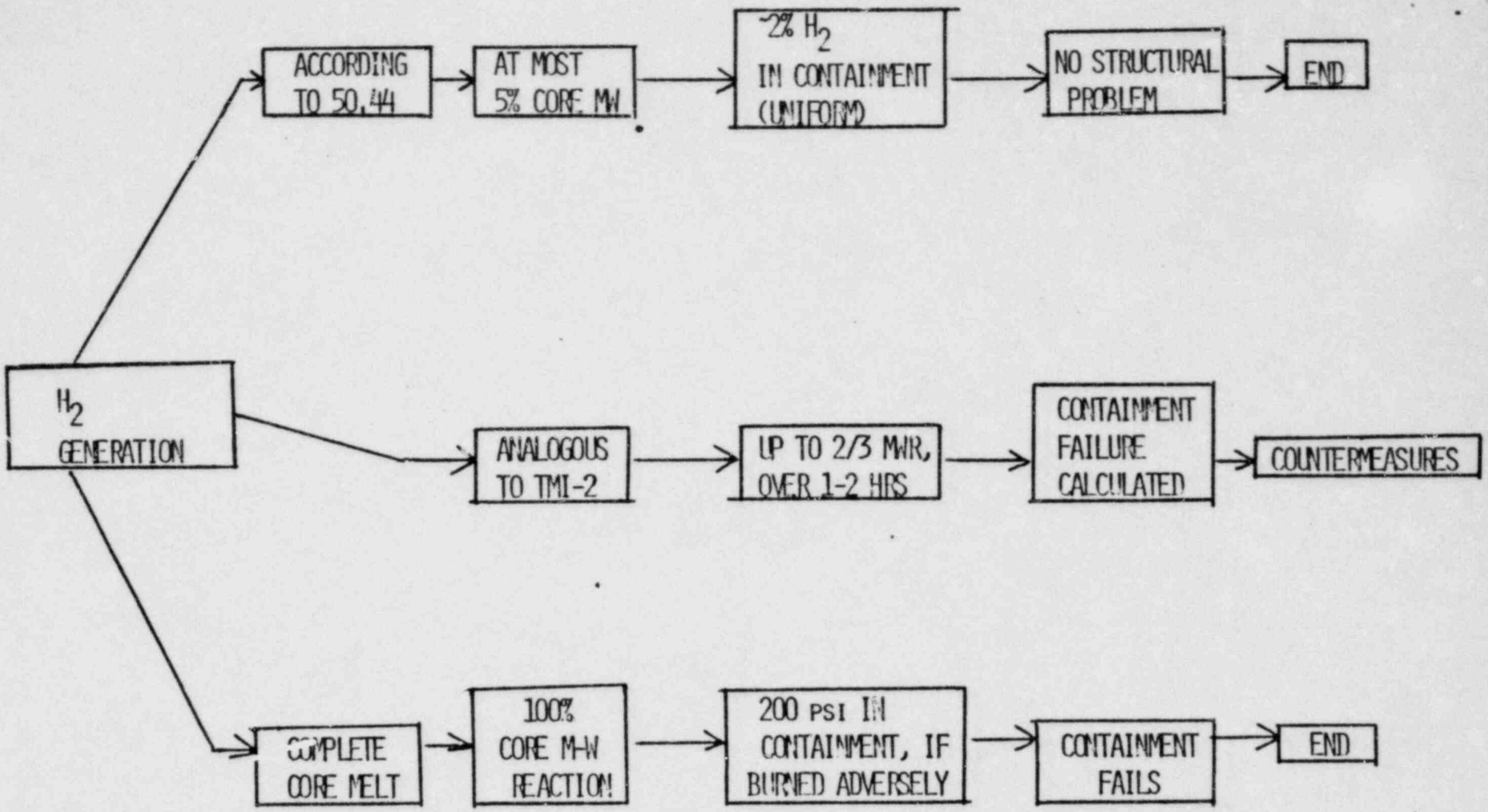
SEQUOYAH NUCLEAR PLANT

COMMISSION BRIEFING

AUGUST 14, 1980

OUTLINE

- H_2 SOURCE TERM
- EFFECTS OF H_2 COMBUSTION ON EXISTING DESIGN
- POSSIBLE REMEDIES AND CONTRAINDICATIONS
  - X INTERIM MEASURES
  - X LONG-TERM MEASURES
- CONCLUSIONS AND RECOMMENDATIONS



H_2 GENERATION
ACCORDING TO 50.44
AT MOST 5% CORE MW
~2% H_2 IN CONTAINMENT (UNIFORM)
NO STRUCTURAL PROBLEM
END
ANALOGOUS TO TMI-2
UP TO 2/3 MWR, OVER 1-2 HRS
CONTAINMENT FAILURE CALCULATED
COUNTERMEASURES
COMPLETE CORE MELT
100% CORE M-W REACTION
200 PSI IN CONTAINMENT, IF BURNED ADVERSELY
CONTAINMENT FAILS
END

ADIABATIC CONTAINMENT

HYDROGEN COMBUSTION

CALCULATION

<u>FINAL STATE</u>

VOL = 1.193×10^6 BTU

T_f = 2000 F

P_f = NRT/V = 68.6 PSIA

MOLES O_2 = 450

MOLES N_2 = 2324

MOLES H_2O = 331

REACTION PRODUCTS

HEATED BY COMBUSTION

$$H_C = \sum C_{V,I} (T_T - T_O)$$

<u>INITIAL STATE</u>

VOL = 1.193×10^6 FT^3

T_O = 77 F

P_O = 16.3 PSIA

MOLES O2 = 615

MOLES N_2 = 2324

MOLES H_2 = 331 = 300KG

ALL HYDROGEN

REACTS WITH OXYGEN

H_2 = 331 MOLES (1.04×10^5 BTU/MOLE)

$\Delta H = 34.4 \times 10^6$ BTU

CONTAINMENT STRUCTURAL ANALYSES

. TVA

. Ames

. RDA

CONTAINMENT STRUCTURAL ANALYSES

TVA

- NEGLECTED STIFFENERS
- USED ACTUAL STRENGTH INSTEAD OF MINIMUM CODE YIELD STRENGTH OF STEEL
- 33 PSIG YIELD PRESSURE
- 43.5 PSIG ULTIMATE STRENGTH

AMES LABORATORY

- QUASI-STATIC ANALYSIS
- INCLUDED "SMEARED" STIFFENERS
- 36 PSIG YIELD PRESSURE

R&D ASSOCIATES

- ASSUMED STIFFENERS RELATIVELY INEFFECTIVE
- USED MINIMUM CODE YIELD STRENGTH OF STEEL
- 27 PSIG YIELD PRESSURE

RES

- 34 PSIG YIELD PRESSURE

LICENSEE EFFORTS

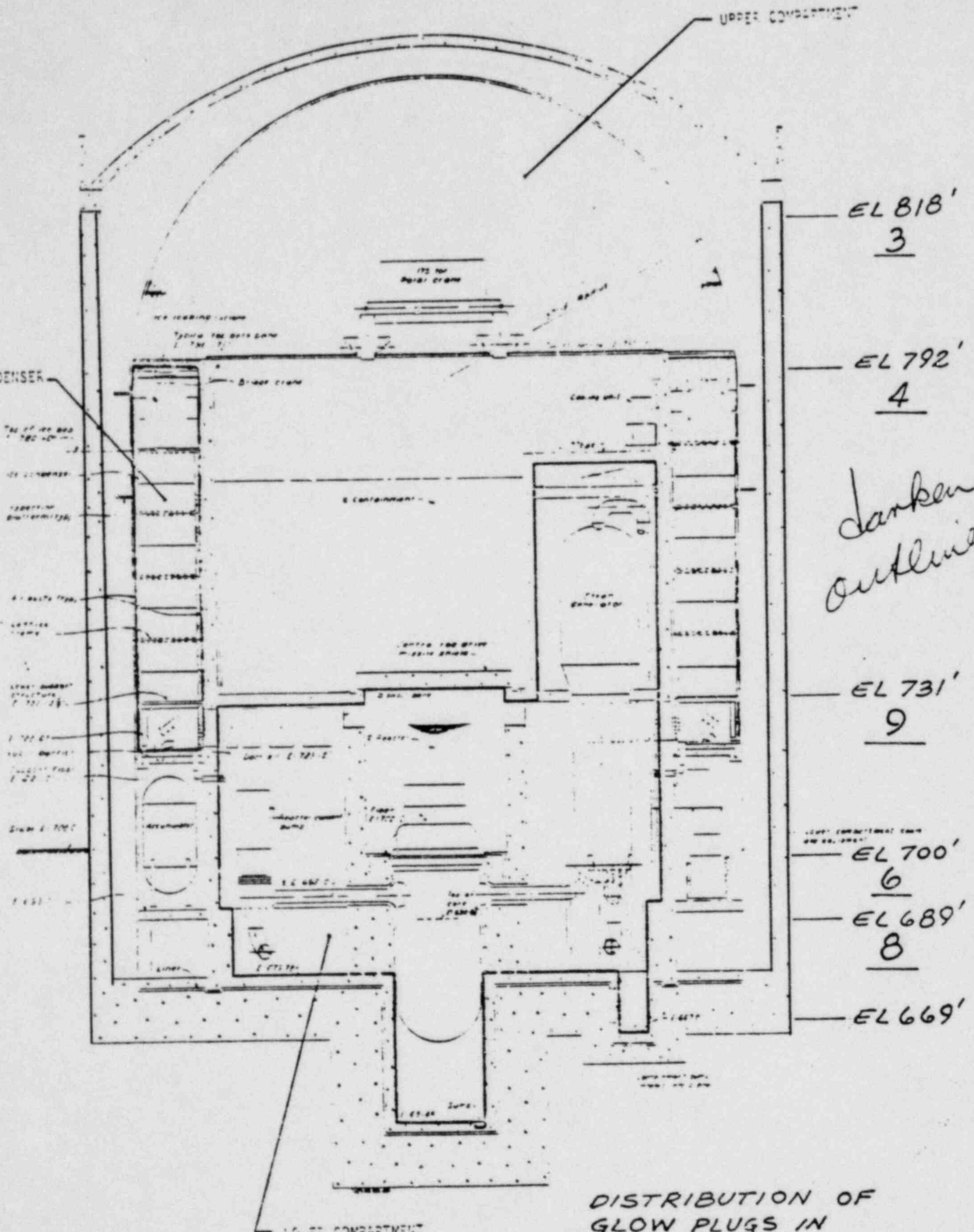
SHORT TERM

PROPOSED DISTRIBUTED IGNITION SYSTEM

PHASE I (INTERIM)

- SYSTEM INSTALLATION AND TESTING COMPLETE BY SEPTEMBER 15, 1980
- PRIOR COMMISSION APPROVAL BEFORE SYSTEM IS MADE OPERABLE (TVA SUBMITTAL BY AUGUST 15, 1980)
- SYSTEM DESIGN
    - 30 GLOW PLUGS
        - 18 IN LOWER COMPARTMENT
        - 5 IN LOWER PLENUM OF ICE CONDENSER
        - 4 IN UPPER PLENUM OF ICE CONDENSER
        - 3 IN UPPER COMPARTMENT
    - GMAC 7-G DIESEL ENGINE GLOW PLUG PRESENTLY BEING TESTED
    - UTILIZING BACKUP LIGHTING CIRCUITS
        - SEISMIC DESIGN
        - POWERED FROM EMERGENCY BUSES (EMERGENCY DIESEL GENERATORS)
        - REMOTE MANUAL CONTROL FROM AUXILIARY BUILDING

SEQUOYAH CONTAINMENT



DISTRIBUTION OF GLOW PLUGS IN CONTAINMENT FIGURE

- Glow Plug Testing (status)

  - Determining glow plug temperature as a function of applied voltage (14 volts - about 1700°F; 12 volts - about 1500°F)

  - Determining durability of glow plug (specimen has continued to operate successfully after 6 days at 1700°F)

  - Determining reliability of glow plug as an ignition source (achieved ignition in dry air mixtures containing 12 volume percent and 7 volume precent hydrogen)

  - Determining the percent completion of hydrogen burns (essentially 100% combustion of dry air mixture containing 12 volume percent hydrogen)

  - Further testing will vary hydrogen concentration and introduce steam environment

PHASE II (IMPROVEMENTS)

- IMPROVEMENTS TO BE IMPELMENTED IN PARALLEL WITH TVA'S LONG-TERM DEGRADED CORE TASK FORCE PROGRAM

- IMPROVEMENTS:

  - EACH IGNITOR WILL HAVE INDIVIDUAL CONTROL FROM THE MAIN CONTROL ROOM
  - MORE HYDROGEN AND OXYGEN MONITORS WILL BE INSTALLED TO GUIDE OPERATORS
  - A PLANT COMPUTER TO WARN OF HYDROGEN CONCENTRATIONS REACHING THE DETONATION LIMIT WILL BE PROVIDED.
  - BACKUP DIESEL POWER SUPPLY TO THE SYSTEM WILL CONTINUE TO BE PROVIDED.
  - ENVIRONMENTAL QUALIFICATION OF DISTRIBUTED IGNITION SYSTEM COMPONENTS WILL BE DETERMINED.
  - EFFECTS OF THE HYDROGEN BURN ENVIRONMENT ON COMPONENTS WILL BE ANALYZED.
  - ALTERNATE AND/OR ADDITIONAL IGNITOR LOCATIONS WILL BE SELECTED BASED ON A BETTER UNDERSTANDING OF THE CHARACTERISTICS OF HYDROGEN COMBUSTION
  - INSTALLATION OF HYDRIDE CONVERTERS NEAR THE REACTOR VESSEL VENT, PORV DISCHARGE, AND AIR RETURN FANS WILL BE CONSIDERED.
  - ADDITIONAL CONTAINMENT PENETRATIONS WILL BE CONSIDERED TO FACILITATE AN EXPANDED HYDROGEN MONITORING CAPABILITY.

PHASE III (FINAL)

- FINAL MODIFICATIONS TO BE IMPLEMENTED AT COMPLETION OF TVA'S LONG-TERM DEGRADED CORE TASK FORCE PROGRAM.

- DEGRADED CORE TASK FORCE PROGRAM
  - LONG-TERM (2 YEAR) EFFORT
  - MAJOR TASKS

1. CONTROLLED IGNITION
2. HALON SUPPRESSANTS
3. RISK ASSESSMENT
4. CORE BEHAVIOR, HYDROGEN GENERATION AND TRANSPORT
5. HYDROGEN BURNING AND CONTAINMENT RESPONSES

TVA ANALYSES

- ANALYTICAL EFFORT

  - WESTINGHOUSE/OFFSHORE POWER SYSTEMS

  - ABOUT/YEAR STUDY OF CRITICAL PARAMETERS FOR VARIOUS ACCIDENT SCENARIOS TO DETERMINE CONTAINMENT RESPONSE

  - USING CLASIX CODE (UNDER DEVELOPMENT)

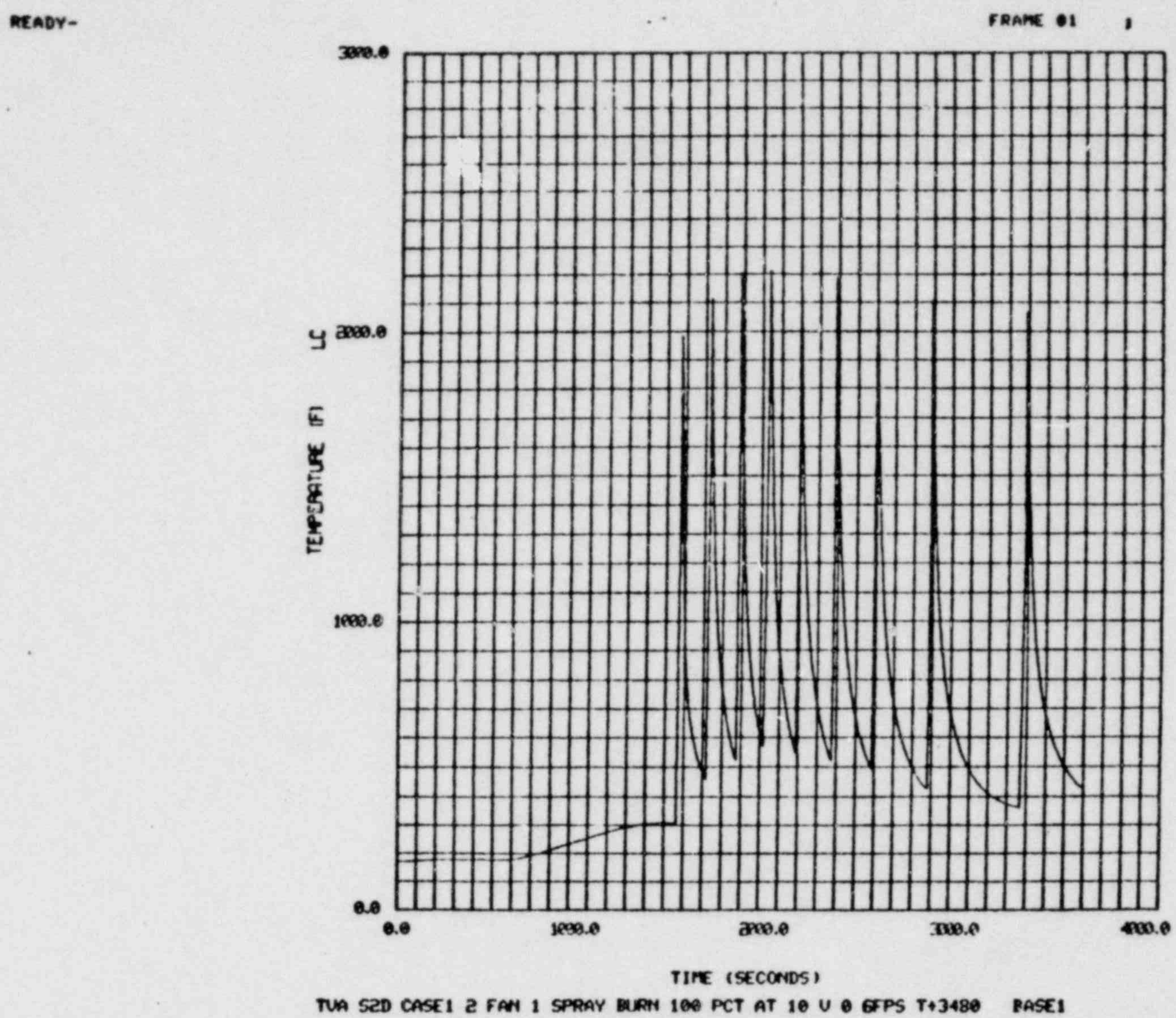
CLASIX CAPABILITIES

1. VENT FROM UPPER COMPARTMENT
2. ICE CONDENSER
3. RECIRCULATION FAN
4. DOORS - LOWER INLET AND INTERMEDIATE
5. INDIVIDUAL REPRESENTATION OF O_2, H_2, N_2 AND H_2O
6. SATURATED AND SUPER-HEATED STEAM
7. SPRAYS
8. H_2, N_2 AND HEAT ADDITIONS
9. BREAK FLOW
10. BURN CONTROL

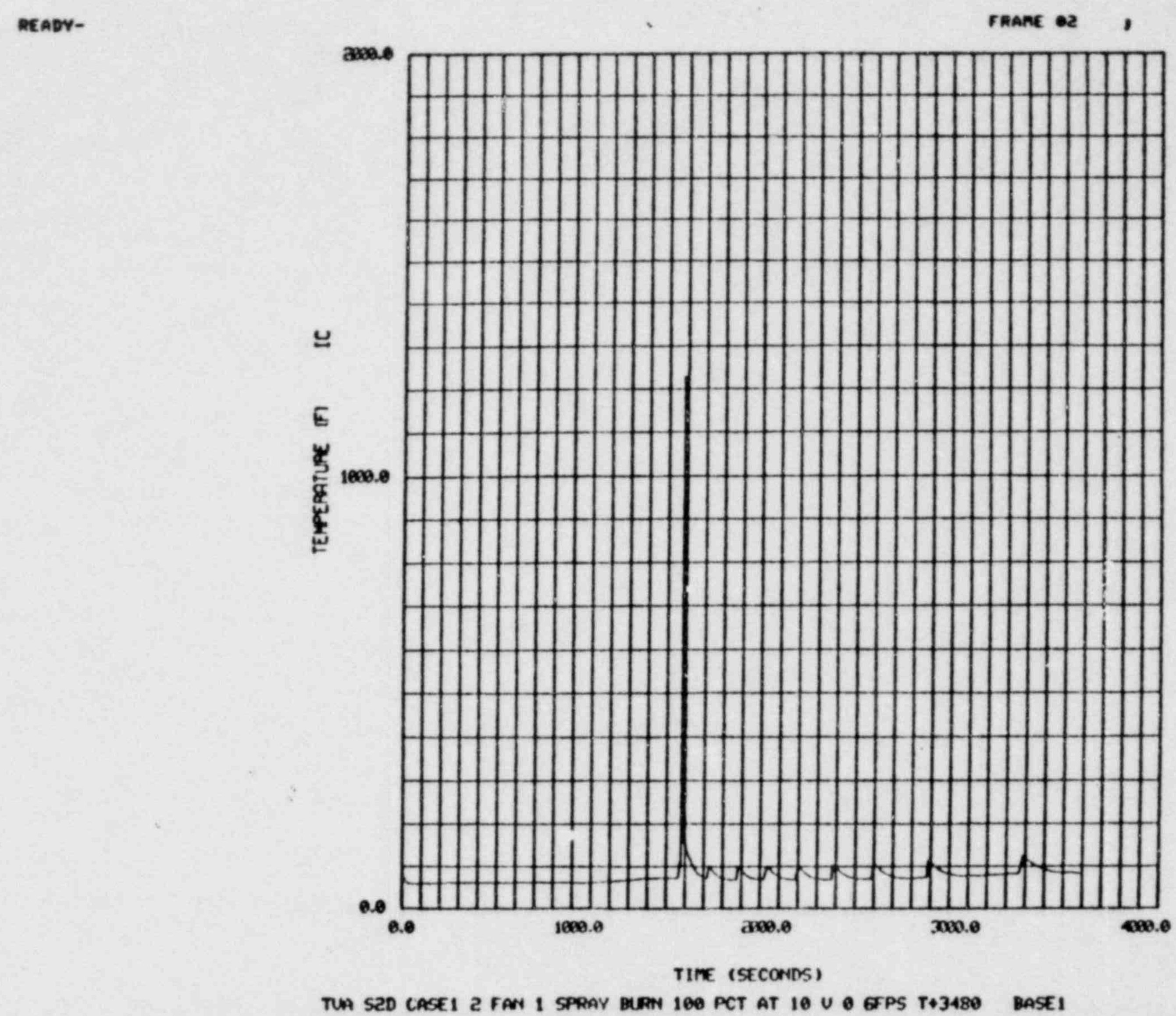
- Preliminary analytical results
  - selected small break LOCA resulting in degraded core cooling (S_2D sequence of WASH-1400)
  - Rate of hydrogen release based on MARCH code calculation (onset of hydrogen release 3500 sec after accident initiation and assumed to continue unimpeded for 3000 sec, resulting in reaction of about 80% of total zirconium in core)
  - hydrogen combustion assumed when 10 volume percent hydrogen reached
  - varied assumptions regarding air return fan and upper compartment spray performance, and ice availability.

BASE CASE PARAMETERS

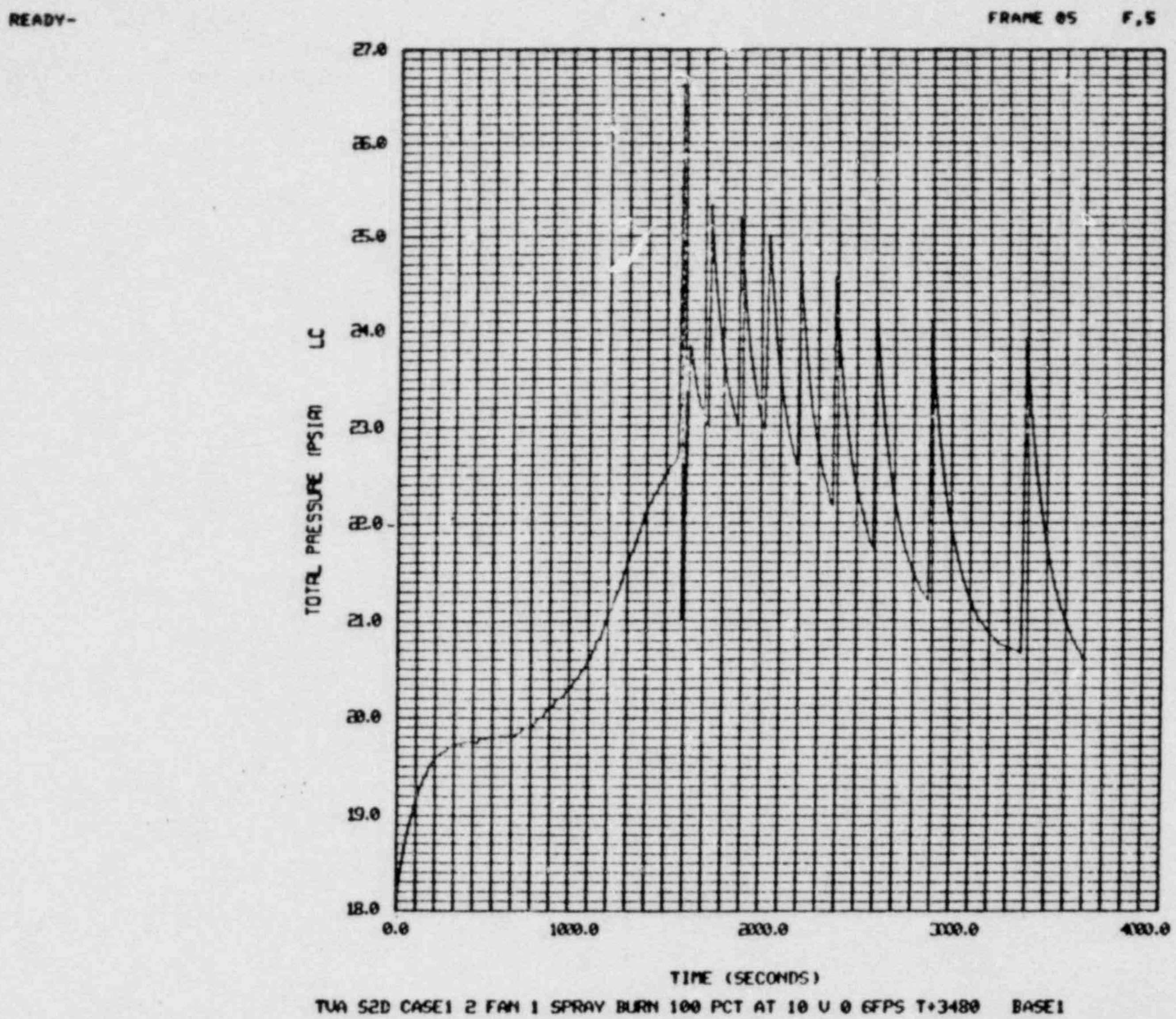
1. INITIAL CONDITIONS:	VOLUMES	
	TEMPERATURES	
	PRESSURES	LOTIC
	ICE MASS	CODE
	ICE HEAT TRANSFER AREA	
2. BURN PARAMETERS:	H_2 FOR IGNITION	10 V/O
	H_2 FOR PROPAGATION	10 V/O
	O_2 FOR IGNITION	5 V/O
3. AIR RETURN FANS:	NUMBER OF FANS	2
	CAPACITY OF EACH FAN	40000 CFM
4. SPRAY SYSTEM:	FLOW RATE	6000 GPM
	TEMPERATURE	125 F
	HEAT TRANSFER COEFFICIENT	20 BTU/HR FT^2F
5. ICE CONDENSER DRAIN TEMPERATURE		32 F
6. BREAK RELEASE DATA		MARCH CODE



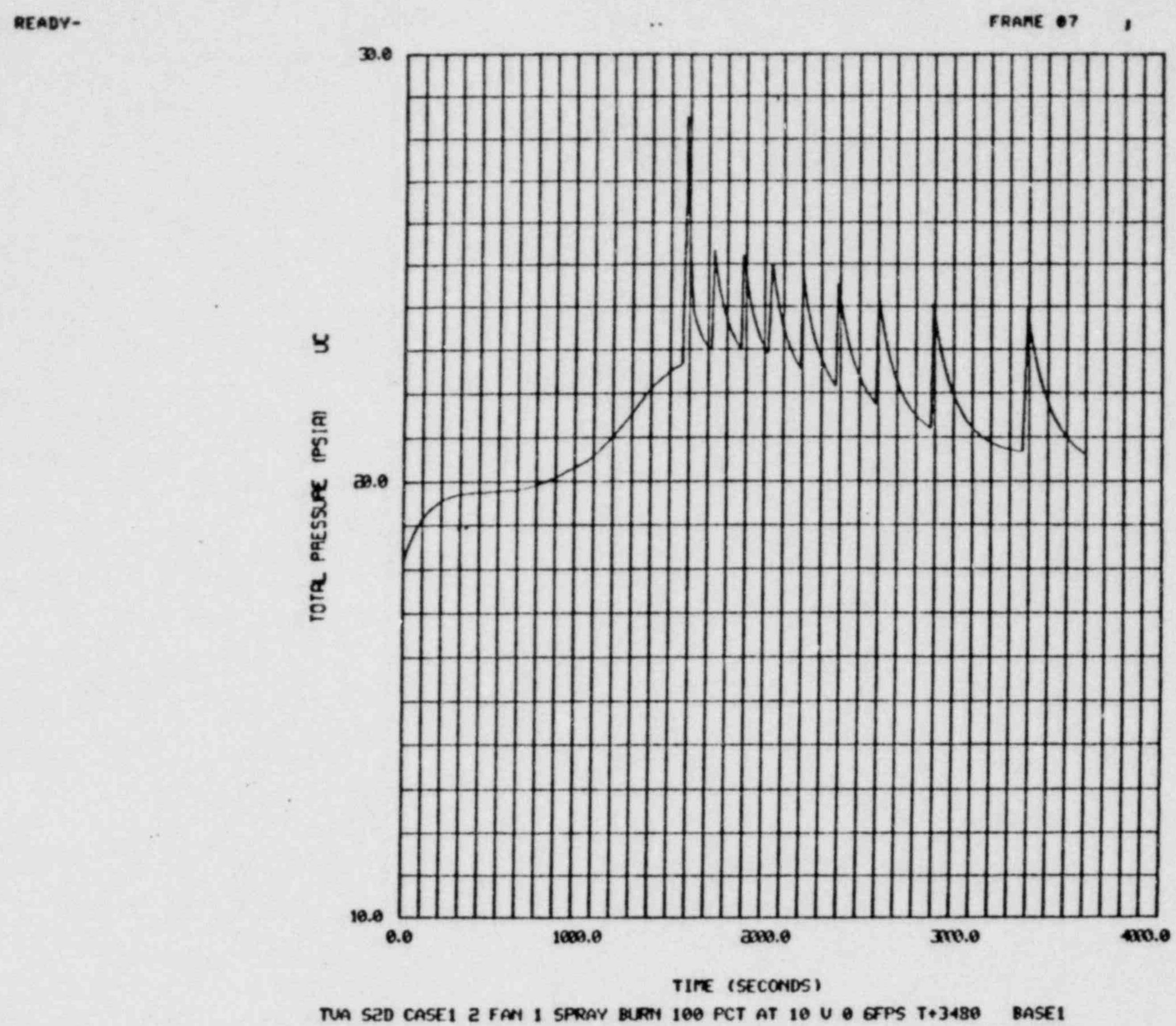
LOWER COMPARTMENT TEMPERATURE



ICE CONDENSER TEMPERATURE



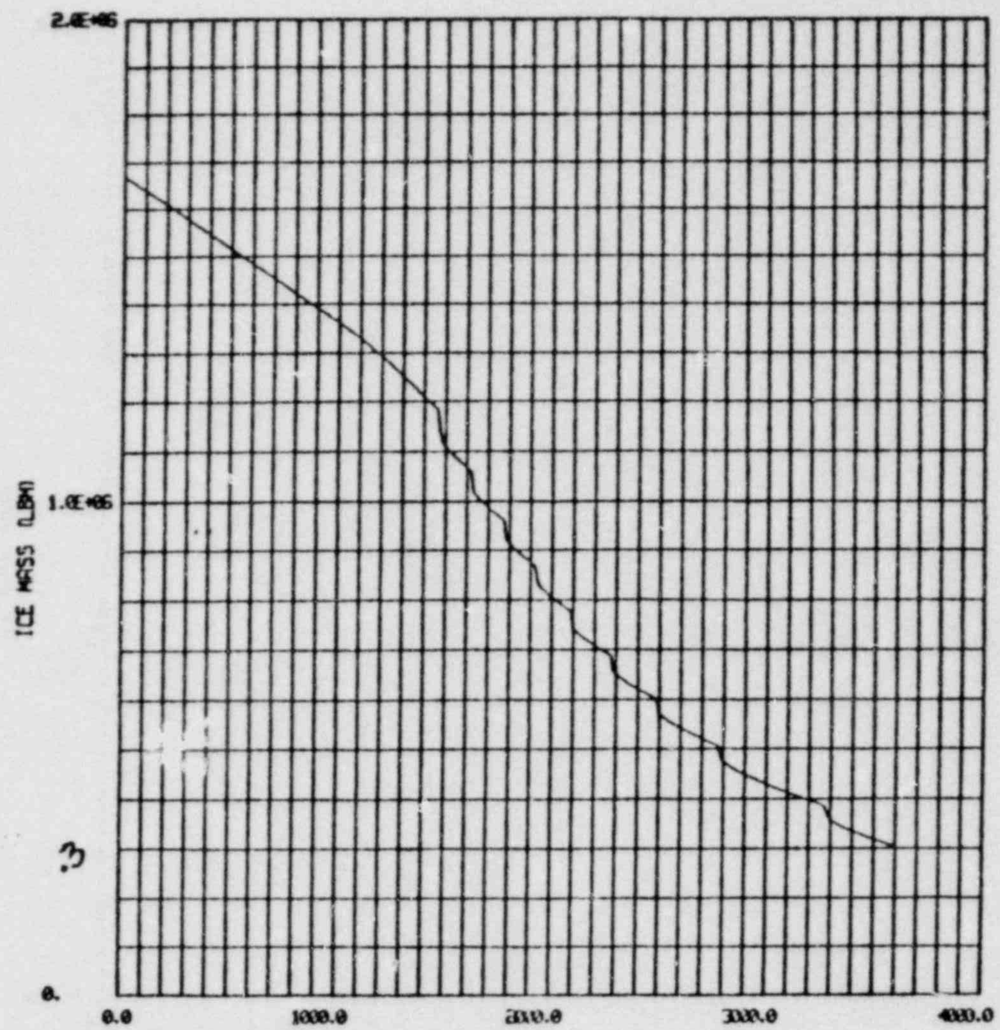
LOWER COMPARTMENT PRESSURE



UPPER COMPARTMENT PRESSURE

READY-

FRAME 41 F,41



TVA S2D CASE1 2 FAN 1 SPRAY BURN 100 PCT AT 10 V 0 6FPS T+3480 BASE1

ICE MASS

TABLE 1. PRELIMINARY CONTAINMENT ANALYSIS SENSITIVITY STUDIES

	TOTAL H_2 BURNED (LB)	PEAK TEMP. (°F)			PEAK PRESS (PSIA)	
		LOWER COMPARTMENT	ICE BED	UPPER COMP.	LOWER COMP.	UPPER COMP.
1. BASE CASE	900	2200	1200	150	26.5	28.5
2. H_2 IGNITION AND PROPAGATION @ 8%	1050	1200	700	260	28.5	30.5
3. 1 AIR FAN	900	2200	1350	160	26.5	29.5
4. NO ICE*	850	2400	2000	270	41	41
5. NO AIR FANS	1200	2370	2580	1090	46.4	92.4

* ICE EXISTS ONLY FOR THE FIRST TWO OF 7 BURNING CYCLES.

NRR EFFORTS

- LLNL Igniter Tests
- BCL Analyses

LLNL WORK

- OBJECTIVE: EXPERIMENTALLY EVALUATE IGNITER EFFECTIVENESS AND RELIABILITY

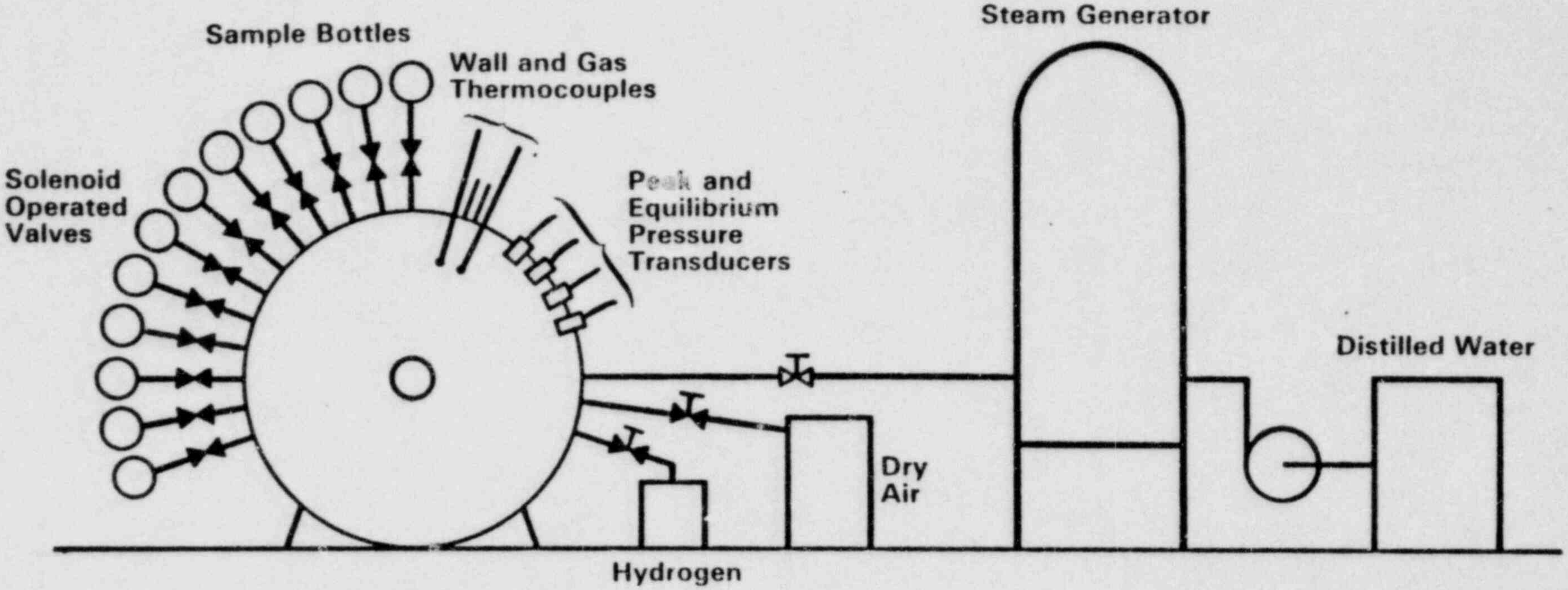
- FACILITY: 700 PSIG PRESSURE VESSEL
  4 FEET DIAMETER X 8 FEET LONG

- INSTRUMENTS: PRESSURE
  TEMPERATURE
  GAS SAMPLING

- SCHEDULE:

DESIGN & BUILD	:	JULY - SEPT. 1980
TESTS	:	SEPT - OCT., 1980
REPORT	:	OCT., 1980

Schematic View of Igniter Test Apparatus



BCL WORK

- Objective: Evaluate efficacy of Proposed Igniter system
- Analysis Model: MARCH Code
- Features of Code

  Models primary system

  Models containment system

  - multi-compartment
  - tracks atmosphere constituents
  - models heat sinks, ice bed, fans, sprays

- Schedule

  Preliminary work: done
  Balance of work: October 1980

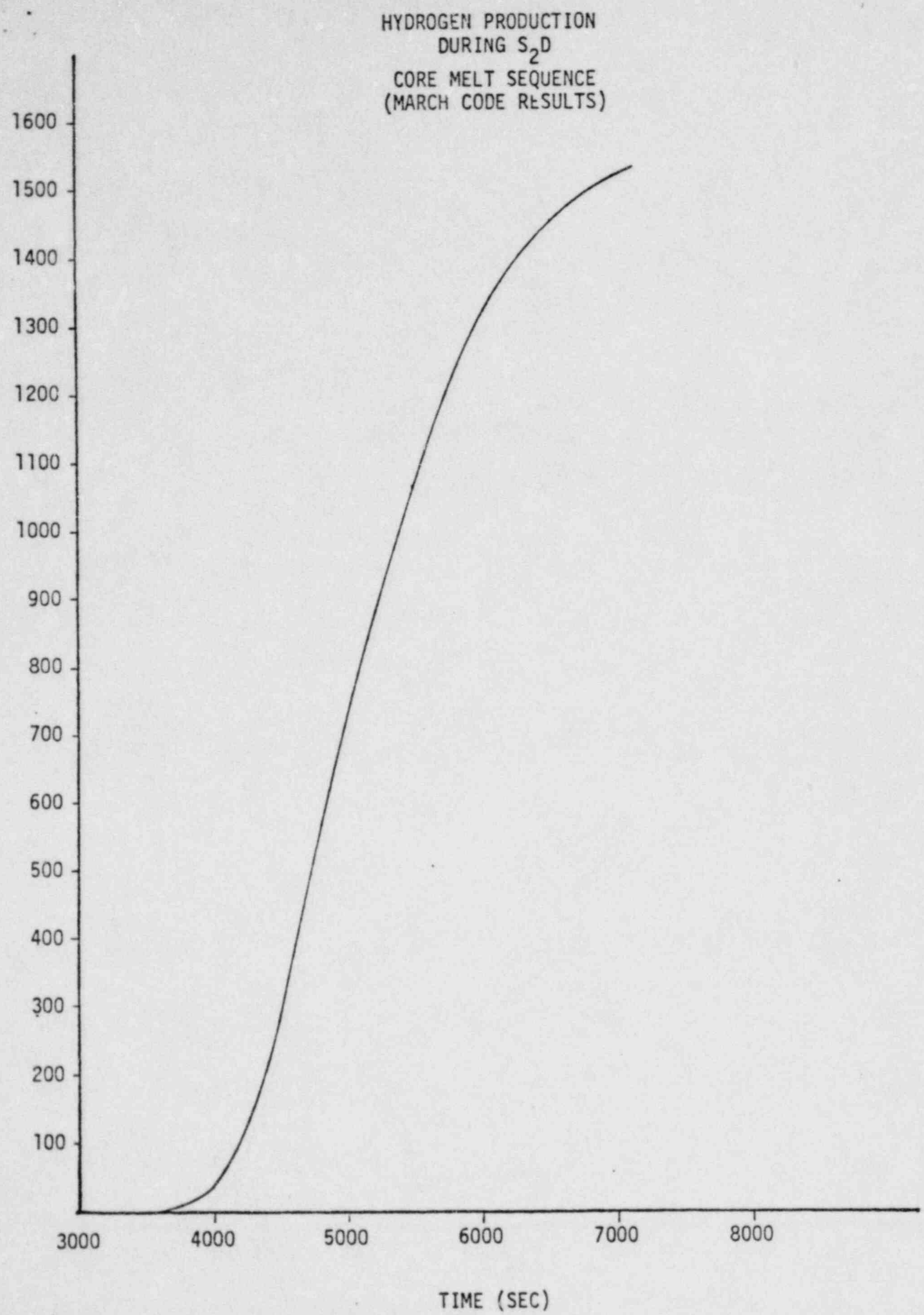

HYDROGEN PRODUCTION
DURING S_2D
CORE MELT SEQUENCE
(MARCH CODE RESULTS)
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
3000
4000
5000
6000
7000
8000
TIME (SEC)

TABLE . BATTELLE ANALYSIS OF H_2 BURNING IN SEQUOYAH CONTAINMENT

CASE	H_2 IGNITION SETPOINT (%)	H_2 BURN LIMIT (%)	BURN TIME (SEC)	CONTAINMENT PEAK PRESSURE (PSIA)	
				ACTUAL	ADIABATIC
1	10	0	1	≈ 23	58.
2	10	0	25	≈ 22	58.
3	12	0	1	≈ 24	64.
4	8	0	25	≈ 22	51.
5	8	4	1	≈ 22	36.
6	10	0	1	≈ 31	79.

CASE 6 - ICE BED MELTED BEFORE BURNING OCCURS.

CONCLUSION

- Likelihood of a degraded core accident is significantly reduced by implementation of TMI Short Term Lessons Learned
- TVA has proposed to further improve safety margins by use of an Interim Distributed Ignition System
- Decision Options:
  - Option A: Hold at 5%
  - Option B: Nominal 50% Limit
  - Option C: Limited 100%
  - Option D: Unlimited 100%
- Staff Recommendation: Option B

For cat # 5 of 81-320

Battelle

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Telephone (614) 424-6424
Telex 24-5454

February 29, 1980

Dr. Richard Coats
Sandia Laboratories
Albuquerque, New Mexico 87115

Dear Dick:

I have reviewed Joe Rivard's "Review of In-Vessel Meltdown Sequence", and have the following comments. In general, I feel that Joe has done an excellent job of evaluating the analysis capability of MARCH for this phase of the meltdown accident, particularly considering the timing and constraints imposed on him. Our own feelings about the deficiencies in the existing models are in good agreement with Joe's. Although I will make some comments about the review, none of them indicate significant disagreement with these conclusions.

An overall comment that I would like to make is that the modelling requirements for meltdown analyses may be more demanding for studies relating to mitigation of meltdown accidents than for studies investigating absolute risk. In the latter case, there are other major sources of uncertainty which obscure uncertainties in the meltdown models. When we attempt to mitigate the consequences of core melt accidents, on the other hand, the actual behavior of the physical processes of core melting becomes much more important. I believe that Joe is quite correct in pointing out how the uncertainties in meltdown behavior cascade with time into the accident. As a result, it becomes very important to model the initial slumping behavior accurately.

Specific Comments

(1) On page 5, the need for improvements to the modelling of heat transfer to the steam generator is indicated. The needed improvements are probably more extensive than implied. We believe a few volume loop capability is necessary and have layed out the basic model. We are not yet authorized to make the improvement, however. The modelling changes will improve the code's capability to model break flow, pressurizer hydraulics, and secondary behavior as well as steam generator heat transfer.

(2) The description of boiloff on page 7 is conceptually instructive but ignores the significance of heat generation from metal water reaction.

(3) On page 12, the results are presented of an analysis of the fraction of the core which must be covered to provide adequate steam to remove the decay heat from the remaining portion of the core. My calculations indicate the number should be more like 1/4 than 1/2.

(4) On page 17 there is discussion of the possibility of core barrel failure prior to failure of core support structure. We have done some evaluation of core barrel failure and agree that within the associated uncertainties this is possible. We would not say, however, that it is the most likely pathway. The important conclusion is that, within the existing uncertainties, it is not possible to choose between different scenarios for in-vessel core melting behavior which can have a major impact on subsequent phases of the accident.

(5) The amount of conservatism in the treatment of fission product release from the fuel as described on page 23 is probably small.

(6) MARCH has the capability to model steam generation in a steam explosion, failure of the pressure vessel (by input control), and failure of the containment building (by input control). I don't believe that more mechanistic modelling of steam explosions (page 28) in a systems code like MARCH is necessary; at least it should not be given high priority.

(7) Heating of structures above the core (page 43) is currently modelled in MARCH. A gross heat balance should probably be made on the vessel and internals, however, which is not currently done.

(8) The modelling of fuel motion in MARCH is discussed on pages 15-16. It should be pointed out that, while we normally speak of three distinct meltdown models, the code does permit the use of various combinations of the available fuel slumping options. This may be accomplished by choice of input options. Furthermore, MARCH does include provision for the holdup of the core debris on lower support structures but does not model heatup of the structures mechanistically.

If we can be of further assistance, please give me a call.

Sincerely,

Rich

Richard S. Denning
Research Leader
Nuclear and Flow
Systems Section

RSD:erc

xc: Mr. Joseph Rivard
Sandia Laboratories

Mr. James Curry
Nuclear Regulatory Commission