S. A. Hodge
Jan. 28, 1985

Talking Paper

# STATUS OF ORNL MODELS FOR HYDROGEN GENERATION IN BWR CORES

Background Model development has been necessary to support ORNL SASA program studies of severe accidents at the Browns Ferry BWR. Over the years, the special BWR models have been grafted onto the ORNL version of MARCH 1.1. Recently, we entered into a cooperative agreement with the SASA program at Sandia (SNL) and began the process of transferring these models from MARCH 1.1 to the SNL code MARCON, which is MARCH 2.0 with the corium-concrete reaction simulation subroutine INTER replaced by CORCON.

About two years ago, the special BWR models that had been created at that time were made available to BCL for incorporation into the then-under-development MARCH 2.0. Subsequently, the development of additional BWR models at ORNL, as necessary to support new SASA studies, has continued.

Current Status of the ORNL Version of MARCH 1.1 The special BWR models provided in the ORNL version of MARCH 1.1 that are not available in MARCH 2.0 are:

1. more extensive package for calculation of hydrogen and steam properties
2. improved equation of state for the hydrogen-steam mixture
3. improved depressurization algorithm
4. improved representation of safety/relief valve actuation effects
5. provision of heat transfer correlations for covered region of core
6. accurate calculation of reactor vessel water level
7. corrected $Zr/H_2O$ reaction algorithms
8. separation of fuel and cladding
9. separation of the water inventory in the reactor vessel into separate entities; core, lower plenum, and downcomer.

Current Status of the ORNL Version of MARCON All of the special BWR models available in the ORNL version of MARCH 1.1 have been incorporated into the ORNL version of MARCON except for item 9, separation of the water inventory. Incorporation of this item will be completed by the end of February.

Planned Future BWR Model Development at ORNL The only known requirement for the development of additional BWR models for currently planned SASA studies is the need to include an algorithm for the reaction of the control rod $B_4C$ powder with steam once the stainless steel control rod sheaths have been melted. It should be noted that the reaction of $B_4C$ with steam results in the liberation of a significant amount of hydrogen.

1/30/85

Enclosure 1 [illegible] meeting

Task 1 Establish most probable [illegible]

Task 7 Generation of hydrogen [illegible] histories.

Page No.

1 Attendees

2-4 [illegible] presented by [illegible]

5-32 Results of MARCH code [illegible] by [illegible]

33-49 Results of meltdown tests of [illegible] and SCDAP [illegible] by EG&G, Consultant to NRC.

50-56 Features of [illegible] MAAP [illegible] by EPRI

57-61 Results of study of [illegible] by Fauske & Associates [illegible] to NRC.

62-67 [illegible] summary [illegible] by [illegible]

③

January 30, 1985

Attendees

Meeting with Hydrogen Control Owners Group

| Name | Affiliation |
|---|---|
| CG TINKLER | CSB/NRR/NRC |
| JE Rosenthal | RSB/NRR |
| Chris Allison | EG+G |
| JIM HAN | [redacted] FSRB/RES/NRC |
| Marvin Morris | Gulf States Utilities |
| Bob Evans | Enercon Services Inc |
| Sam Hobbs | Mississippi Power & Light Company |
| K. I. PARCZEWSKI | NRC/NRR/CMEB |
| BRIAN SHERON | NRC/NRR/RSB |
| Kathy Ann Baker | Illinois Power Company |
| Jiwu Yang | Brookhaven National Lab. |
| [illegible] | ORNL |
| [illegible] | [illegible] |
| Garry R Thomas | EPRI |
| Allen Wang | ACRS |
| Pat Worthington | DAE/CSRB/RES |
| W. R. BUTLER | NRC/CSB |
| A. Notafrancesco | NRC/CSB |
| MJ MANSKI | MP+L |
| James Haley | MP+L |
| T. J. WALKER | RES/DAE |
| Fulvio Nistico' | ENEA (ITALY)/NRC-RSB |
| Eileen Buzzelli | CLEVELAND ELECTRIC ILLUMINATING |
| John D. R[illegible] | ENERCON SERVICES INC |
| W. Johnston | AD |
| L. Kintner | PM LB-4, DL, NRR |
| Marc Wigdor | RSB/NRR |
| Hideo Komoriya | ITS |

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## GOALS FOR THE JANUARY 30 MEETING

- o Review NRC contractor analysis of degraded core hydrogen production using MARCH
- o Discuss PBF test results and other relevant test data
- o Discuss items identified in 1/23 meeting
- o Resolve basis for selecting hydrogen release history as input to 1/4 scale test facility by either:
  - Agreeing upon acceptable basis for using BWR Core Heatup Code
  - Agreeing upon non-mechanistic approach
- o Select hydrogen release history for input to 1/4 scale test program

SUMMARY OF
OPEN ISSUES

- o Should evaluate ECCS reflood hydrogen release history in the test facility

- o Station blackout should be considered in procedures and scenario.

- o Definition of recoverability

- o Hydrogen generation events are likely to produce significant control rod damage. EPG's should direct operator to initiate SLC and throttle injection to prevent SLC dilution.

- o Hydrogen predictions from the BWR Core Heatup Code do not agree with predictions from MARCH

- o Hydrogen predictions shown to date are in vessel, not necessarily at suppression pool surface

- o Compromise possible by using non-mechanistic hydrogen release history

# REVIEW OF MARCH ANALYSIS

- o Identify version of MARCH used for analysis
- o Assess assumptions used in MARCH analysis
  - Compare to assumptions used in BWR Core Heatup Code Analysis
  - Compare to expected degraded core pheonomena
- o Discuss reasonableness of results
  - Hydrogen production predictions
  - Core behavior

Table 1 Summary of MARCH Results (Transient Time = 150 Minutes)

| Case | Cooling Water Injection | | TMWOFF* | % Oxidation | | | % Melt | | | $H_2$ Production, | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | gpm | (min) | (3860F) (2400K) | Clad | Channel Box | Control Blade | Clad | Channel Box | Control Blade | Clad | Channel Box |
| A | 0 | - | Yes | 30 | 16 | 25 | 65 | 100 | 100 | 1130 | 480 |
| B | 300 | 43.3 | Yes | 31 | 29 | 65 | 0 | 35 | 77 | 1140 | 870 |
| C | 300 | 70 | Yes | 35 | 30 | 45 | 19 | 85 | 100 | 1290 | 900 |
| D | 300 | 75.5 | Yes | 33 | 29 | 42 | 27 | 90 | 100 | 1210 | 870 |
| E | 500 | 75.5 | Yes | 33 | 24 | 28 | 14 | 81 | 98 | 1230 | 730 |
| F | 7450 | 75.5 | Yes | 27 | 14 | 10 | 0.5 | 71 | 91 | 995 | 420 |
| G | 7450 | 75.5 | No | 45 | 12 | 10 | 35 | 76 | 93 | 1660 | 360 |
| H | 0 | - | No | 77 | 45 | 19 | 100 | 100 | 100 | 2840 | 1350 |

*TMWOFF = Zr/steam reaction cut-off temperature.

Table 1 Summary of MARCH Results (Transient Time = 150 Minutes)

| FF* | % Oxidation | | | % Melt | | | $H_2$ Production, lb | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| DF) DK) | Clad | Channel Box | Control Blade | Clad | Channel Box | Control Blade | Clad | Channel Box | Control Blade | Total |
| [illegible] | 30 | 16 | 25 | 65 | 100 | 100 | 1130 | 480 | 140 | 1750 |
| [illegible] | 31 | 29 | 65 | 0 | 35 | 77 | 1140 | 870 | 360 | 2380 |
| [illegible] | 35 | 30 | 45 | 19 | 85 | 100 | 1290 | 900 | 250 | 2400 |
| [illegible] | 33 | 29 | 42 | 27 | 90 | 100 | 1210 | 870 | 230 | 2290 |
| [illegible] | 33 | 24 | 28 | 14 | 81 | 98 | 1230 | 730 | 150 | 2110 |
| [illegible] | 27 | 14 | 10 | 0.5 | 71 | 91 | 995 | 420 | 55 | 1490 |
| [illegible] | 45 | 12 | 10 | 35 | 76 | 93 | 1660 | 360 | 55 | 2075 |
| [illegible] | 77 | 45 | 19 | 100 | 100 | 100 | 2840 | 1350 | 110 | 4300 |

tion cut-off temperature.

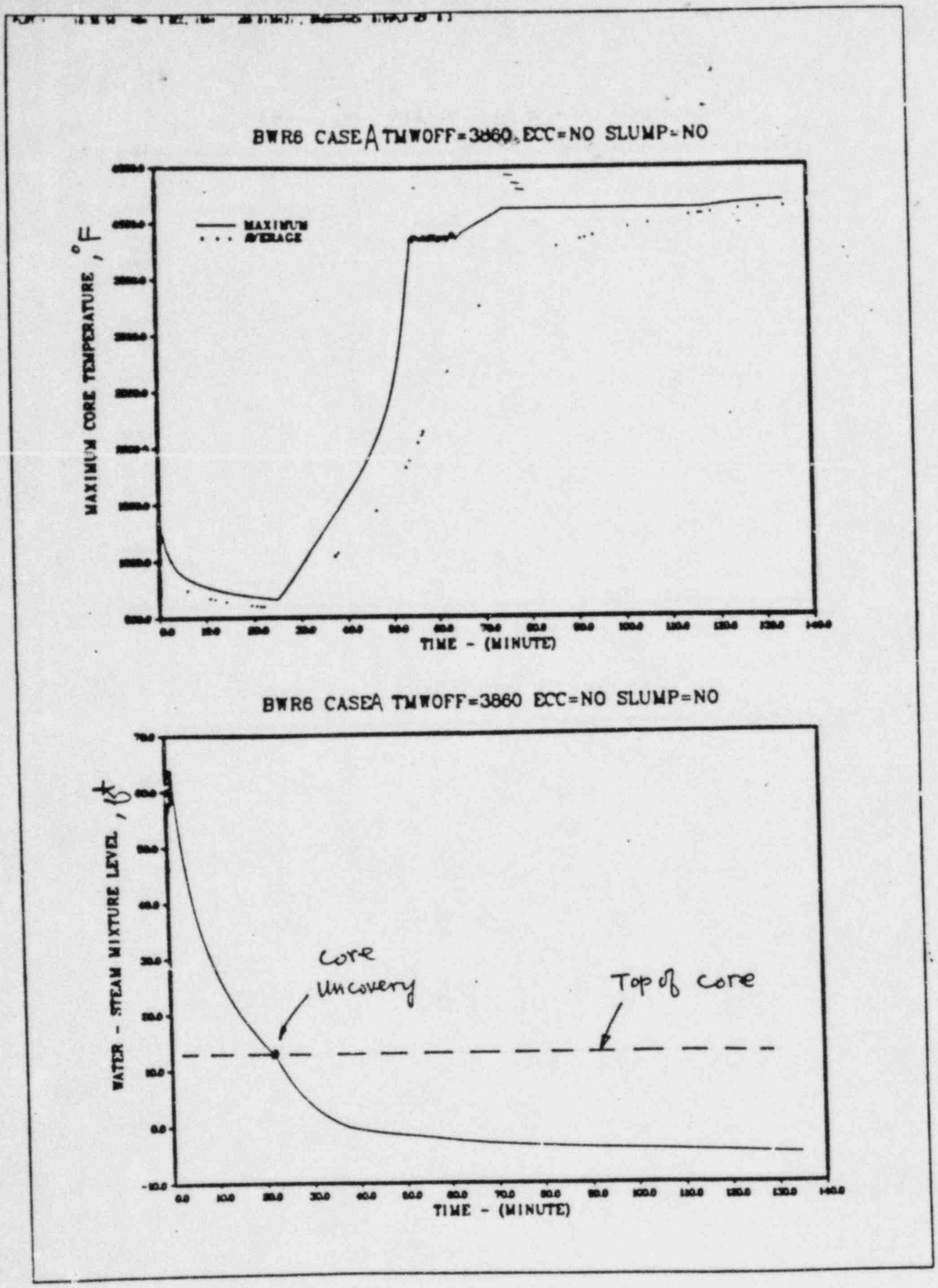



Figure 1 Case A: Core Temperature and Water level

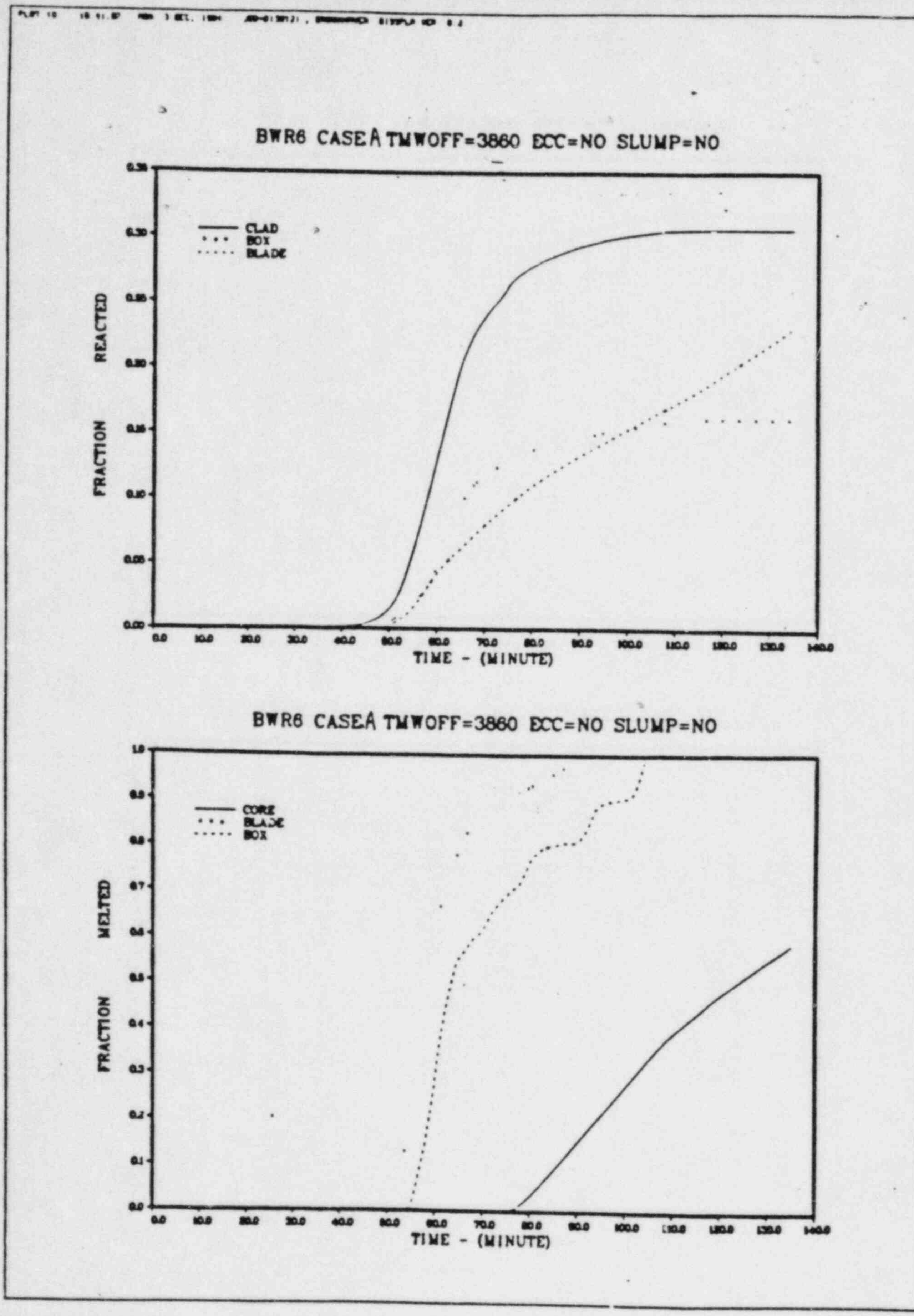
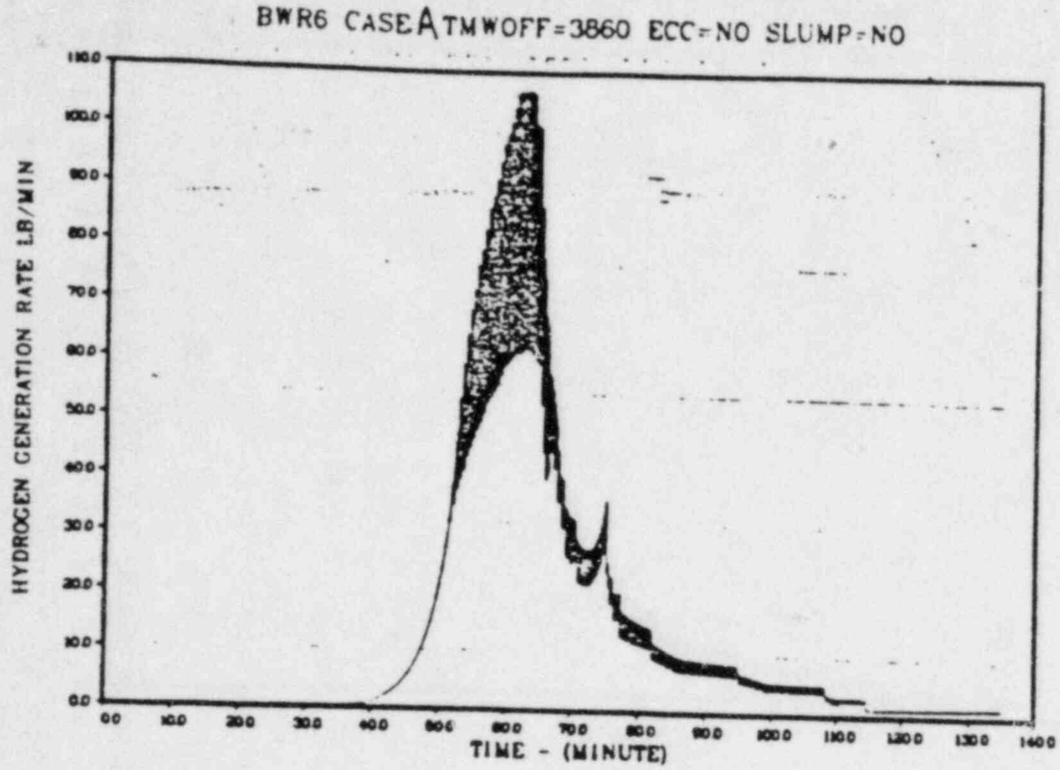



Figure 2 Case A: Fraction Reacted and Fraction Melted



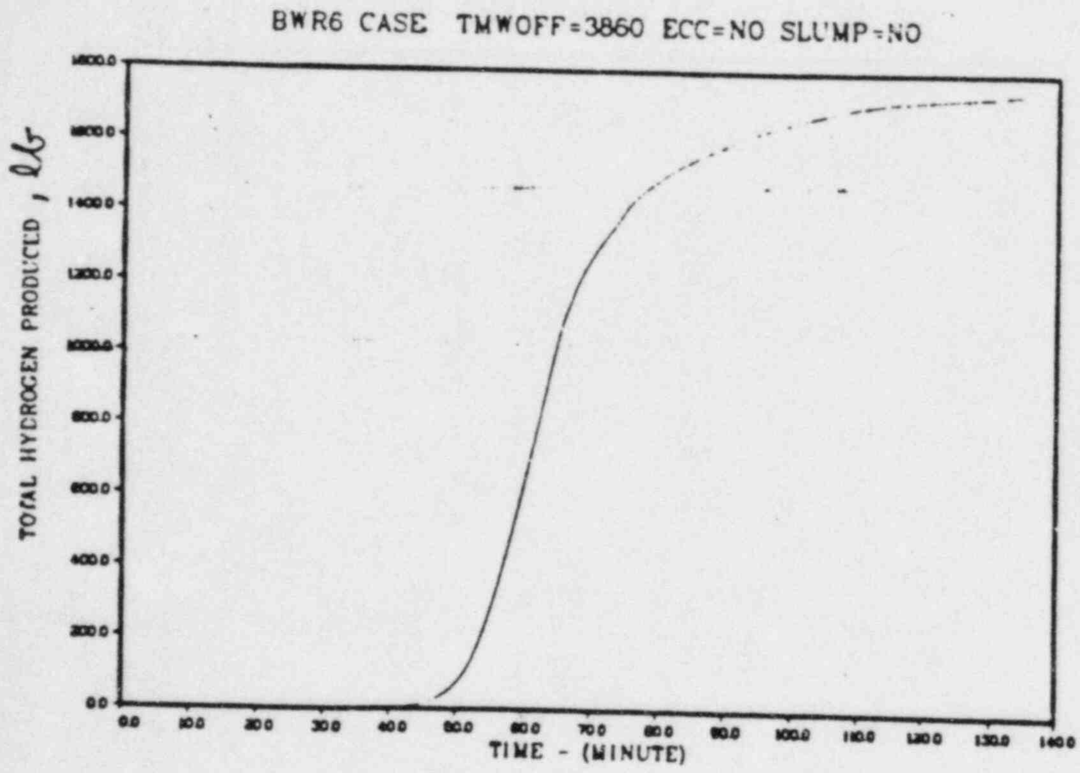




Figure 3 Case A: Hydrogen Generation

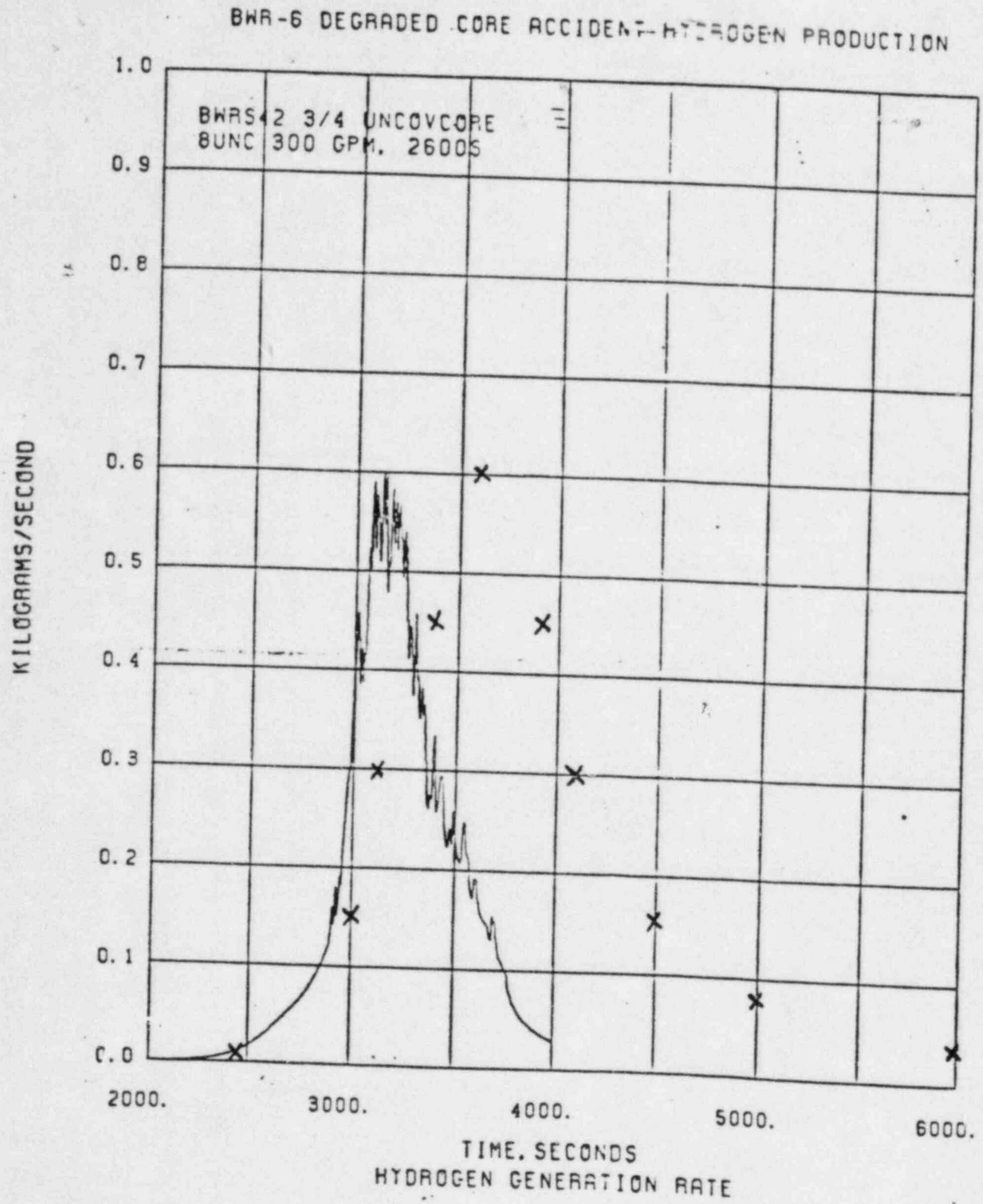



Figure 4 Comparison of $H_2$ generation Rate

—— HCOG sample problem

× MARCH Case A

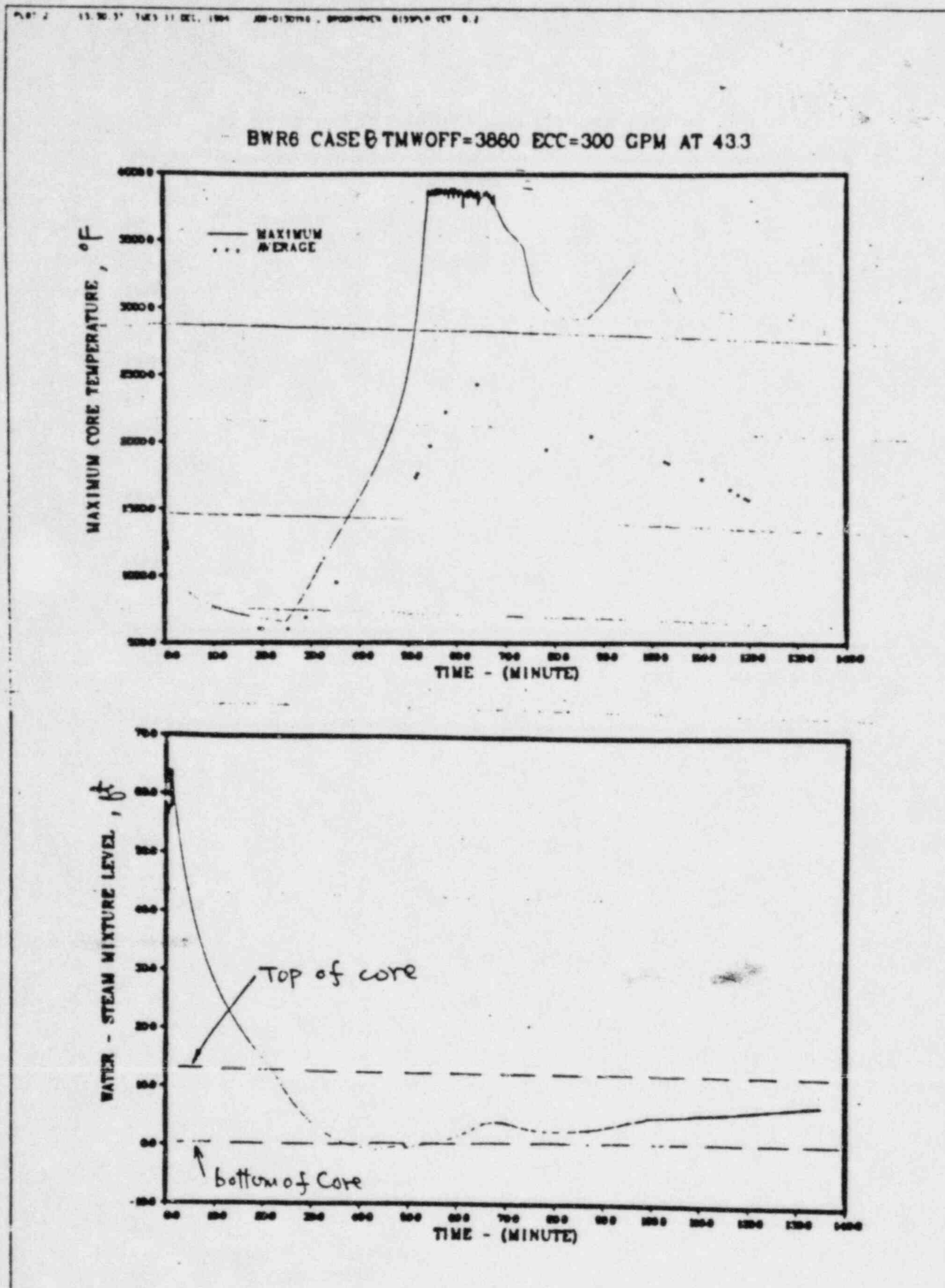



Figure 5 Case B: Core Temperature and Water Level

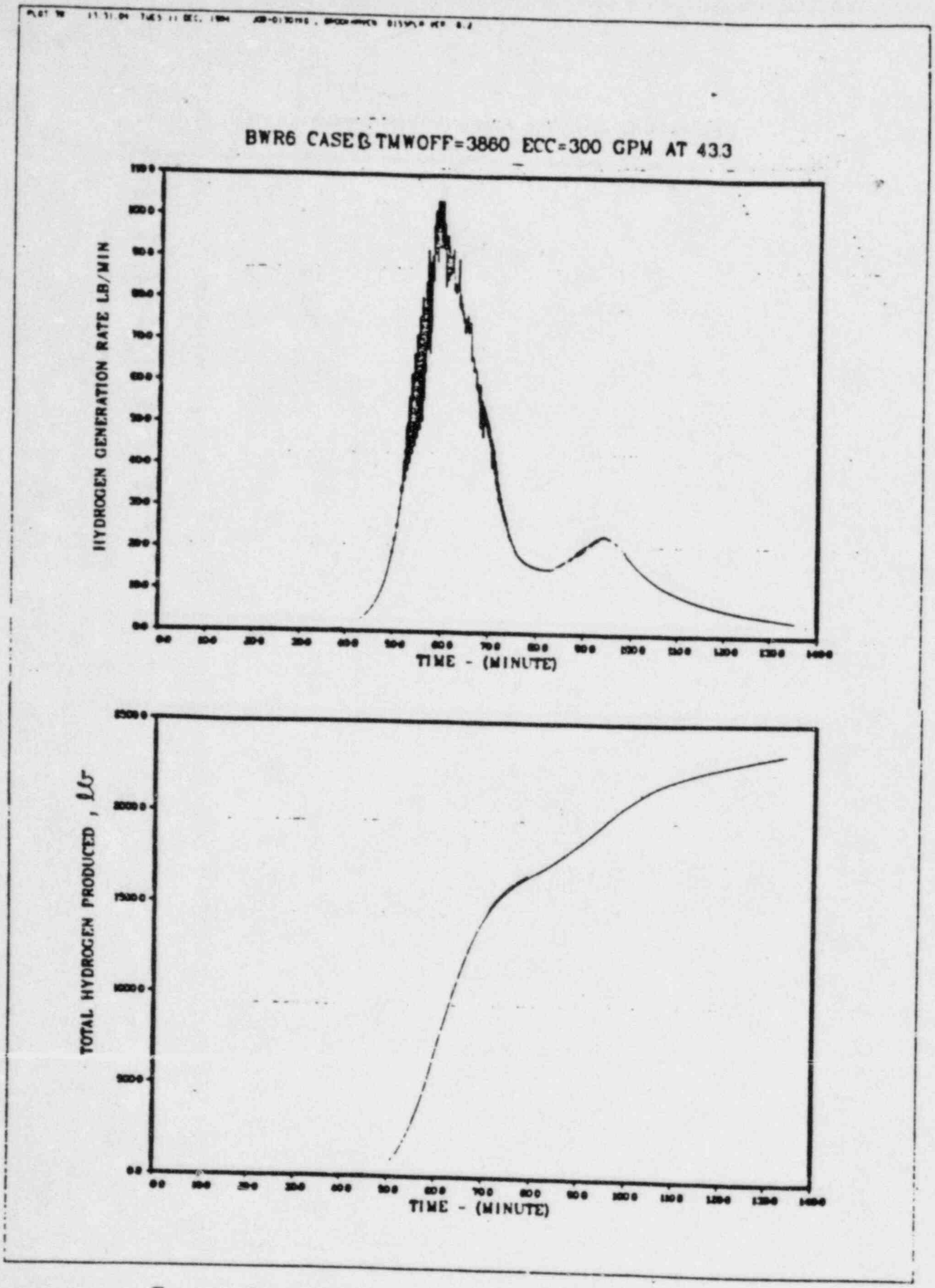



Figure 6: Case B: Hydrogen Generation

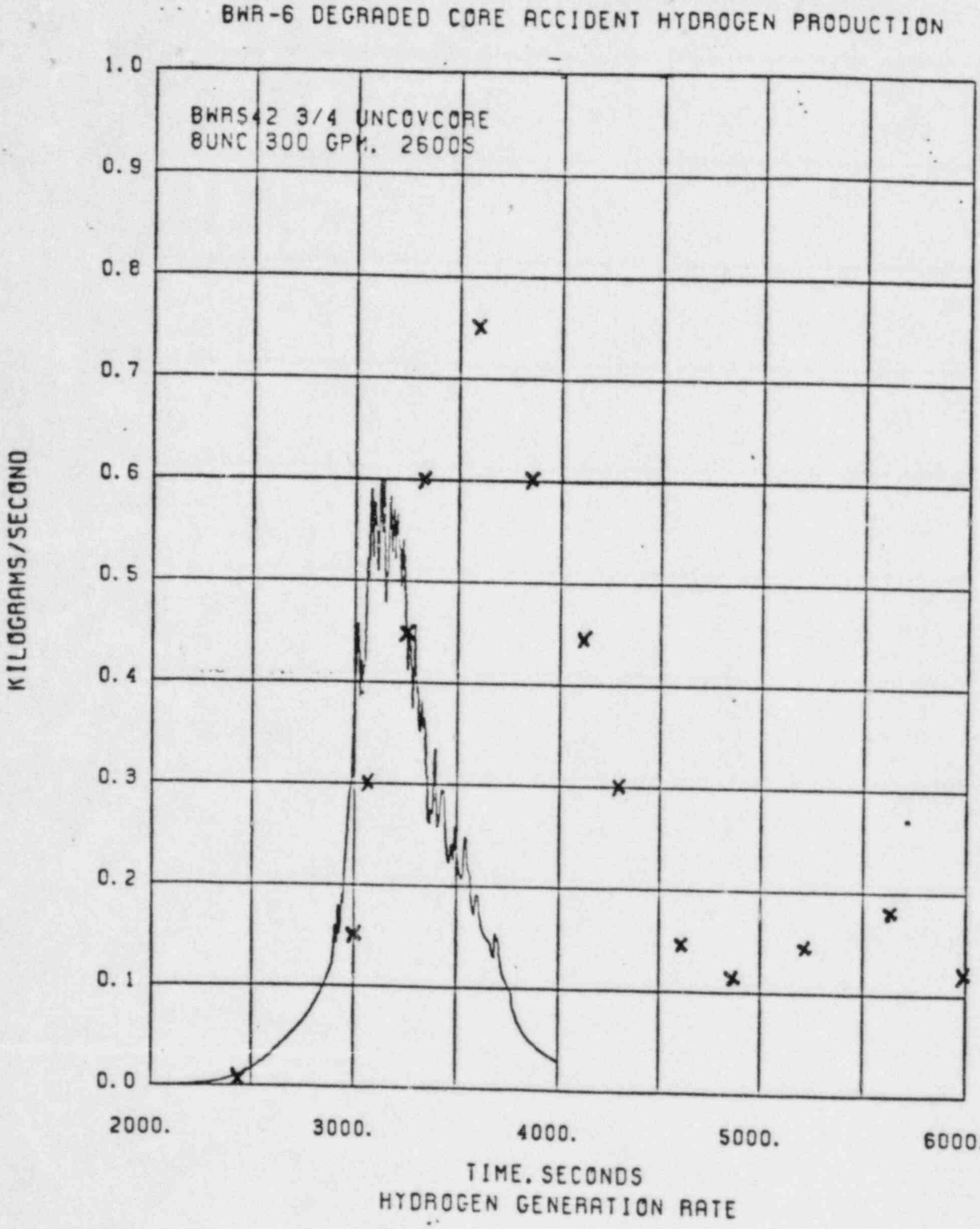



Figure 7 Comparison of $H_2$ Generation Rate

—— HCOG Sample problem

X MARCH case B

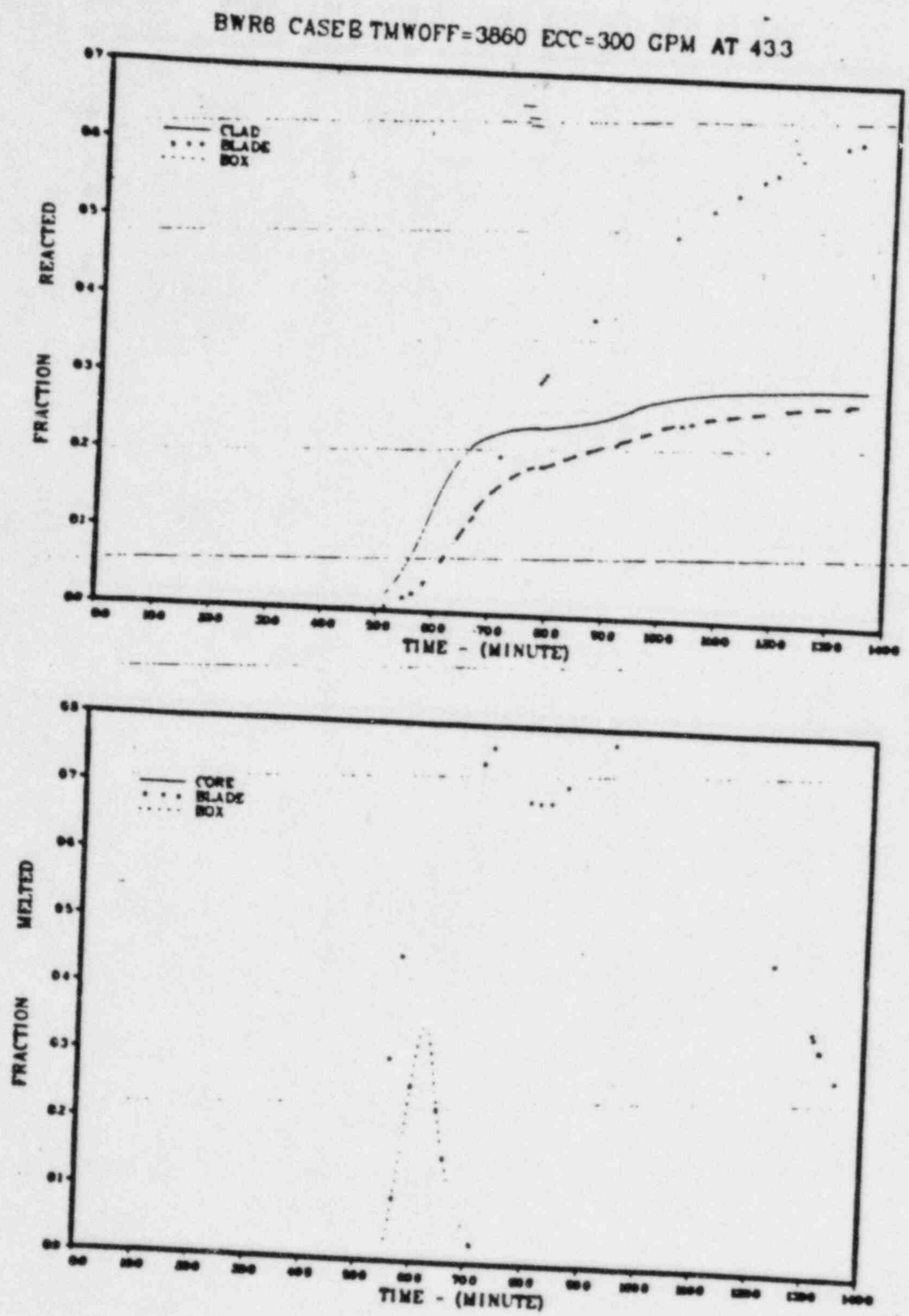



Figure 8 Case B Fraction Reacted and Fraction Melted

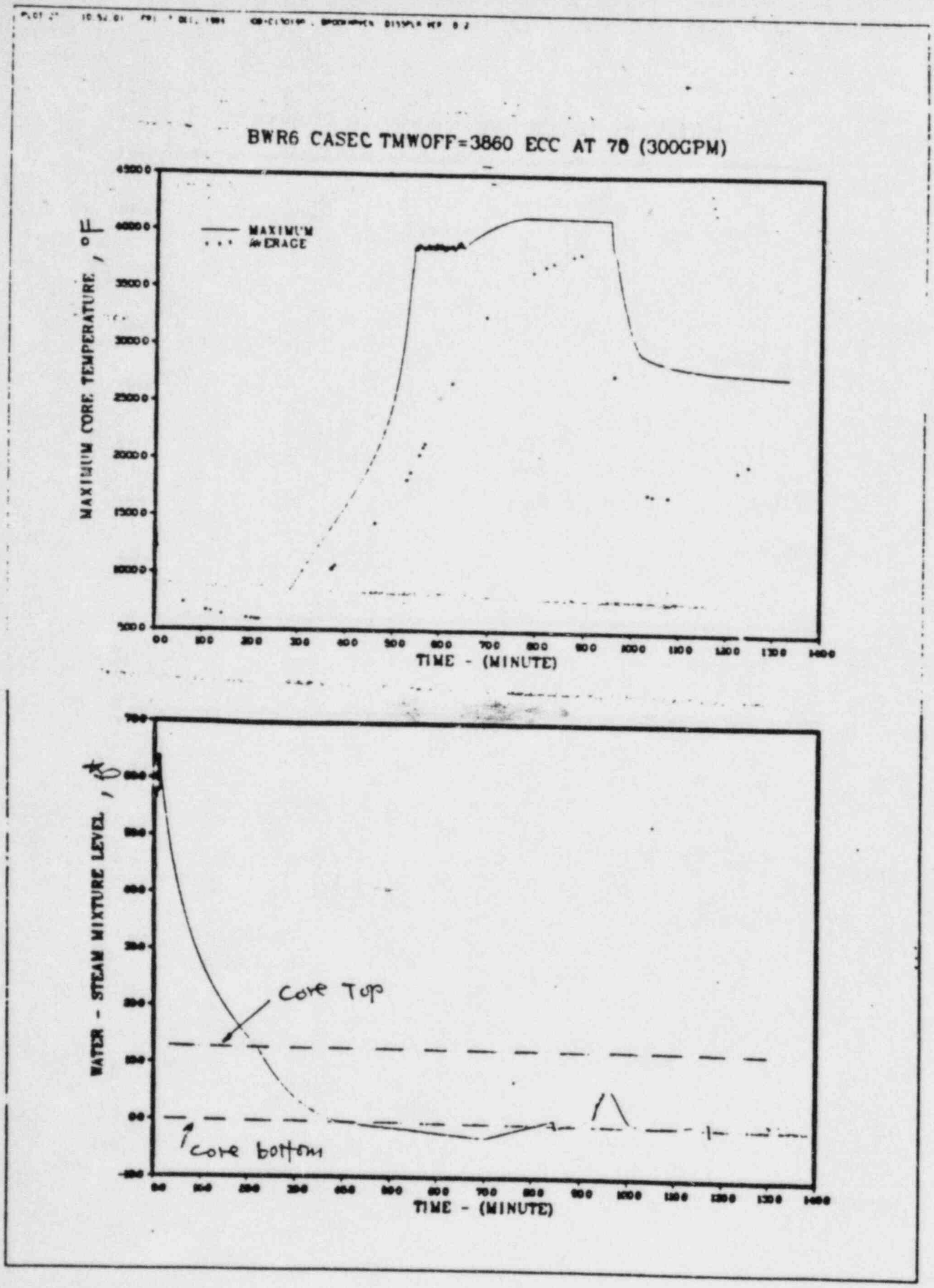



Figure 9 Case C: Core Temperature and Water Level

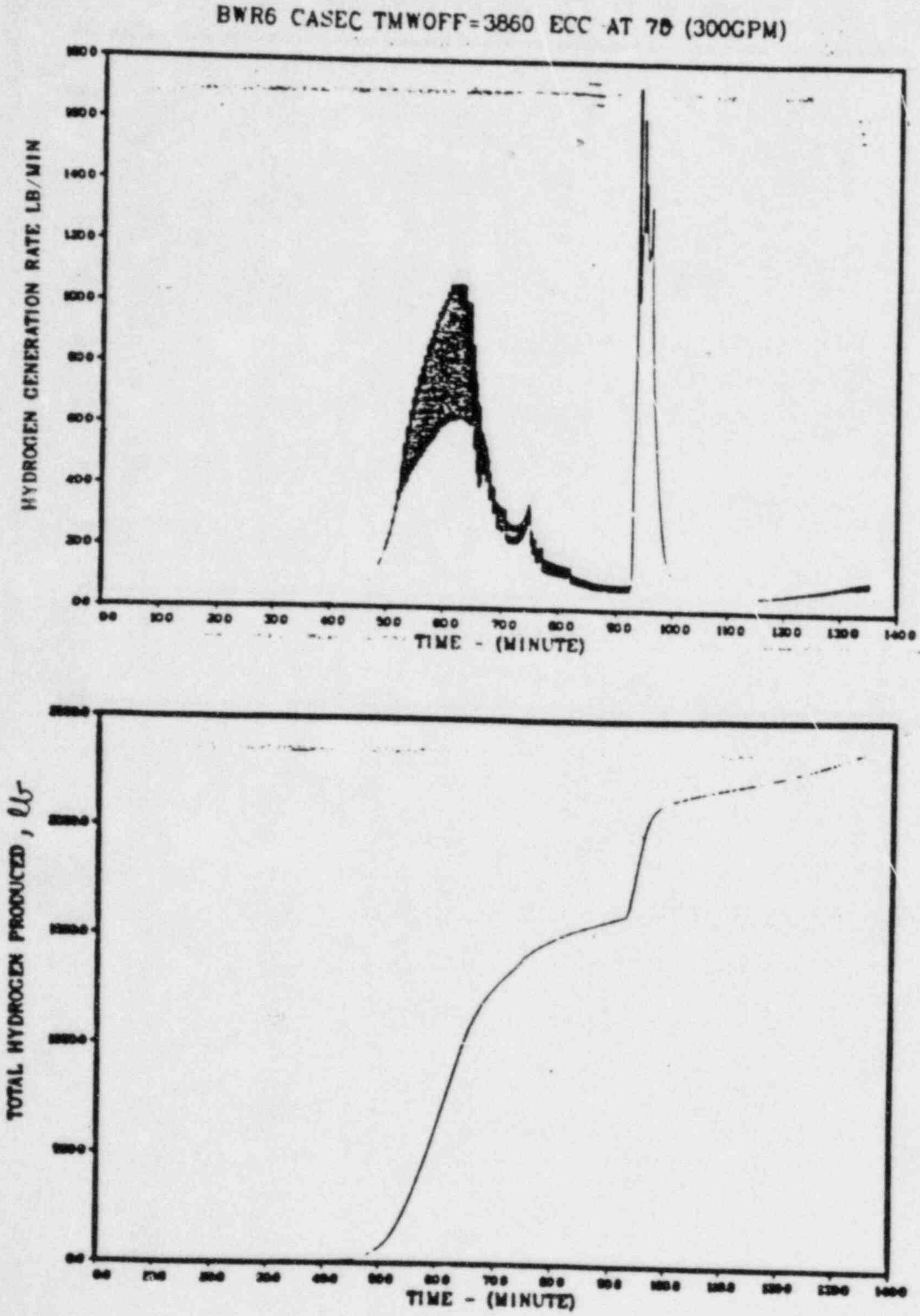



Figure 10 Case C: Hydrogen Generation

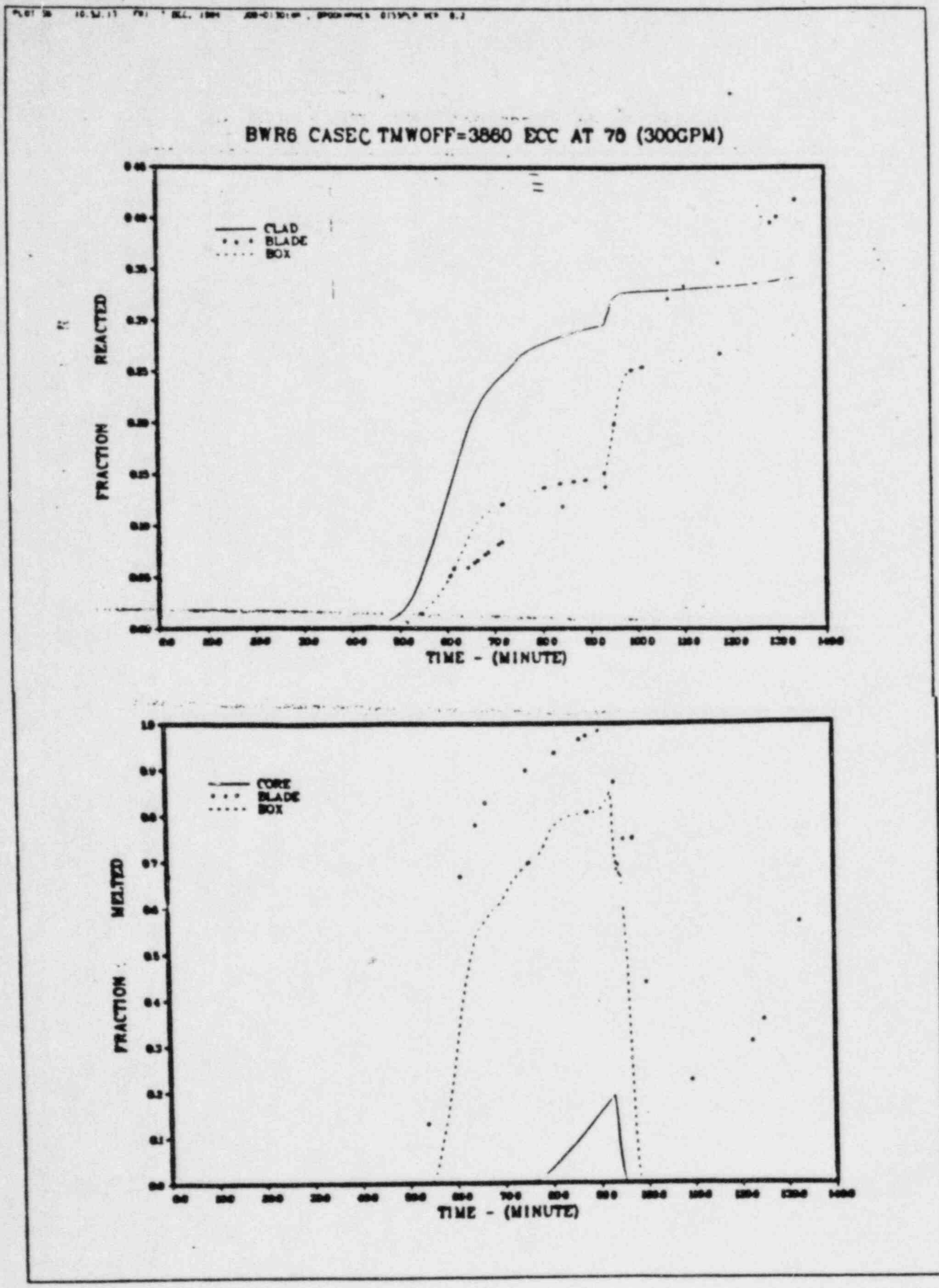



Figure 11 Case C: Fraction Reacted and Fraction Melted

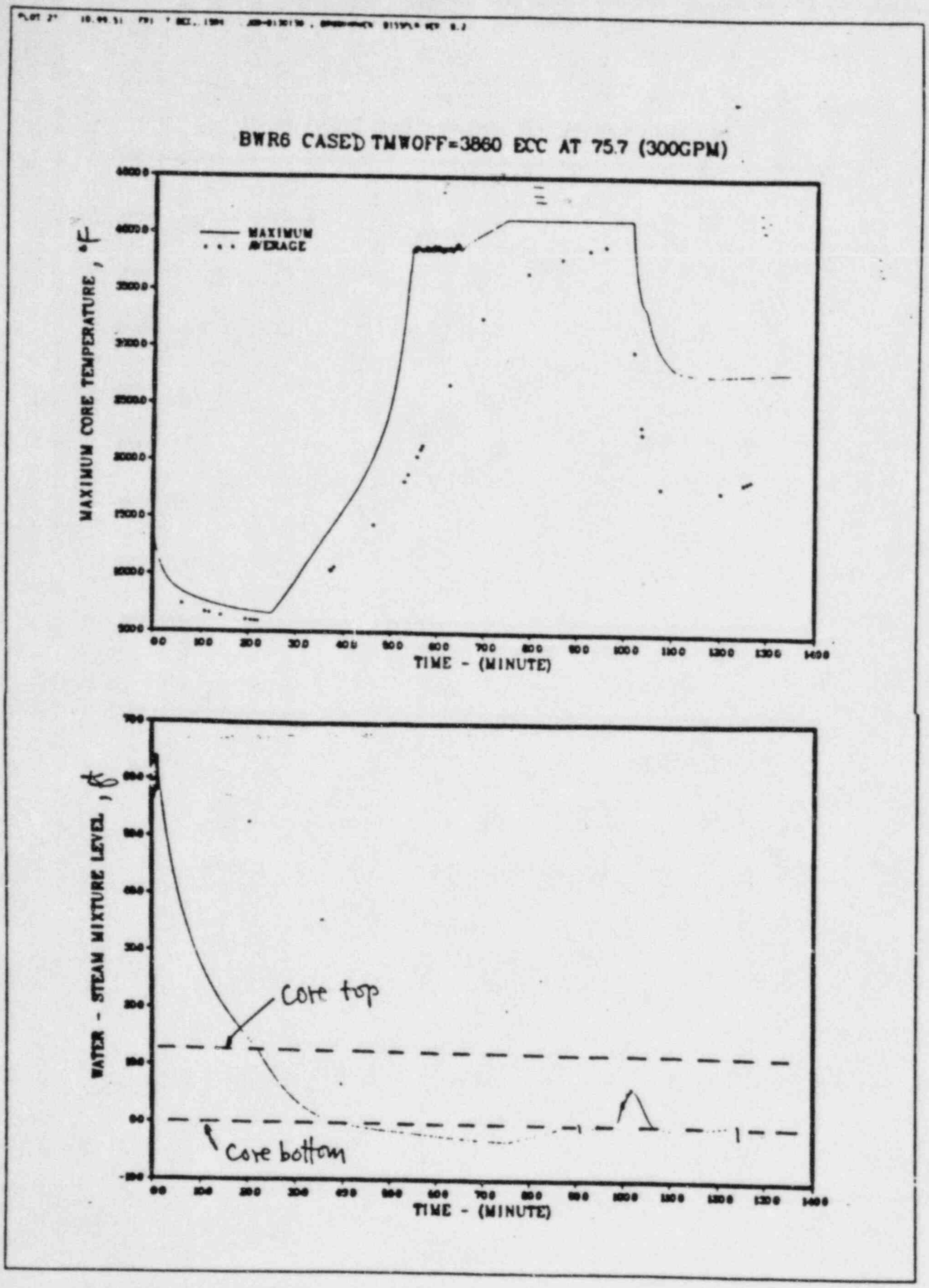



Figure 12 Case D: Core Temperature and Water Level

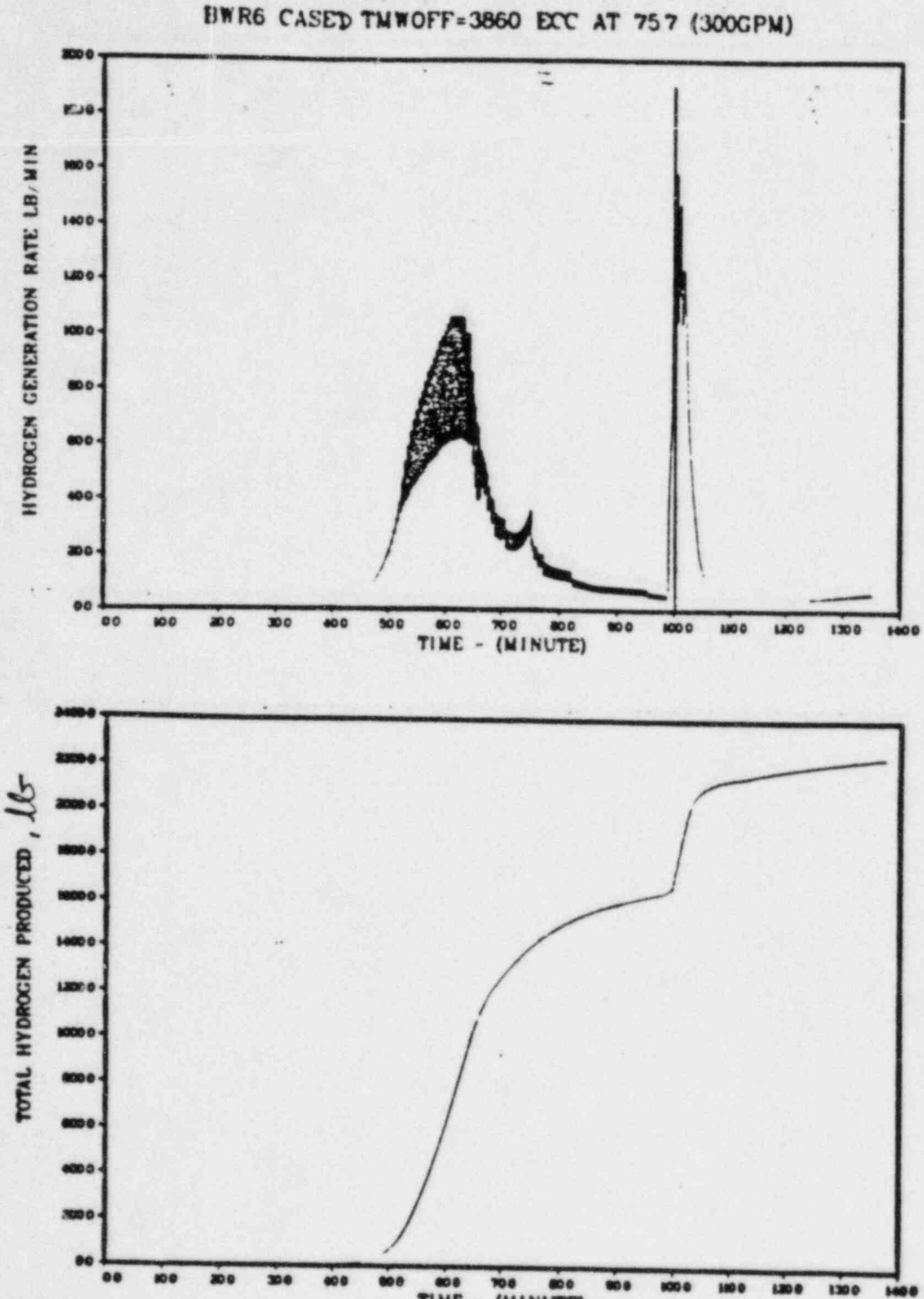



Figure 13 Case D: Hydrogen Generation

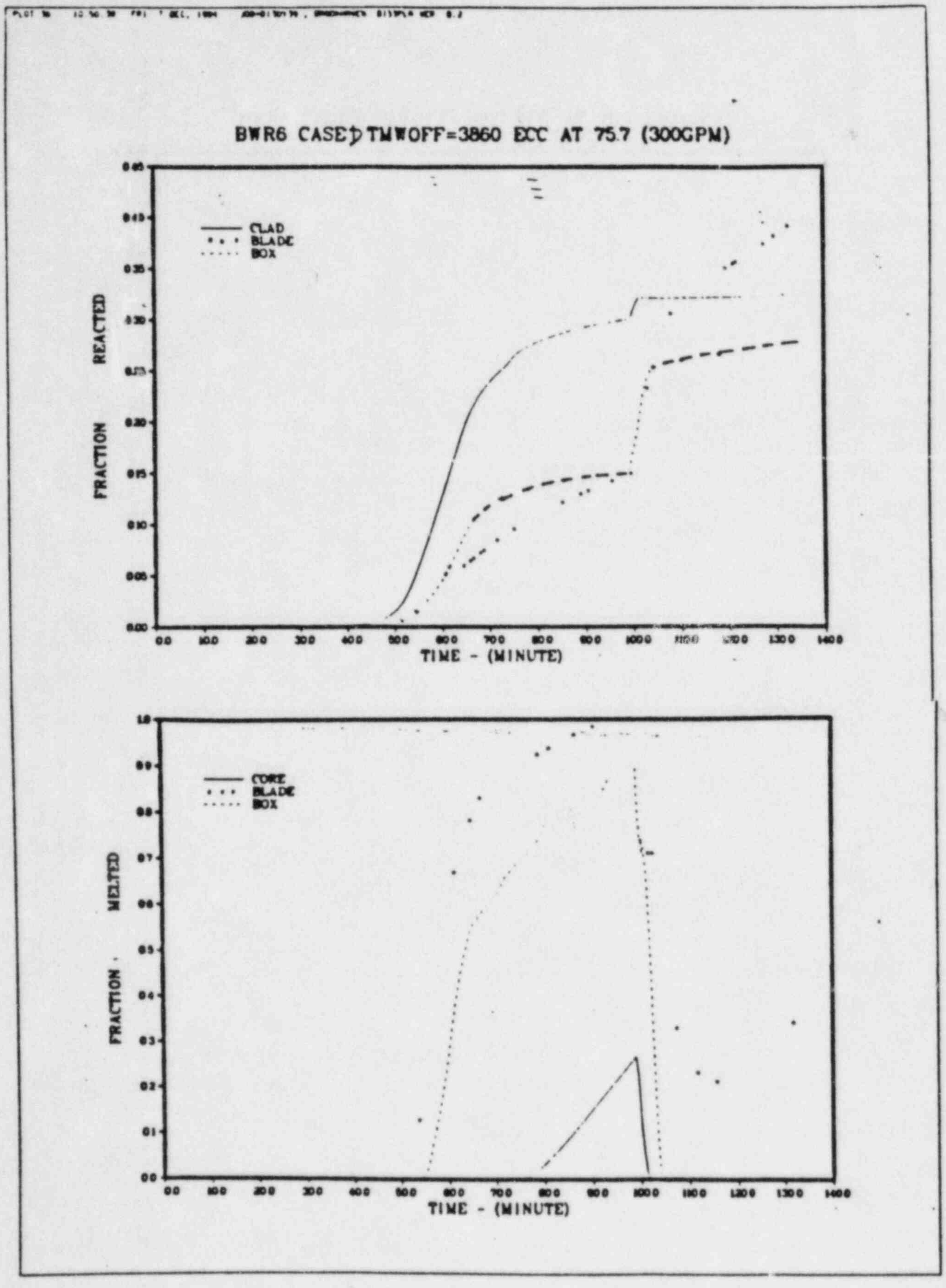



Figure 14 Case D: Fraction Reacted and Fraction Melted

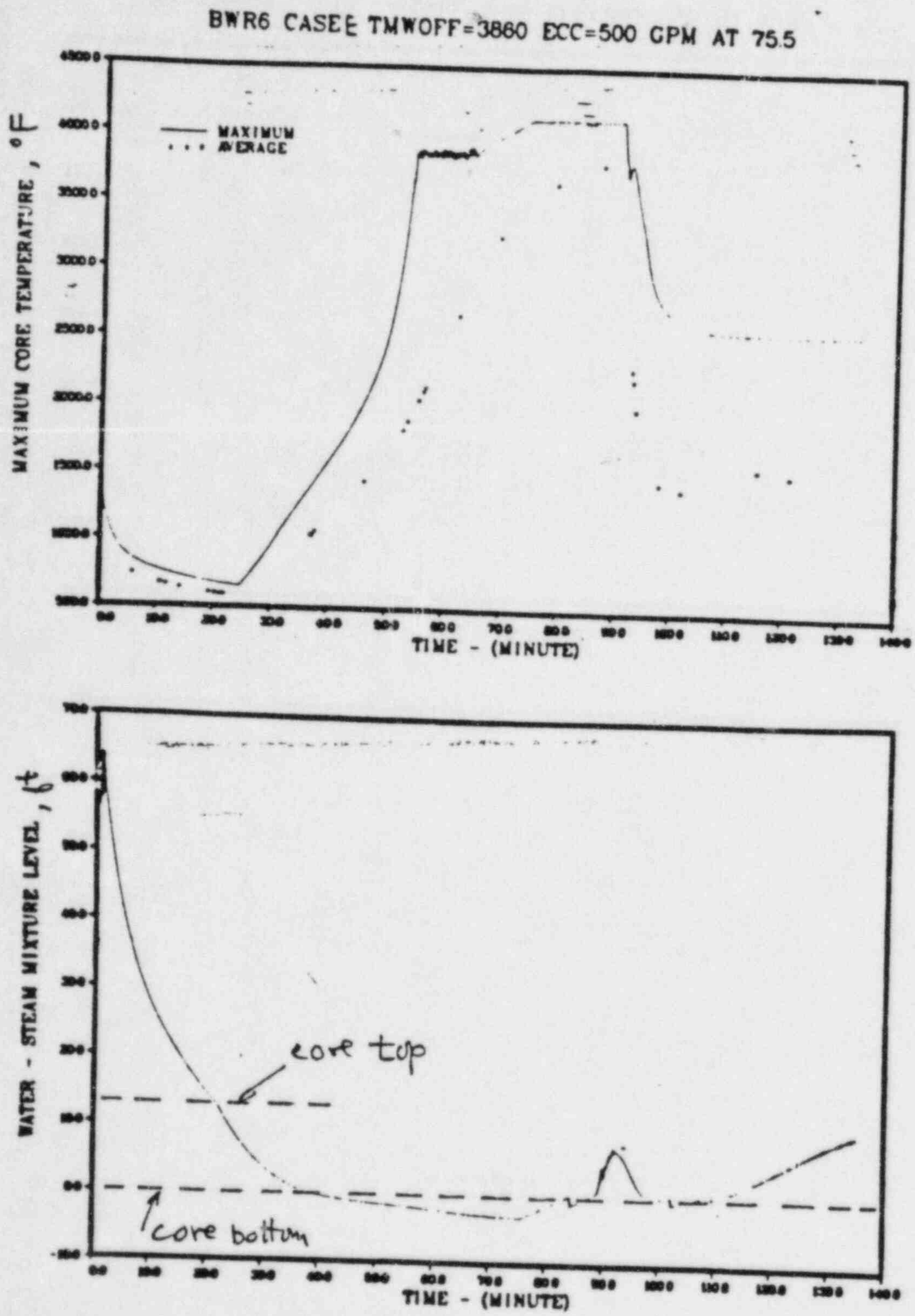



Figure 15 Case E: Core Temperature and Water Level

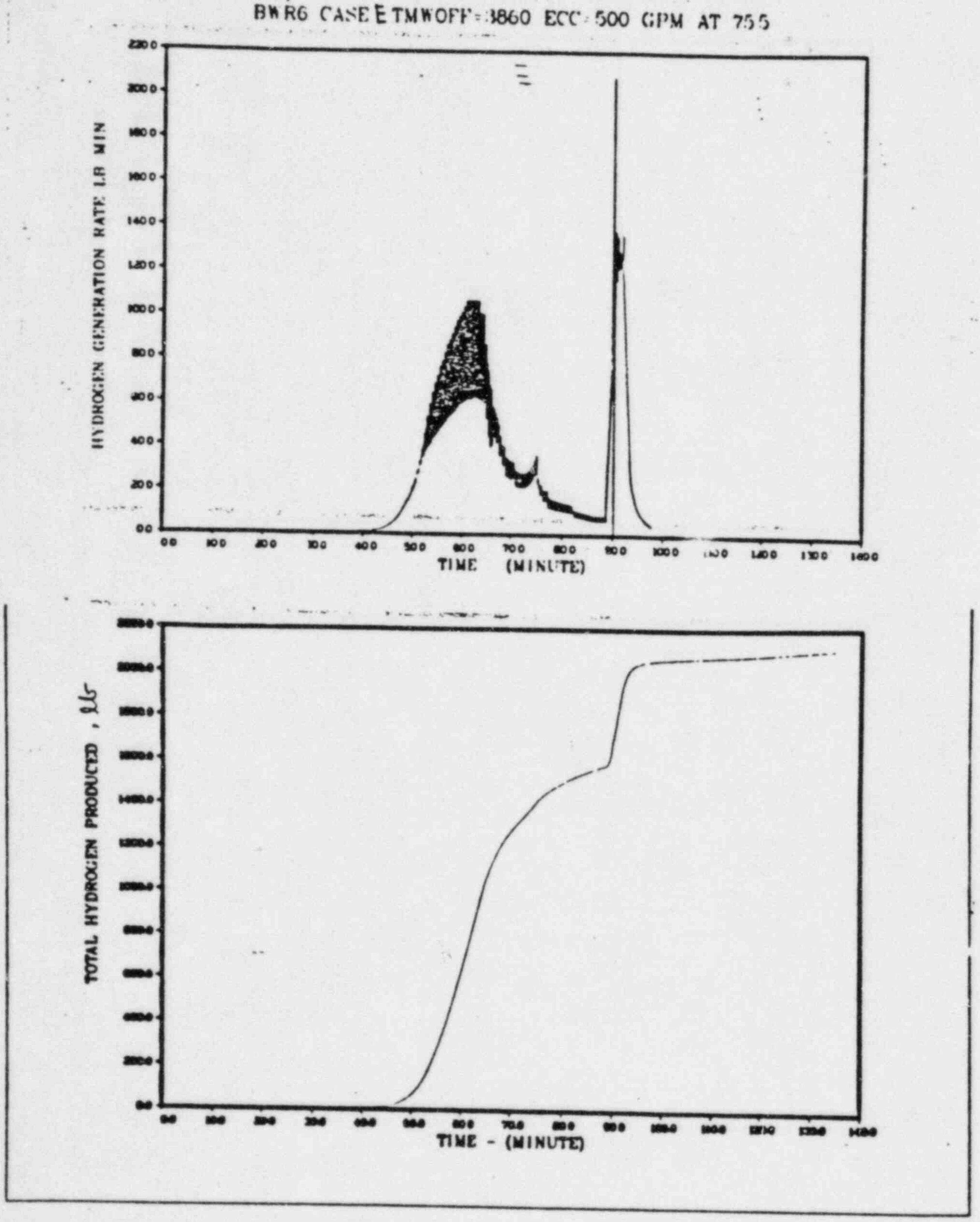



Figure 16 Case E: Hydrogen Generation

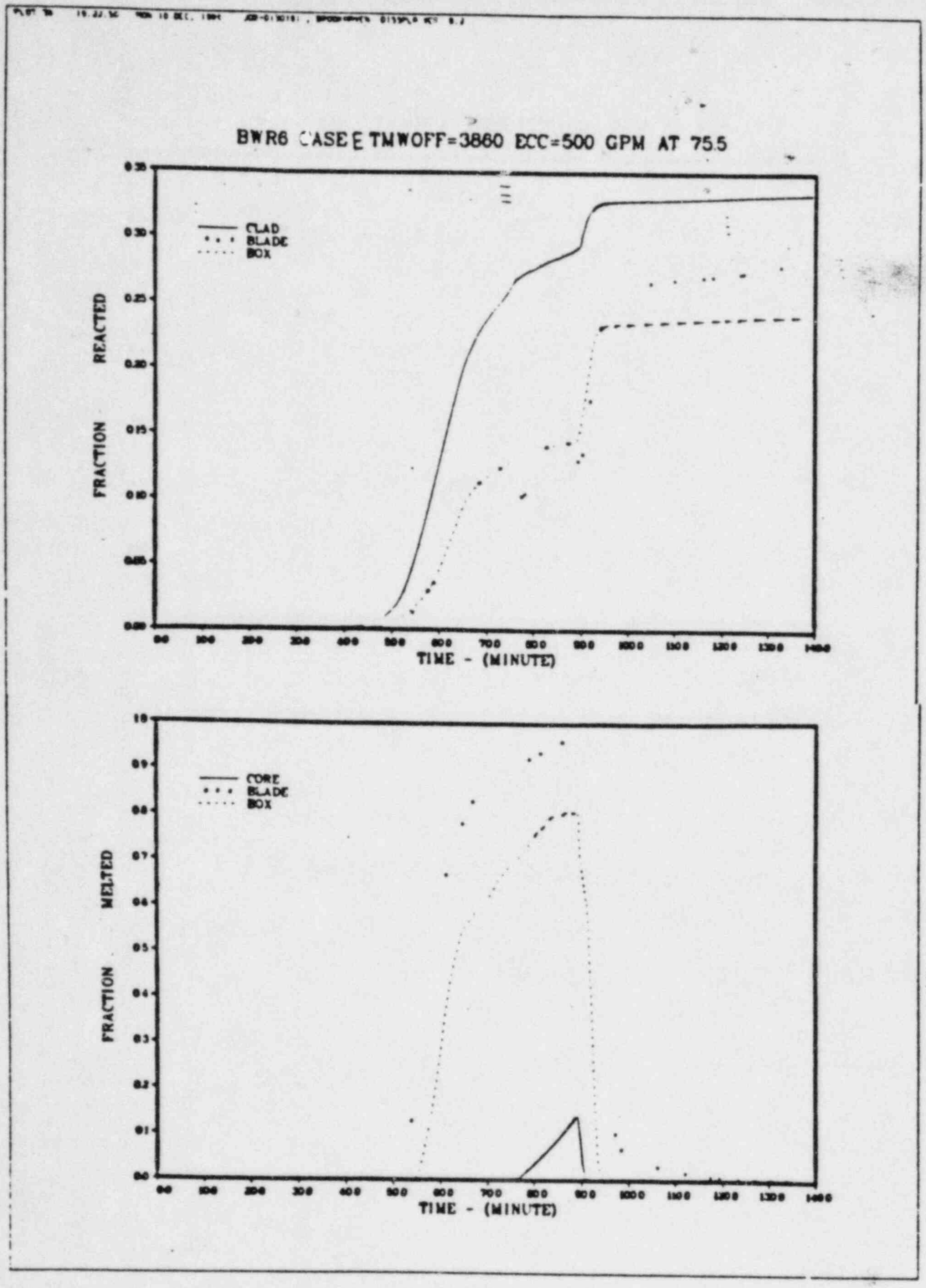



Figure 17 Case E: Fraction Reacted and Fraction Melted

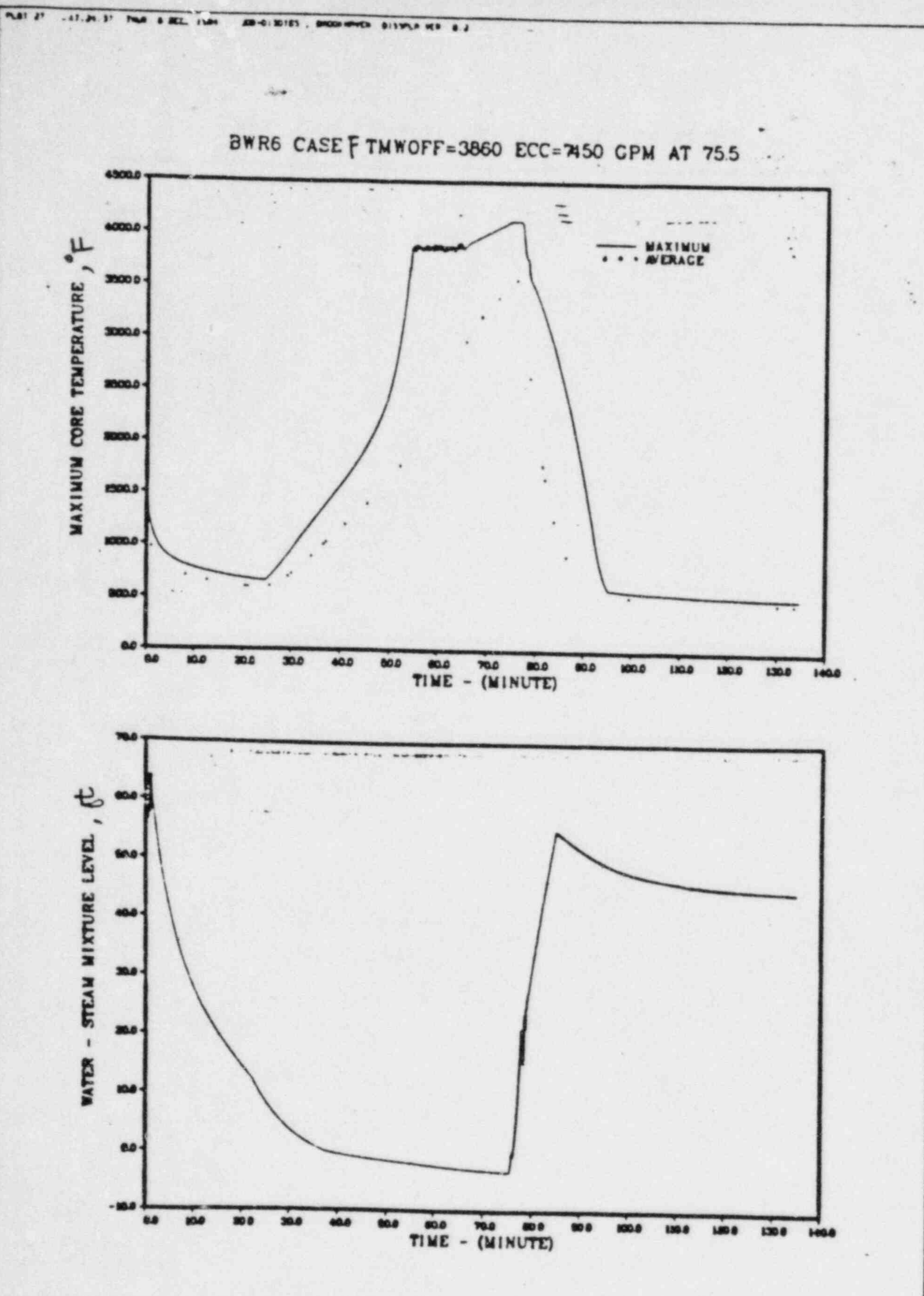



Figure 18 Case F: Core Temperature and Water Level

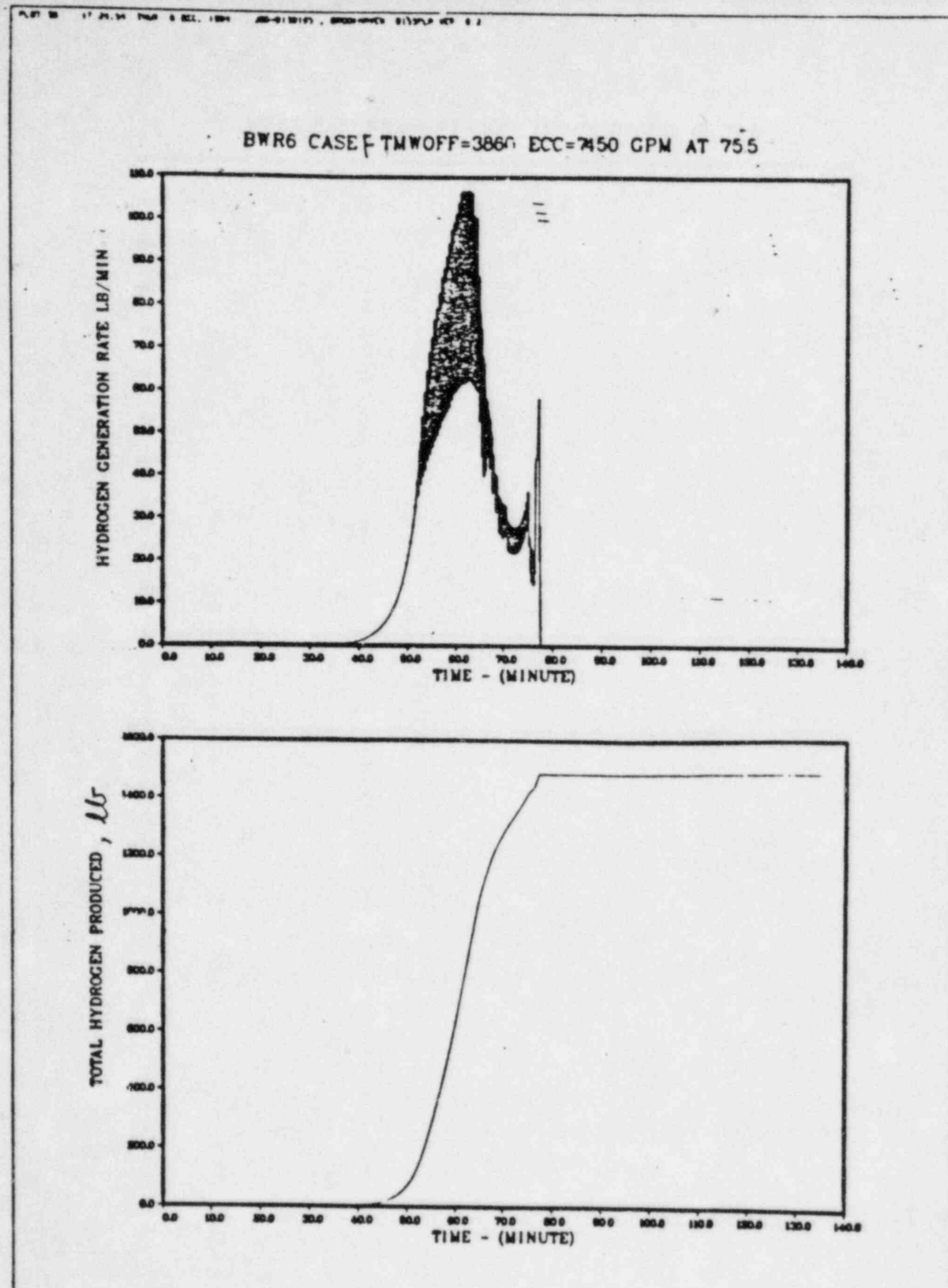



Figure 19 Case F: Hydrogen Generation

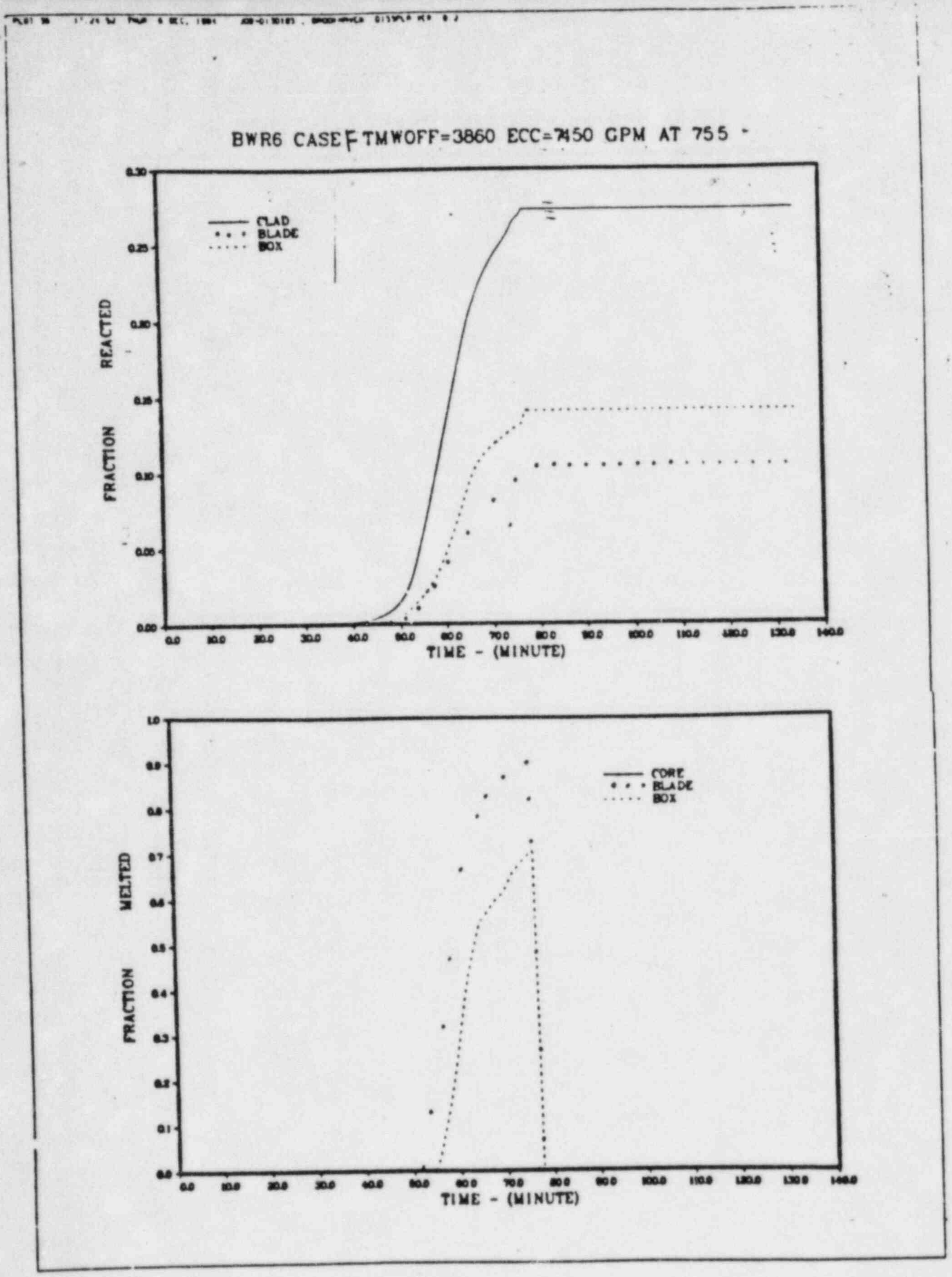



Figure 20 Case F : Fraction Reacted and Fraction Melted

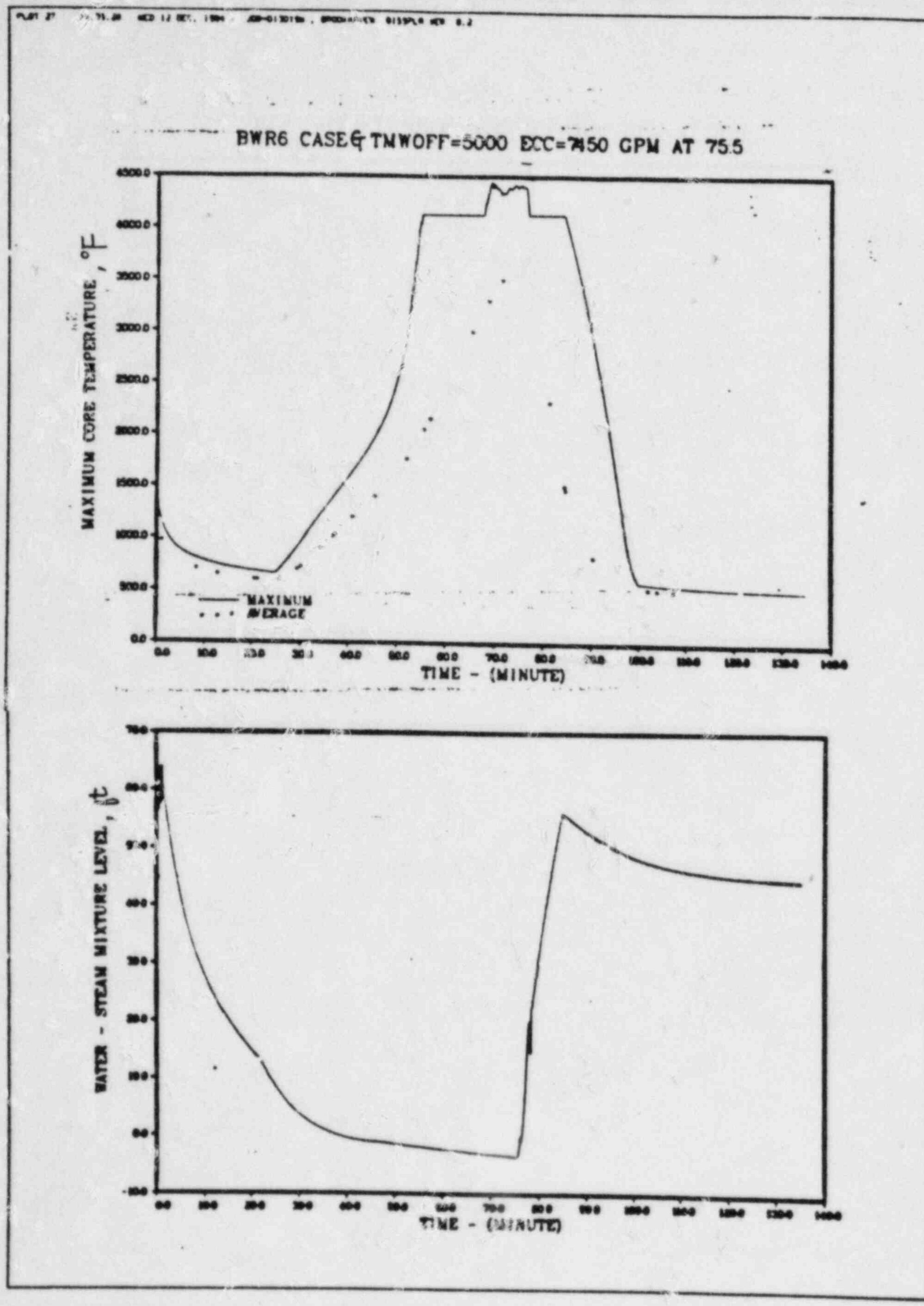



Figure 21 Case G: Core Temperature and Water Level

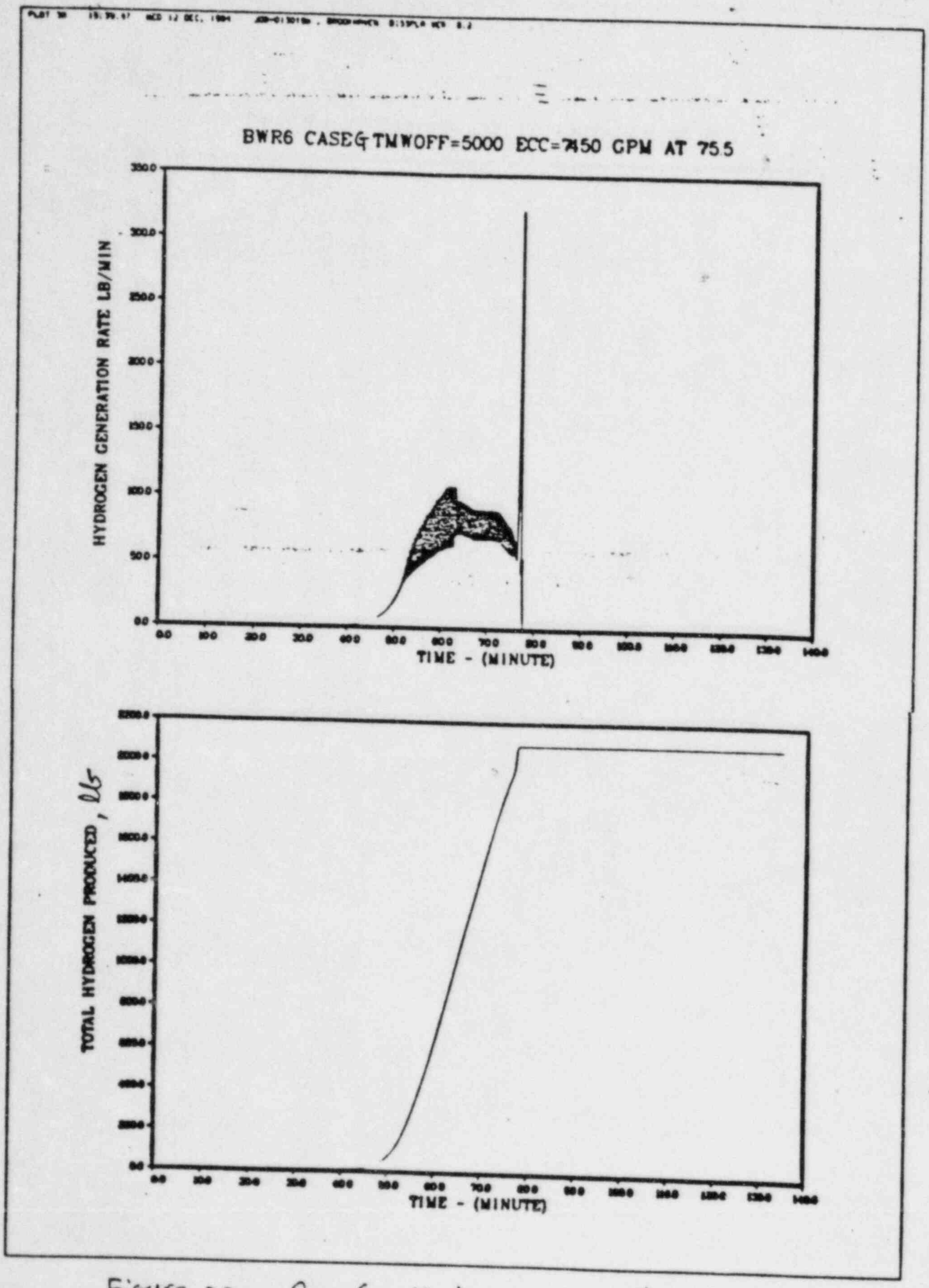



Figure 22 Case G: Hydrogen Generation

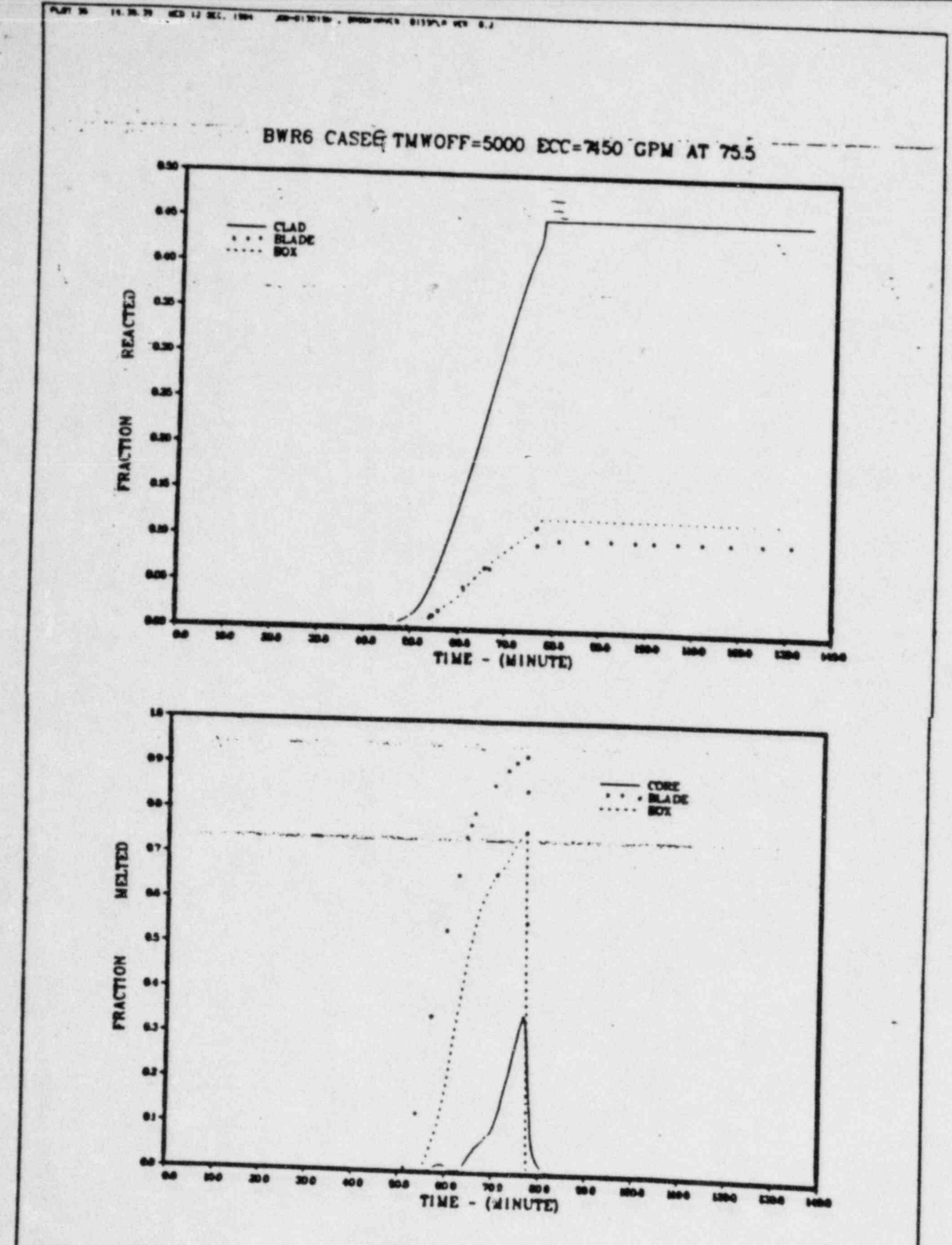



Figure 23 Case G: Fraction Reacted and Fraction Melted

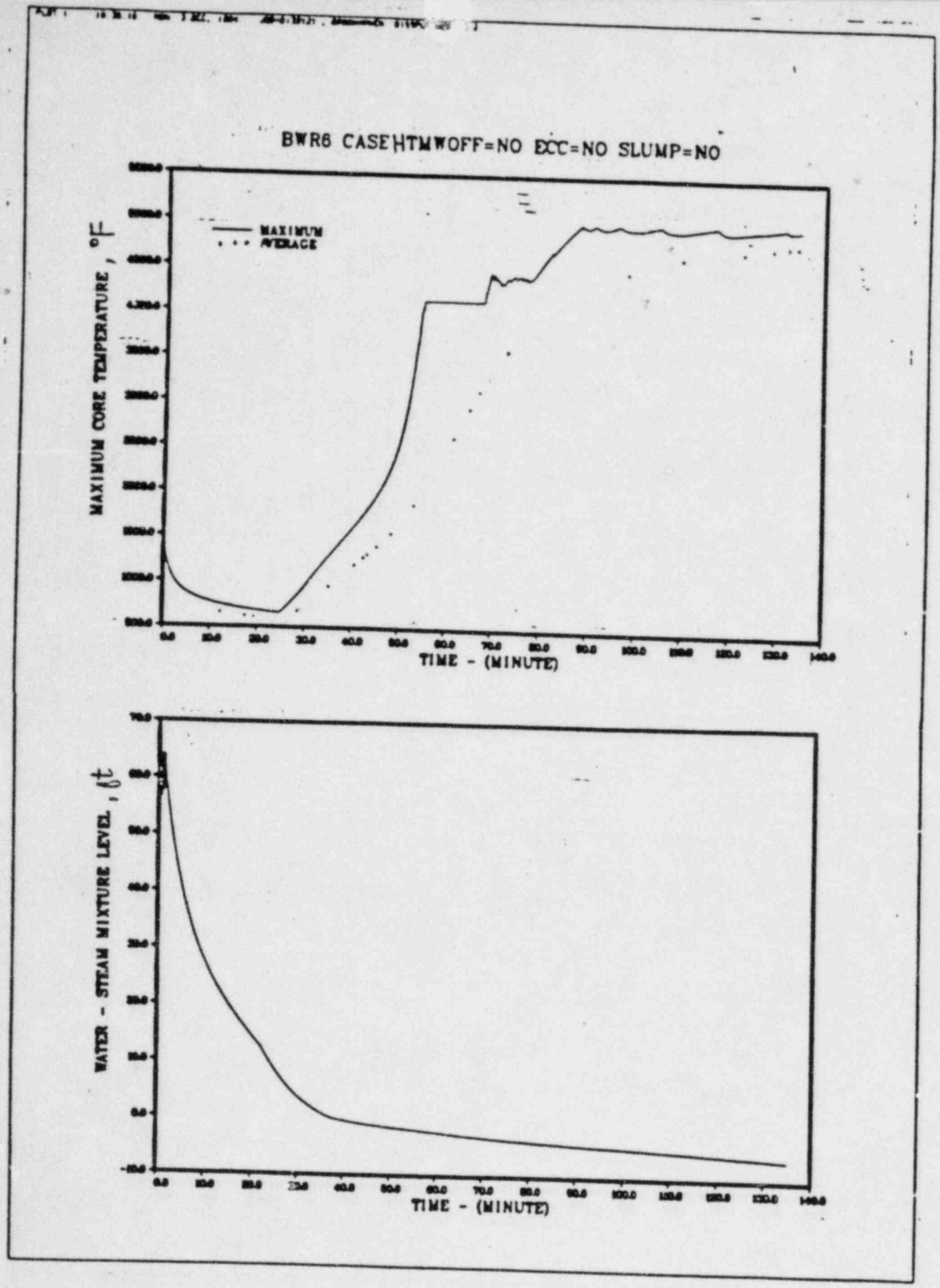



Figure 24 Case H: Core Temperature and Water Level

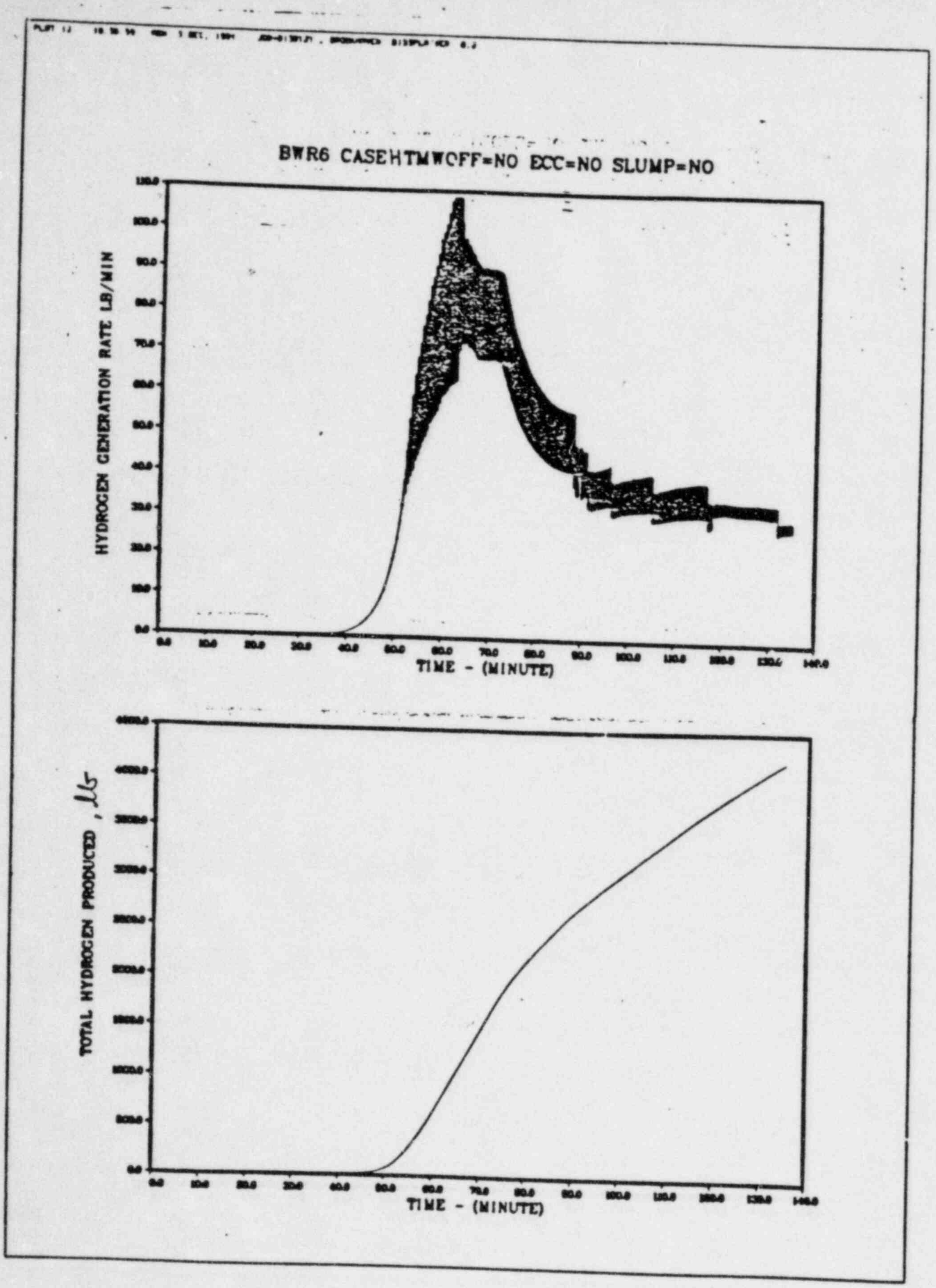



Figure 25 Case H: Hydrogen Generation

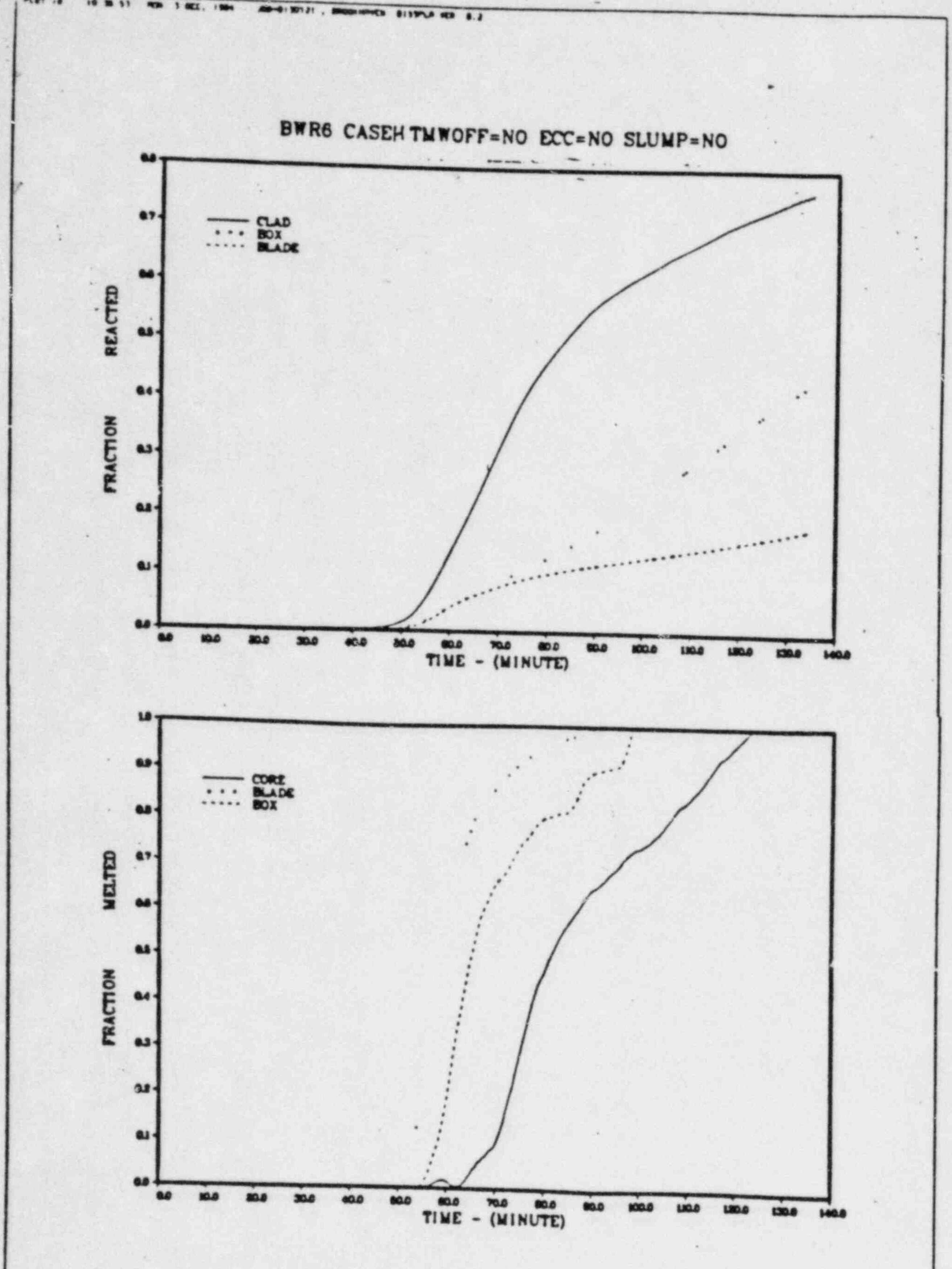



Figure 26 Case H: Fraction of Reacted and Fraction Melted

# Zircaloy Oxidation and Melting

C.M. Allison

EG&G Idaho, Inc.

# OUTLINE

- BRIEF REVIEW OF FUEL ROD HEATUP AND MELTDOWN EXPERIMENTS
- BRIEF REVIEW OF HYDROGEN PRODUCTION DATA AND SCDAP ANALYSIS

## HAGEN AND SFD EXPERIMENTS

- CONDITIONS NECESSARY FOR FLOW BLOCKAGES ARE NOT WELL UNDERSTOOD BUT ARE STRONG FUNCTIONS OF:
  - ZIRCALOY OXIDATION (INITIAL DT/DT)
  - PEAK TEMPERATURE
  - $\Delta$ P
- LIQUEFIED FLOW RANGES FROM
  - NO FLOW - EXTENSIVE OXIDATION, STRONG - $\Delta$ P
  - NON WETTING AND WETTING RIVULET FLOW

    INTERNAL TO $ZrO_2$ (SAME AS NO FLOW)

    EXTERNAL TO $ZrO_2$ (?)
  - PLUG OR BLOCKAGE FLOW (?)
- SHROUD FAILURE HAS ALWAYS BEEN ASSOCIATED WITH FLOW BLOCKAGE OR PLUG FLOW


Figure 26. Early KfK heatup and meltdown experiments in Helium.


Figure 27. Early KfK heatup and meltdown experiments in steam.


Figure 28. Later KfK experiments, ESSI-4 through ESSI-7 and ESSI-10 and ESSI-11, in steam.

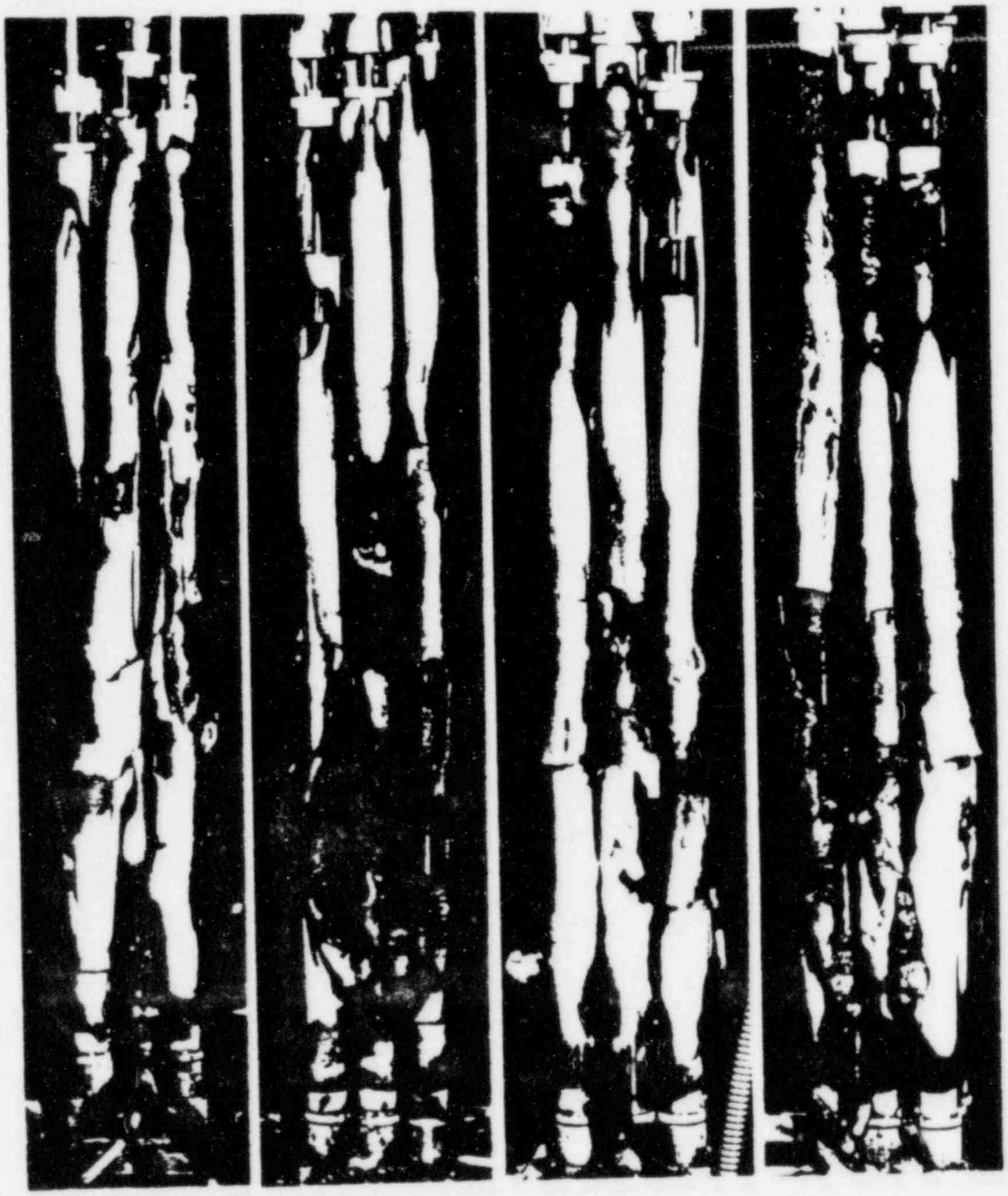
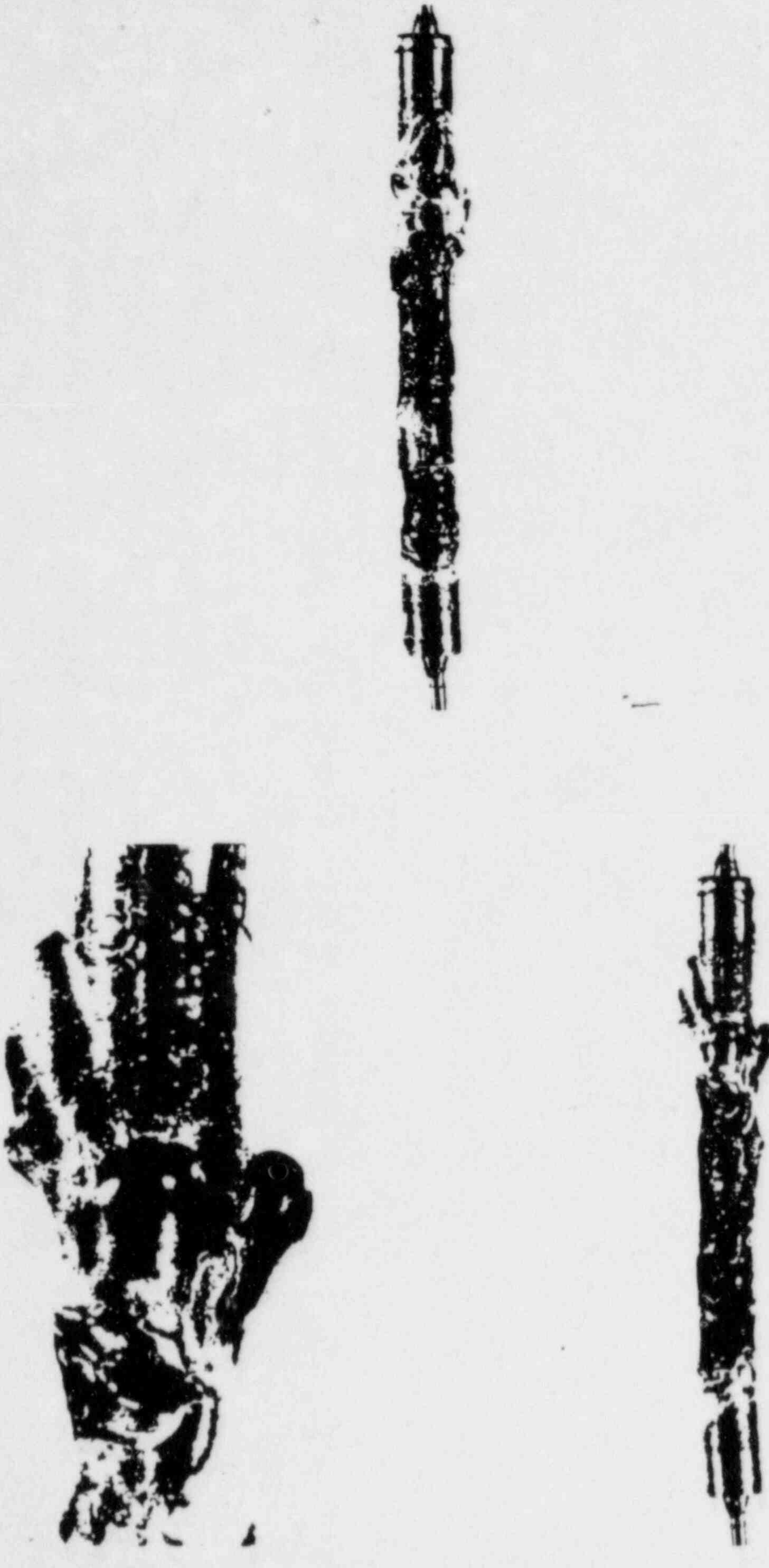



Figure 32. Early KfK bundle experiment heated in steam at an initial heatup rate of 2 K/s.

Steam flow: 0.09 g/s-rod
Heatup rate: 2 K/s
Peak temperature: 2450 K

S2 3571

Figure 35. KfK ESBU-1 experiment.



123N 2000°C 10 K/s 46 bar

Shroud of ESBU-1 after removel of the insulation

## HYDROGEN PRODUCTION

- CALCULATED AND MEASURED $H_2$ PRODUCTION IN EXCELLENT AGREEMENT WITH SFD 1-1 AND SFD 1-3 (LIMITED STEAM AND SLOW COOLDOWN TESTS WITH EXTENSIVE BLOCKAGES).

- CALCULATED $H_2$ PRODUCTION SIGNIFICANTLY LESS THAN MEASURED FOR SFD-ST AND TMI-2 (REFLOODED CONDITIONS - GOOD STEAM AVAILABILITY WHEN HOT).

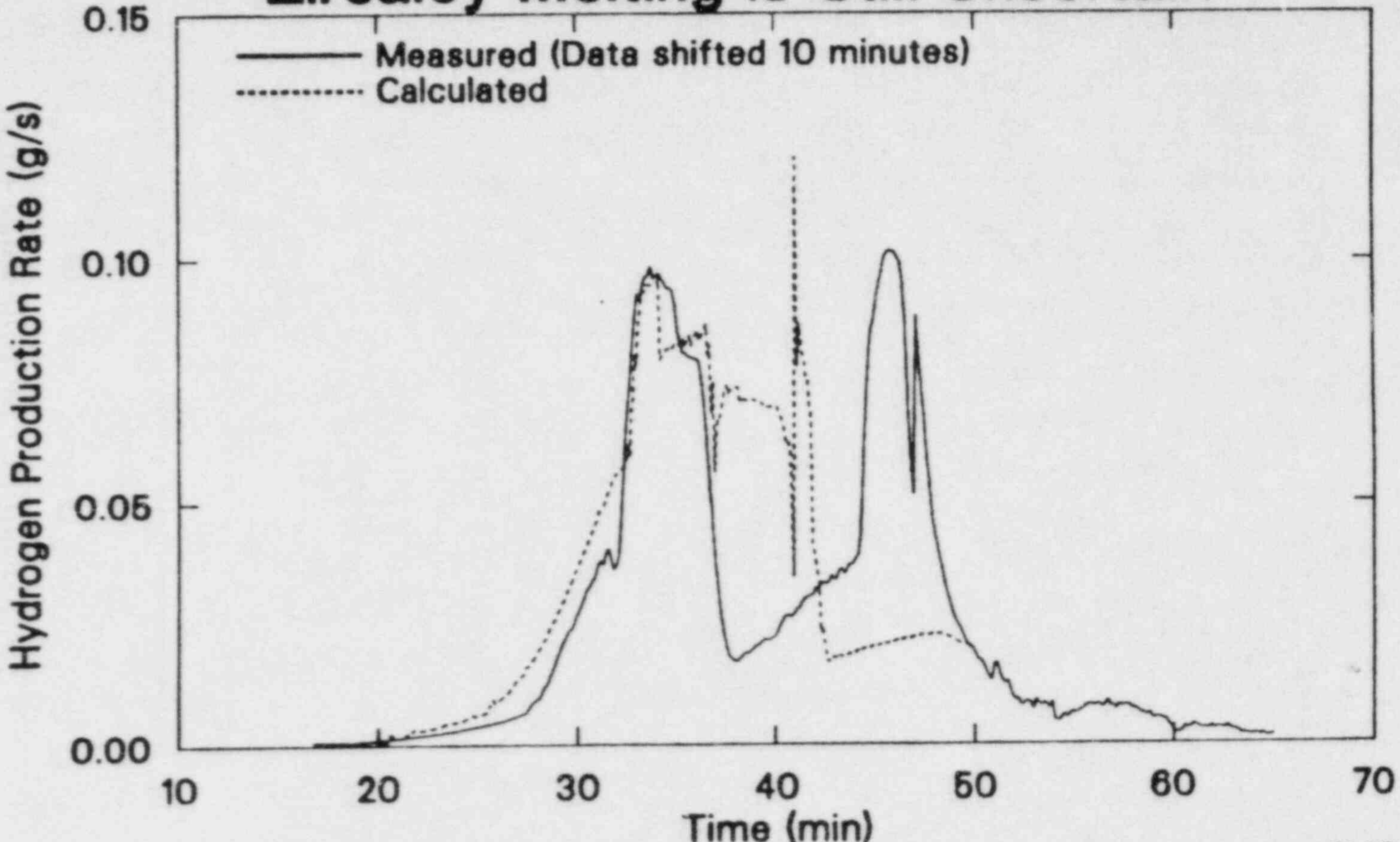
- HYDROGEN PRODUCTION RATES IN EXCELLENT AGREEMENT UNTIL LIQUEFACTION AND RELOCATION IS PREDICTED USING CONSTANT FLOW BOUNDARY CONDITIONS. BEYOND THAT POINT DATA SHOWS MULTIPLE PEAKS AS FLOW BLOCKAGES AND SHROUD FAILURES (?) TAKE PLACE.

## HYDROGEN PRODUCTION

| TEST | CALCULATED | MEASURED |
|---|---|---|
| SFD 1-1 | 71 G | 70 ± 11 G |
| SFD 1-3 | 60 | 55 ± 11 |
| SFD - ST[A] | 111 | 375 ± 140 |
| TMI-2[A] | 250-330 KG | 370 - 459 KG |

[A]BOTH TMI-2 AND SFD-ST WERE REFLOODED WHILE SFD 1-1 AND SFD 1-3 WERE SLOW COOLED. CALCULATED TOTALS ARE FOR BUNDLE OR CORE MATERIALS, MEASURED TOTALS MAY INCLUDE OTHER STRUCTURES.

# Hydrogen Production Following Zircaloy Melting is Still Uncertain

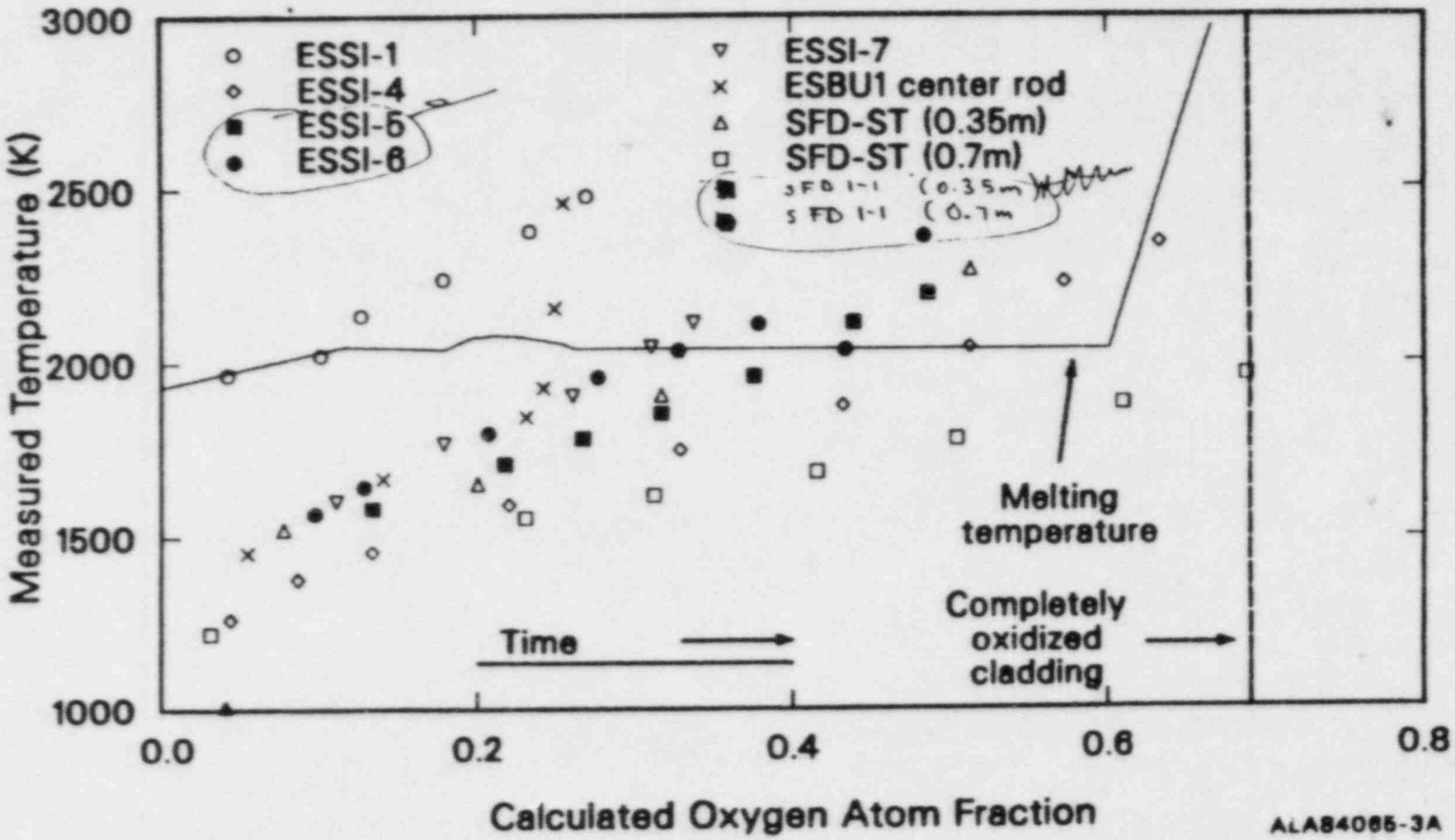



ALA84024-21

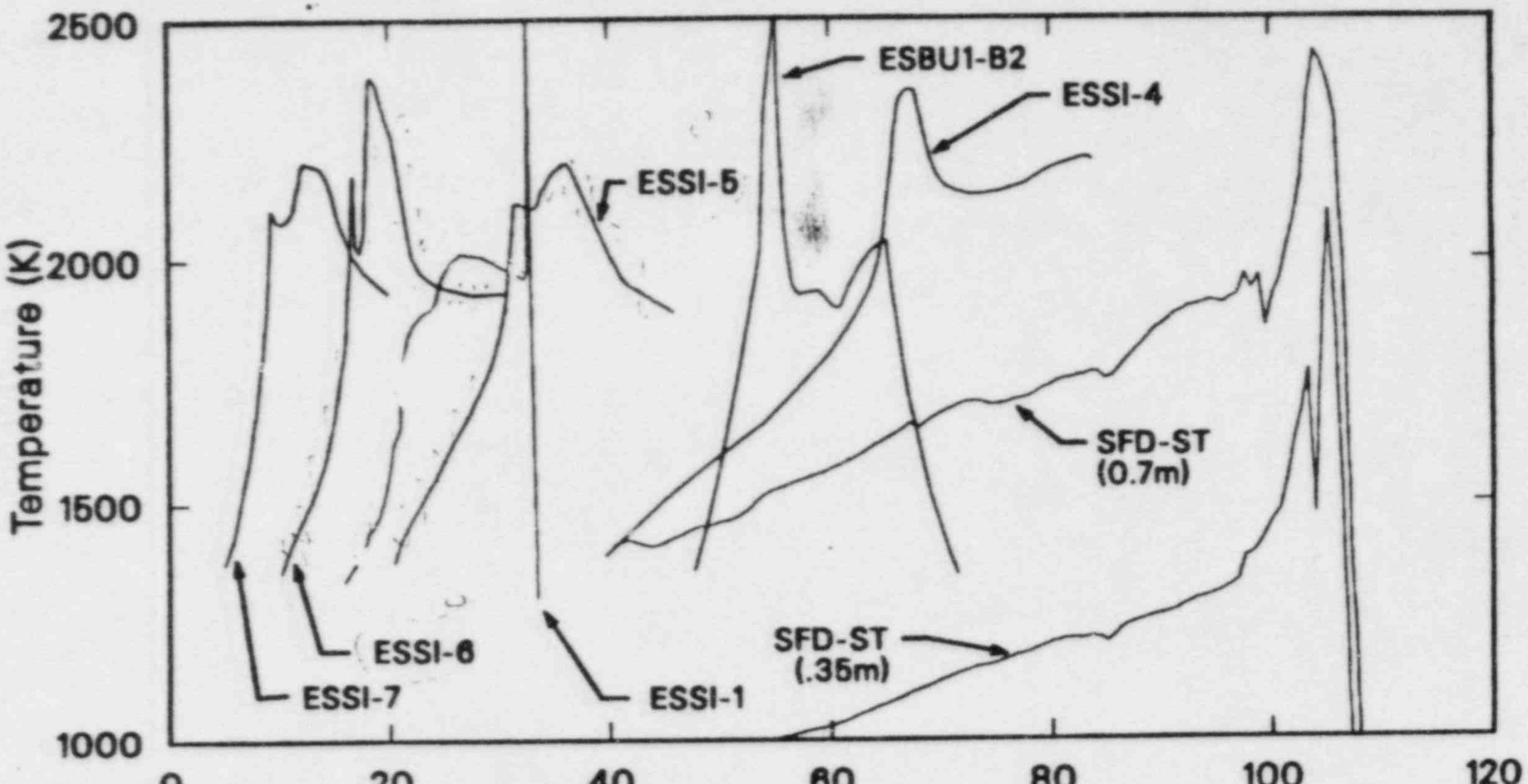
## CONCLUSIONS

- LIQUEFACTION AND RELOCATION NOT SUFFICIENTLY WELL UNDERSTOOD TO PREDICT THE LIKELIHOOD, THE TIMING, OR THE TEMPERATURE OF COMPLETE FLOW BLOCKAGE.
- TOTAL HYDROGEN PRODUCTION DURING HEATUP AND MELTDOWN WELL CHARACTERIZED BY SCDAP OXIDATION AND LIQUEFACTION MODELS.
- HYDROGEN PRODUCTION RATE OVER PREDICTED AFTER FLOW BLOCKAGE USING IDEALIZED CONSTANT FLOW BOUNDARY CONDITION.
- HYDROGEN PRODUCTION MAY BE SIGNIFICANTLY UNDER PREDICTED FOR REFLOOD.

# Oxygen Uptake for Integral Tests



# Experiments Cover Wide Range of Heatup Rates




ALA84065-1

Add SFD 1-1 at 0.7 + 0.35m

Add SFD 1-1 at 0.7 + 0.35m

## EVALUATION OF TEST DATA ON HYDROGEN PRODUCTION

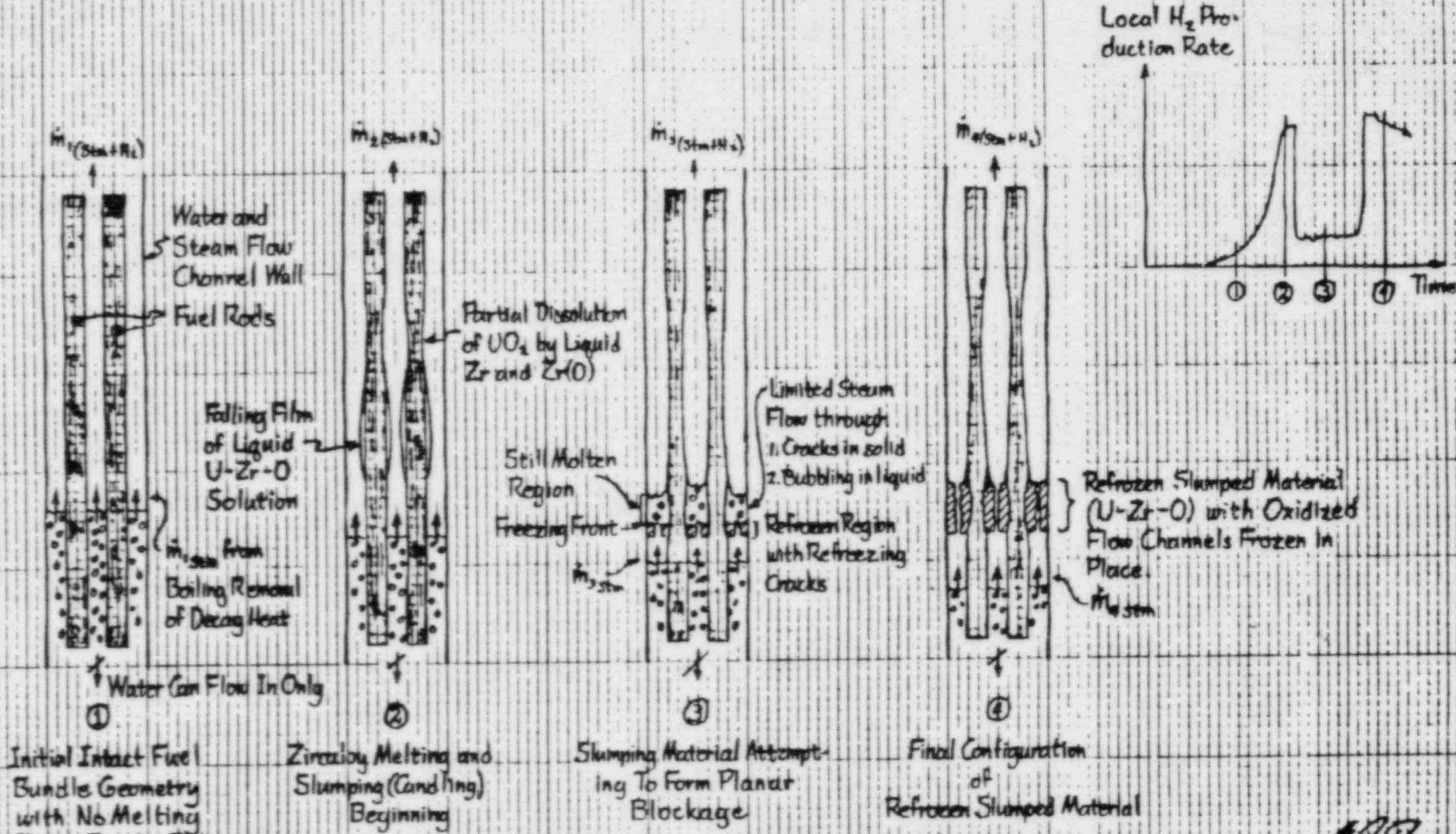
- o HCOG analysis terminates hydrogen production in a given node when the node temperature exceeds a specified temperature
  - Oxidation termination is irreversible
  - Oxidation termination represents expected phenomena
- o Experimental evidence exists to support oxidation cutoff
  - Karlsruhe Out of Pile Experiments
  - PBF Severe Fuel Degradation Experiments
  - Simulant Fluid Experiments
  - LMFBR R series tests
- o Treatment of pheonmena in BWR Core Heatup Code is conservative
  - Does not effect oxidation of nodes above or below nodes which experience oxidation cutoff
  - Does not effect global oxidation behavior

## TEST DATA SUPPORTING IRREVERSIBLE OXIDATION CUTOFF

- Karlsruhe Out of Pile Experiments
  - Showed significant blockage formation
  - Peak temperature and by inference oxidation are limited by the blockage formation
  - Test configuration not directly applicable to BWR/6 fuel geometry
- PBF Severe Fuel Damage Experiments
  - Data shows formation of significant blockages
  - Temperature measurements show substantial decrease as blockage forms
  - Hydrogen production measurements show significant decrease as blockage forms
  - Test configuration not directly applicable to BWR/6 fuel geometry
- Simulant Fluid Experiments
  - Experiment shows when bypass is present, coherent blockages will form
  - Experiment shows in positive displacement geometry, coherent blockages would not be expected to form
- LMFBR R Series Experiments
  - Significant intact blockages will occur in geometry similar to BWR/6 fuel

## Modeling of Fuel Bundle Degradation

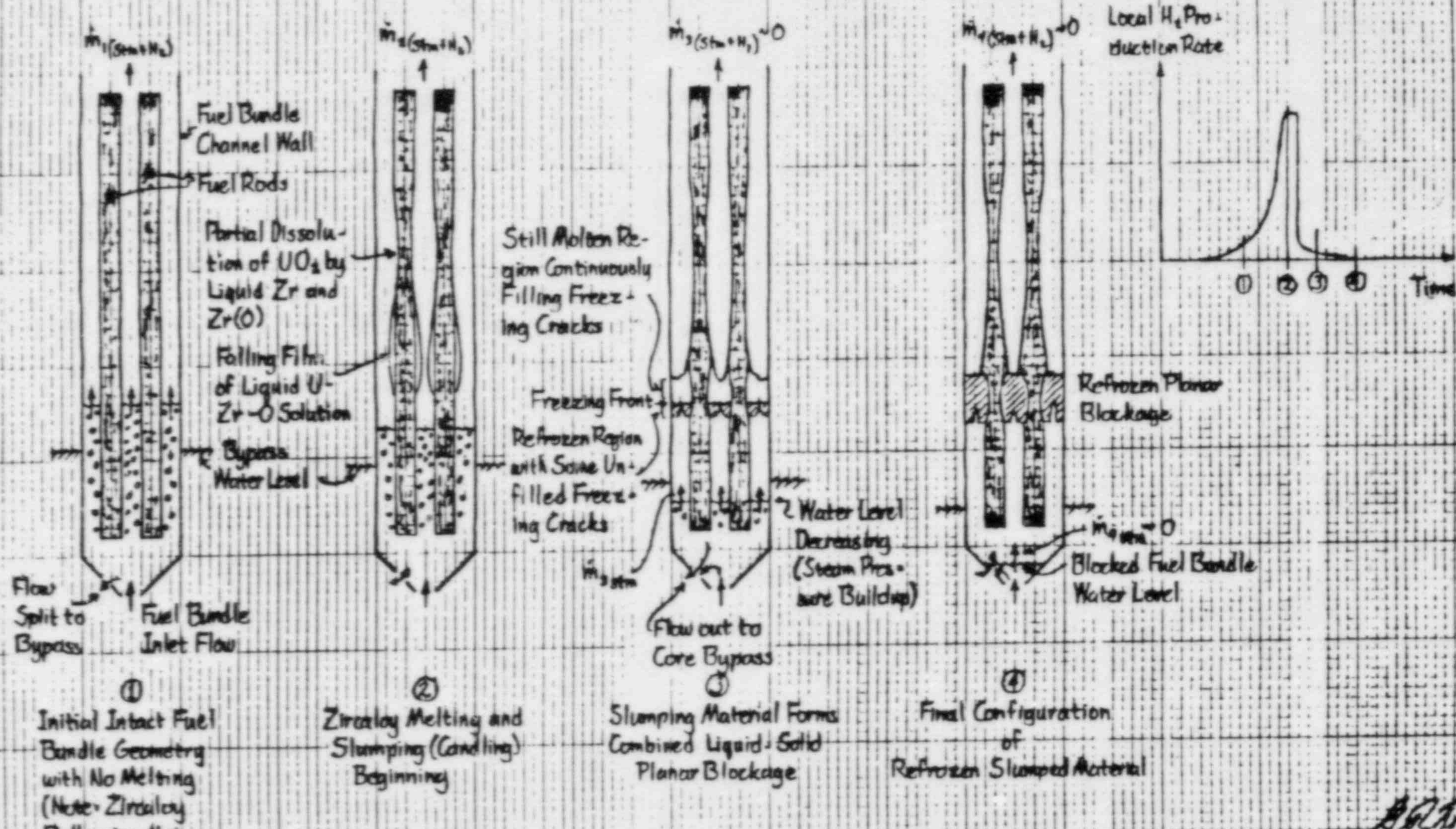
- Review fuel bundle degradation
  - As occured in experiments
  - As modeled by SCDAP Code
  - As would occur in a BWR core
  - As modeled in the BWR Core Heatup Code



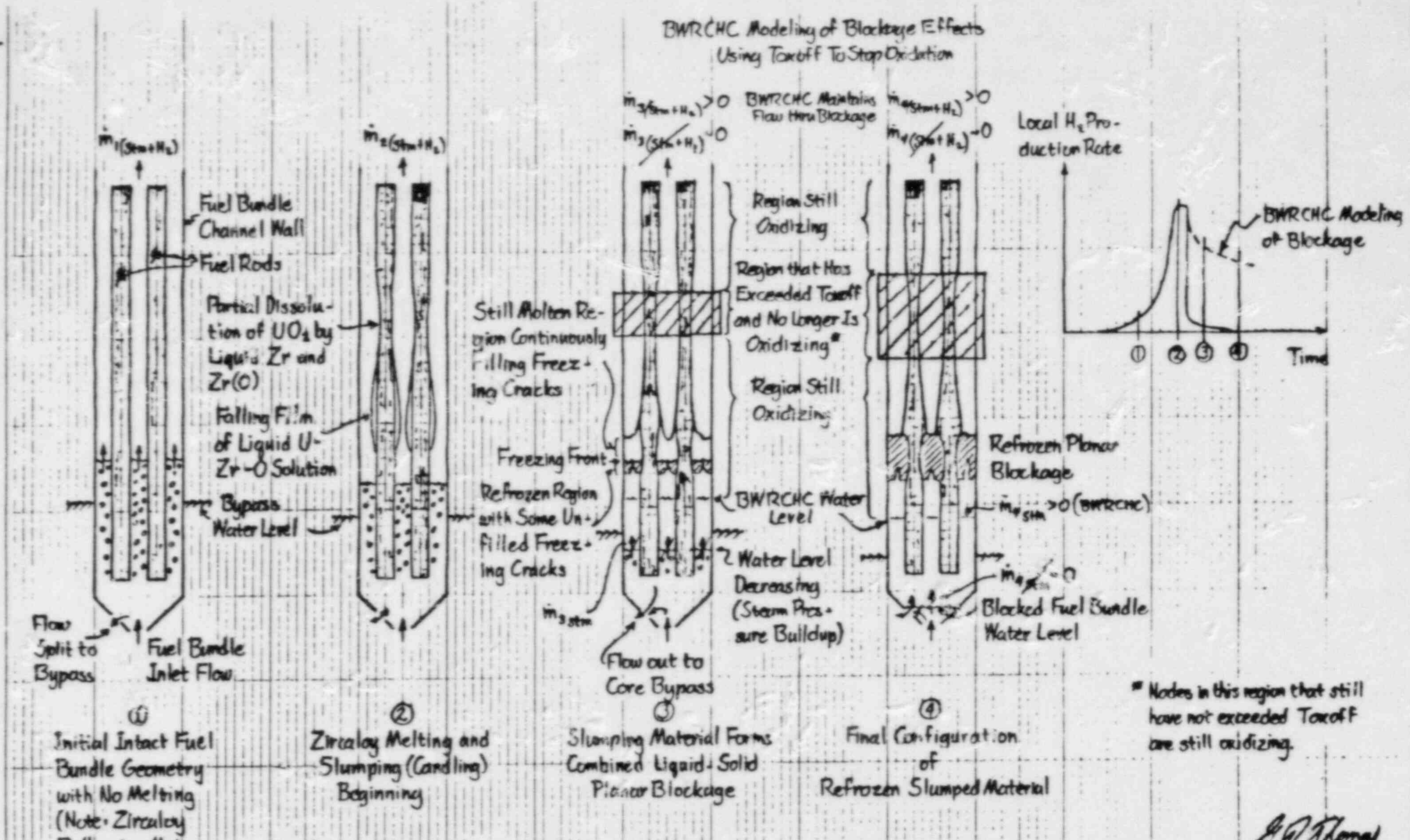

Schematic Fuel Rod Slumping-Blockage in Uni-directional Flow Geometry

PBF Severe Fuel Damage and Karlsruhe Candling Experiments and SCDAP Computer Code

12 January 1985



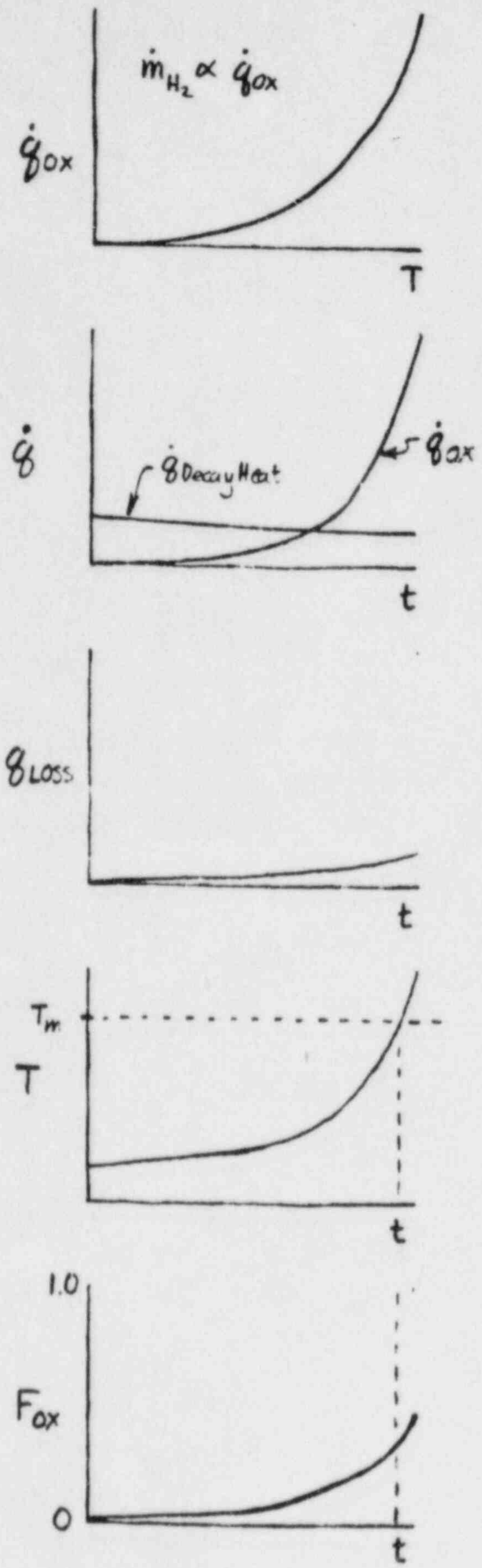

Schematic Fuel Rod Slumping-Blockage in a Typical BWR Fuel Bundle




Schematic Fuel Rod Slumping-Blockage in a Typical BWR Fuel Bundle

Views ③ and ④ Modified To Show BWR Core Heatup Code (BWRCHC) Modeling of Blockage Effects

G. R. Thomas
28 January 1985




Zircaloy Oxidation Power = f(Temperature + Oxide Thickness)

Decay Heat and Oxidation Power = f(Time)

Localized Heat Loss = f(Time)

Localized Temperature = f(Time)

Localized Oxidation Fraction = f(Time)

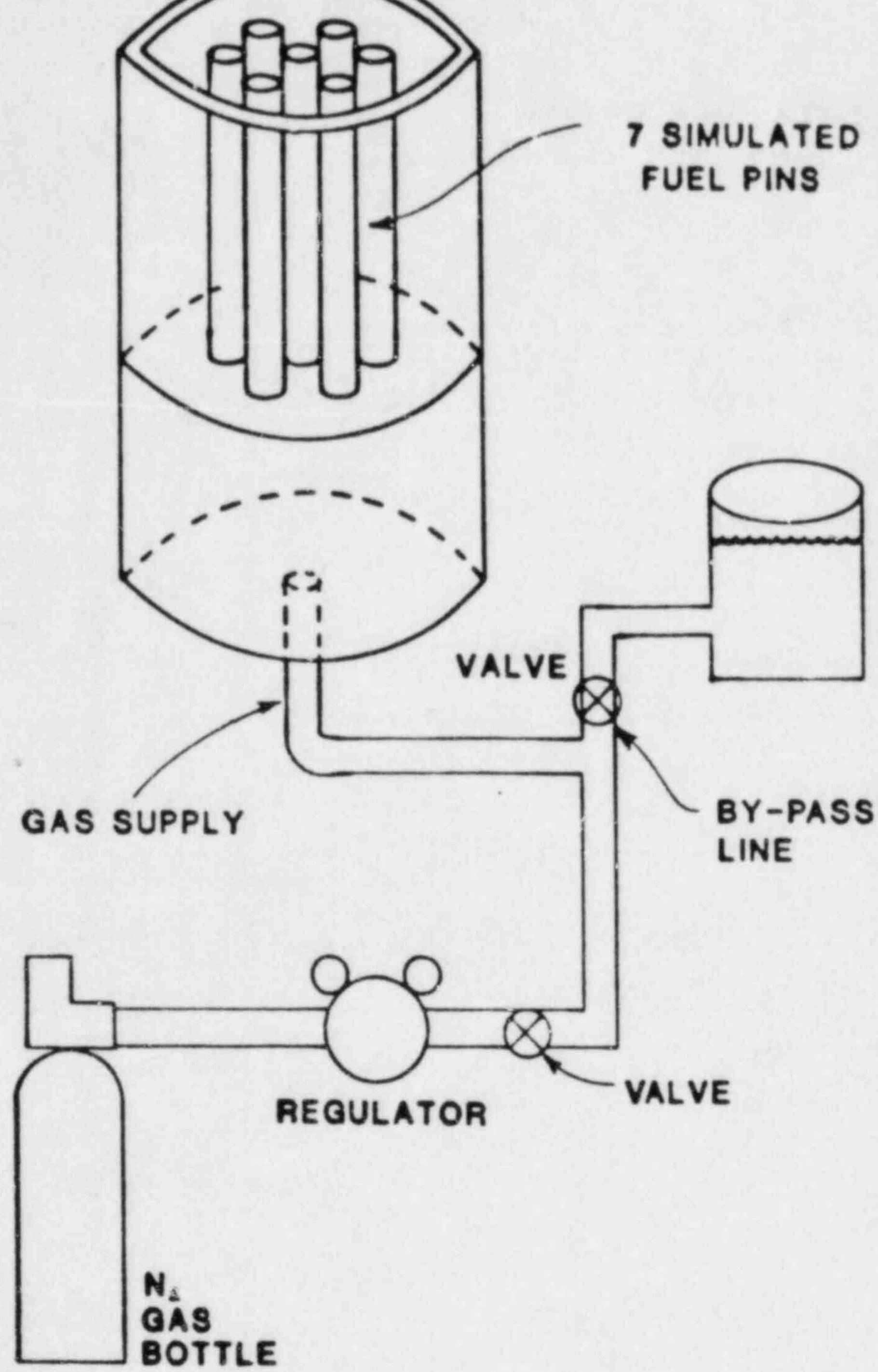
Zircaloy Oxidation and Temperature Transients in Large (LWR Core Size) Fuel Rod/Bundle Arrays

23 Jun '85

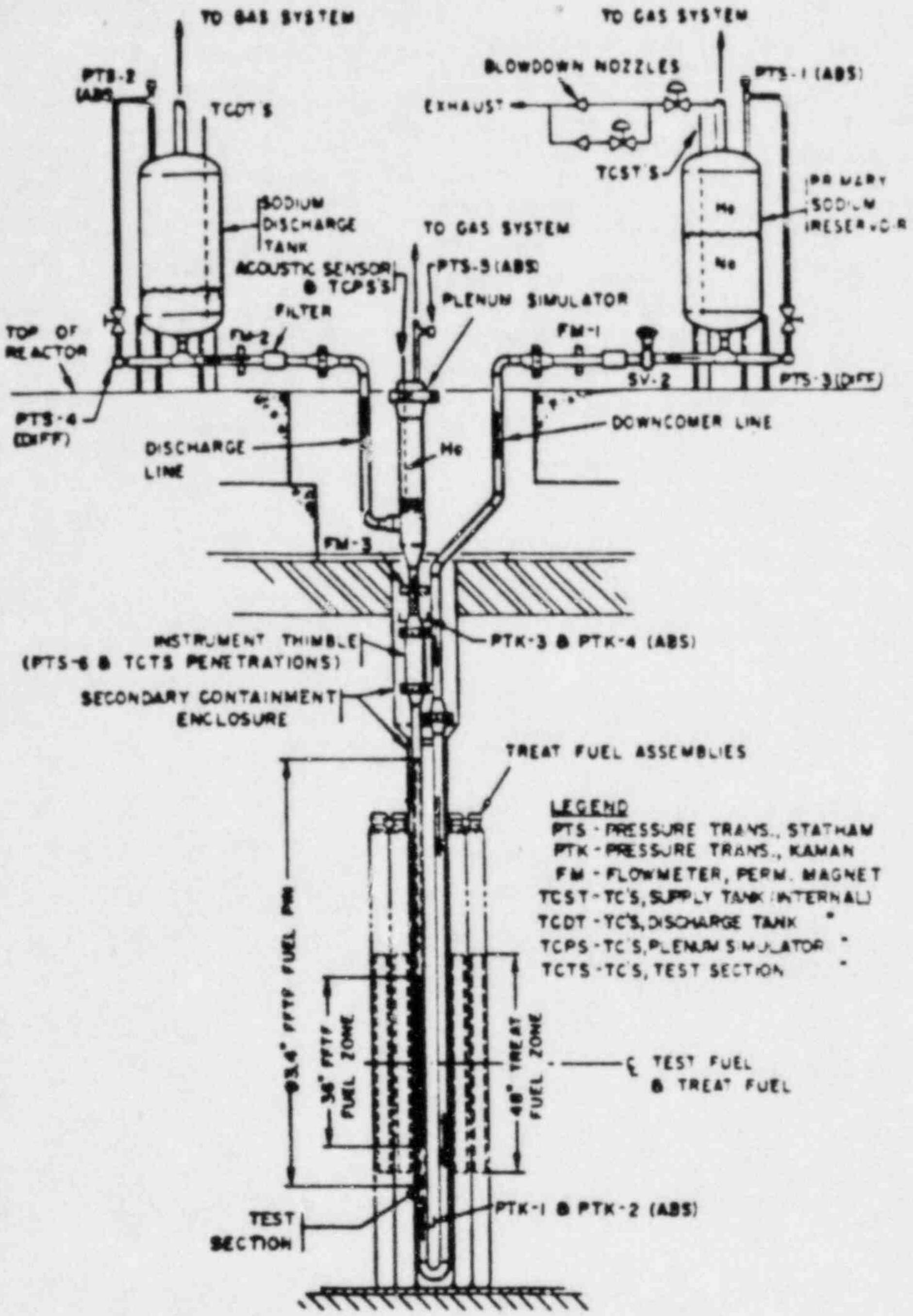
## INFLUENCE OF HYDRODYNAMIC BOUNDARY CONDITIONS DURING SLUMPING

- Constant Flow
  - Complete blockage cannot occur. Flow resistance may increase, but sufficient flow area must be available to pass the imposed flow.

- Constant Pressure Difference
  - Flow can only occur as long as the pressure difference is sufficient to support the weight of molten material in the core. Flow can be stagnated. Complete blockage can occur.

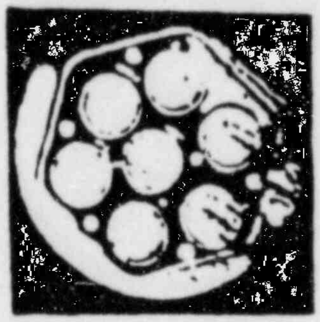



SCHEMATIC OF 7 PIN TEST ASSEMBLY

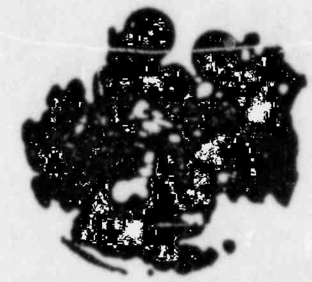



**R-SERIES TEST APPARATUS**

59

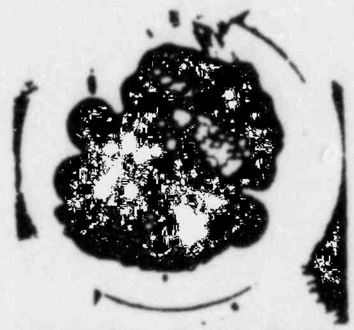


SECTION A. 4.8 CM BELOW BOTTOM OF FUEL COLUMN. REFLECTOR RODS IN ELEMENTS. SOME MELTED STEEL.



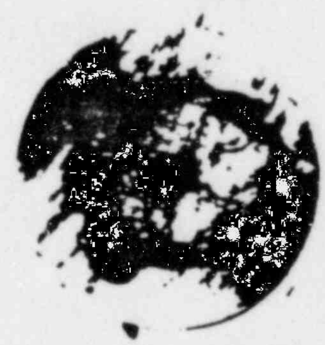
SECTION D. 10.8 CM ABOVE BOTTOM OF FUEL COLUMN. MELTED FUEL. FUEL PELLETS IN STEEL MATRIX.

SECTION B. 0.6 CM ABOVE BOTTOM OF FUEL COLUMN. UNMELTED FUEL PELLETS IN MATRIX OF STAINLESS STEEL.



SECTION E. 18.1 CM ABOVE BOTTOM OF FUEL COLUMN. MELTED FUEL. PARTS OF PELLETS IN STEEL MATRIX.

SECTION C. 5.7 CM ABOVE BOTTOM OF FUEL COLUMN. MELTED FUEL AROUND PELLETS IN STEEL MATRIX



SECTION F. 22.9 CM ABOVE BOTTOM OF FUEL COLUMN. MELTED FUEL. PARTS OF PELLETS IN STEEL MATRIX

**TRANSVERSE SECTIONS THROUGH SECTION 40-R4-17**

UPPER (LEFT) AND LOWER (RIGHT) SEGMENTS
OF SECTION 40-R4-17 AFTER CLEANING

## HCOG SUMMARY

- Hydrogen control rule requires owners of Mark III containments to install systems which are capable of mitigating the consequences of recoverable degraded core accidents involving hydrogen production equivalent to oxidizing 75% of the active fuel cladding

- Not required to mechanistically predict 75% MWR

- The BWR Core Heatup Code models the significant phenomena important to predicting hydrogen production in a BWR

- The BWR Core Heatup Code is an appropriate tool for predicting hydrogen production from degraded core accidents in BWRs

- A mechanistic approach should be used to define limiting case high hydrogen production rates for recoverable degraded core accidents

## HYDRODYNAMIC BOUNDARY CONDITIONS

### Categories and Observations for Experiments and Reactor Systems

| System | Constant Flow | Constant Pressure Difference | Observation |
|---|---|---|---|
| KfK 9 Pin Experiments (Hagen) | Positive Displacement Pump | | Blockage with "Blow Holes" |
| PBF 32 Pin Severe Fuel Damage Experiments | Positive Displacement Pump | | Blockage with "Blow Holes" |
| Simulant Fluid Tests | Large Pressure Difference | | Blockage with "Blow Holes" |
| 7 Pin R Series Experiments | | Constant Static Head | Extensive Complete Blockage |
| Simulant Fluid Tests | | Constant Static Head | Complete Blockage |
| TMI-2 | | Static Head of Water in the Downcomer | Large Thermal Conduction Lengths |

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# HCOG CONCLUSIONS
# ON BWR CORE HEATUP CODE

- o Code represents state-of-the-art for predicting hydrogen production in a BWR core

- o Code accurately models BWR6 core

  - Accurate representation of BWR bypass/bundle thermal hydraulics

  - Treats oxidation of control blades, fuel rods and fuel channels

  - Includes extremely detailed representation of core power distribution

- o Code conservatively treats phenomena in a BWR core

  - Oxidation kinetics equations are conservative

  - Intact geometry assumed, nodes which exceed the zircaloy oxidation cutoff temeperature do not continue to oxidize

  - Steam flow to all nodes with temperatures below the oxidation cutoff is not impeded by any other node having exceeded the oxidation cutoff temperature

## HCOG CONCLUSIONS ON HYDROGEN GENERATION IN RECOVERABLE DEGRADED CORE ACCIDENTS

- It is not possible in a BWR6 to mechanistically predict hydrogen production equivalent to oxidizing 75% of the active cladding and maintain a recoverable core geometry

- Unmitigated events do not result in significant hydrogen production and result in events outside the hydrogen control rule

- Accidents mitigated with large reflood rates lead to rapid termination of hydrogen production and production of relatively inconsequential amounts of hydrogen

- Accidents mitigated with small reflood rates should produce the limiting thermal environment
  - sustained hydrogen production above diffusion flame threshold
  - timing of reflood can be adjusted to assure accident remains recoverable

## STATION BLACK OUT (SBO) AS A HYDROGEN GENERATION EVENT

- GE study demonstrated that SBO has similar probability of leading to core melt as events initiated by plant transients

- HCOG elected to evaluate events initiated by operational transients since these events entail the highest probability of occurrence

- HCOG believes SBO has much higher probability of leading to core melt than producing hydrogen and a recoverable accident

  - BWR's are inherently resistant to SBO

  - By the time the core reaches point in SBO where hydrogen production can commence, core is severely degraded

  - Time window for vessel reflood with recoverable core is very narrow

- Cumulative probability of SBO producing significant hydrogen and recoverable geometry is very low

## LOSS OF CONTROL ROD INTEGRITY

- Loss of control rod integrity does not have a significant impact on hydrogen production
  - Oxidation of stainless steel control rods included in BWR Core Heatup Code
  - Any reactivity transients which occur during vessel reflood would have a minor impact on hydrogen production

- Loss of control rod integrity need not be addressed within context of defining hydrogen release histories

January 31, 1985

ATTENDEES

MEETING WITH HYDROGEN CONTROL OWNERS GROUP

| NAME | AFFILIATION |
| --- | --- |
| CG TINKLER | CSB/NRC |
| R. LaGrange | ECQB/NRC |
| W. Johnston | NRC/DE |
| K.I. PARCZEWSKI | NRC/NRR/CMEB |
| A. Notafrancesco | NRR/CSB |
| Marc Wigdor | NRR/RSB |
| Sam Hobbs | MP&L |
| Bob Evans | Enercon Services Inc. |
| Jim D [illegible] | Enercon Services Inc |
| [illegible] A Baker | Illinois Power Co. |
| J. F. Hosler | EPRI |
| Marvin Morris | GSU |
| Erwin J. Zoch | GSU |
| Emin Ertalan | CEI |
| MIKE MANSKI | MP&L |
| John Beranaga | NRR/CMEB |
| L. L. Kintner | NRR/DL/LB-4 |
| G. W. Houston | AD NRR/[illegible] |

(4) (1)

TASK 11 - EQUIPMENT SURVIVABILITY ANALYSIS PROGRAM

Requirements

10 CFR 50.44 (c)(3)(iv)(V) and (c)(vi)(B)(5)(ii)

Equipment which is required to survive degraded core accidents shall be demonstrated to survive. Analyses shall account for local detonations unless probability of local detonations is demonstrated to be sufficiently low.

Task Description

Certain pieces of equipment must be operable during and after accidents which produce large quantities of hydrogen. These components could potentially be exposed to deflagrations, diffusion flames or a severe environment in the drywell. This task involves defining equipment required to survive and verifying by analysis that the equipment will withstand the predicted environments.

TASK 11 - EQUIPMENT SURVIVABILITY ANALYSIS PROGRAM

MAJOR SUBTASKS

## 11.1 Criteria for Equipment Survivability

- Equipment surface temperature remains below equipment qualification temperature
- Critical component temperature remains below equipment qualification temperature
- Component temperature remains below survivability temperature
- Pressure produced by deflagrations remains below qualification pressure
- Component can be shown to be insensitive to pressure

## 11.2 Identify Equipment Required to Survive

- Review all safety related equipment in containment
- Identify components required to survive
- Identify support components

## 11.5 Develop Models of Equipment

- A heat transfer code will be used to calculate thermal response of equipment
- A generic set of equipment models will be developed using a common approach and assumptions on heat transfer coefficients

## 11.11 Analyze Equipment Thermal Response

- Models developed in 11.5 will be used
- Thermal environments produced by deflagrations, diffusion flames or in the drywell will be applied to equipment

TASK 11 - EQUIPMENT SURVIVABILITY ANALYSIS PROGRAM

MAJOR SUBTASKS (CONT)

11.12 Peak Pressure Exceeds Equipment Qualification Pressure

- The peak pressure produced by base case deflagrations will be compared to the pressure equipment can withstand

11.14 Peak Temperature Exceeds Equipment Qualification Temperature

- The peak component temperature resulting from hydrogen combustion shall be compared to the Equipment Qualification temperature

11.16 Critical Component Temperature Exceed Qualification Temperature

- If the decision point at 11.14 shows equipment temperature exceeding qualification temperature, the critical component will be identified

- The critical component temperature will be compared with its qualification temperature

11.17 Identify Survivability Enhancements

- HCOG will investigate various approaches to insuring equipment survivability

  - shielding equipment
  - active cooling
  - relocation
  - equipment replacement

11.21 Prepare Equipment Survivability Report

- Document modeling assumptions

- Document thermal profiles used for analysis

- Document analysis results

- Document equipment survivability

## TASK 11 - EQUIPMENT SURVIVABILITY ANALYSIS PROGRAM

Status

- o Subtasks 11.1 and 11.2 Complete
- o Subtasks 11.3 and 11.6 - 11.8 in progress

Remaining Work

- o Model equipment
- o Finalize thermal environments
- o Analyze equipment thermal response
- o Schedule meeting on thermal environment definition
- o Verify equipment survivability
- o Schedule meeting on survivability resolution
- o Submit equipment survivability report to NRC

## TASK 11 - EQUIPMENT SURVIVABILITY ANALYSIS PROGRAM

Acceptance Criteria

- o A list of equipment required to survive hydrogen combustion shall be prepared
- o Equipment thermal response shall be calculated using an acceptable thermal response analysis code
- o Number of components to be modeled and analyzed can be limited
  - If identical or similar component has been evaluated against a more limiting thermal environment
  - If a similar more thermally sensitive component has been modeled
- o Thermally limiting component shall be the component most likely to fail during or after combustion
- o Thermal environments in drywell and in containment due to deflagrations, diffusion flames or inverted diffusion flames as appropriate shall be defined
  - Deflagrations based on containment response analysis completed in Task 8
  - Diffusion flames based on experimental data in Task 9
  - Drywell environment based on results from analyses in Task 10
- o Equipment shall be judged to survive temperatures
  - If equipment surface temperature remains below qualification
  - If critical component temperature remains below qualification
  - If equipment surface temperature remains below survivability temperature

TASK 11 - EQUIPMENT SURVIVABILITY ANALYSIS PROGRAM

ACCEPTANCE CRITERIA (CONT)

- o Equipment shall be judged to survive pressures
  - If peak pressure experienced by equipment is below qualification
  - Component can be shown to be insensitive to pressure
- o Measures shall be identified to assure survivability
  - Protection
  - Demonstrate equipment can perform function
  - Replacement
  - Relocation

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# TASK 12 - VALIDATION OF ANALYTICAL METHODS

Requirements 10 CFR 50.44 (c)(3)(vi)

Analysis shall be submitted which demonstrates that systems and components necessary to establish and maintain safe shutdown and to maintain containment integrity, will perform their function during and after exposure to environmental conditions created by the burning of hydrogen.

Task Description

To demonstrate conservatisms of CLASIX-3 modeling assumptions, a prediction of a complex calorimeter thermal response will be made using CLASIX-3 thermal environment prediction as input. This prediction will be compared to the measured response of the actual calorimeter during a deflagration test in the 1/4 scale facility. It will be shown that the analytical method is conservative.

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TASK 12 - VALIDATION OF ANALYTICAL METHODS

MAJOR SUBTASKS

12.3 Complete CLASIX-3 Prediction

- o Develop model of 1/4 scale facility
- o Specify input

12.4 Design Complex Calorimeter

- o Instrumented calorimeter with complex geometry
- o Movable in facility to validate methods in varying environment

12.5 Prepare Model of Complex Calorimeter

- o Heat transfer model developed
- o Same methodology as survivability thermal response models

12.7 Compare Measured Results With CLASIX-3/Heat Transfer

- o Evaluates analytical method for predicting response to deflagrations
- o Predicted response of complex calorimeter will be compared with measured response
- o If not acceptable, then modeling assumptions and techniques will be refined
- o Changes in assumptions and results will be documented

12.9 Compare Measured Results With Thermal Response Prediction

- o Measured thermal environment data from diffusion flame tests applied to model of complex calorimeter
- o Techniques and assumptions used to construct thermal response model will be confirmed

## TASK 12 - VALIDATION OF ANLAYTICAL METHODS

### Status

- Task 12.4 complete
- Tasks 12.1 and 12.2 in progress

### Remaining Work

- Complete CLASIX-3 model and prediction
- Prepare thermal response model of complex calcrimeter
- Take measured response data and apply to thermal response model
- Compare measured response with predicted response using CLASIX-3 data
- Compare measured response with predicted response using 1/4 scale test data
- Schedule meeting to discuss methodology validation
- Submit final methods validation report

### Acceptance Criteria

- Predicted response of model in a known thermal environment will be compared to measured response and shown to be conservative
- Thermal response methodology using deflagration data from CLASIX-3 will be shown to be conservative compared to measured response in a known deflagration environment

Enclosure 2 - January ... [illegible]
Regarding:
Task 11 Equipment Survivability Analysis Program
Task 12 Verification of Analysis ... [illegible]

Page No.

1 Attendees
2-7 Task 11 - major subtasks, status and outline of acceptance criteria presented [illegible]
8-10 Task 11 - major subtasks, status and outline of acceptance criteria presented by HCOG

MARK III CONTAINMENT
**HYDROGEN CONTROL OWNERS GROUP** Sam H. Hobbs, Chairman
c/o Mississippi Power and Light • P.O. Box 1640 • Jackson, Mississippi 39205 601-969-2458

February 13, 1985

U. S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Washington, D.C. 20555

Attention: Mr. Robert Bernero

Dear Mr. Bernero:

Subject: Hydrogen Control Owners Group 1/4 Scale Test Facility 3D-Complex Calorimeter HGN-027

On January 31, 1985, the Hydrogen Control Owners Group (HCOG) met with Nuclear Regulatory Commission (NRC) staff. There was a specific request by the NRC staff for additional detailed information concerning the complex calorimeter which is installed in the 1/4 scale test facility. Attachment 1 is a drawing of the calorimeter assembly showing the various parts and the associated material. This drawing also identifies the thermocouples and a description of where and how they are attached. Accompanying this drawing of the calorimeter assembly are 6 drawings showing various details of the construction of the calorimeter.

The complex calorimeter is mounted in the 1/4 scale test facility at the 10 foot elevation (just below the HCU floor) at the 315° Azimuth approximately half way between the drywell and outer containment walls.

The axis of the cylindrical portion of the calorimeter is parallel to a radial line from the facility center with the larger end cap pointed outward toward the outer shell.

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29pp

(5)

The base of the calorimeter extends horizontally along a circumferential line toward the 225$^{\circ}$ chimney area.

The calorimeter is mounted such that thermocouple C-284 faces downward.

The calorimeter is attached to the grating above by a 3/8 inch diameter mild steel rod which extends approximately 3 inches from the upward face of the calorimeter base through two pieces of marinite I insulation material, one below and one above the grating. Because of this mounting arrangement, the calorimeter is essentially thermally insulated from the test facility.

The following figures are included for clarification:

Figure 1 is a view of the complex calorimeter mounted in the facility and Figure 2 shows a view of the 315$^{\circ}$ chimney. Figure 3 is a sketch of the mounting arrangement for the complex calorimeter.

Several measurements are being made in the vicinity (within a 1 foot radius) of the calorimeter for use in defining the thermal environment to which it is exposed. These include gas temperature, vertical gas velocity and radiant heat flux.

The radiant heat flux will be inferred by both a gardon type gage and a set of sphere calorimeters (one gold and one black).

The general location of all these instruments have been shown on the instrument drawings submitted earlier to the NRC staff. The exact location will be determined later by a field survey.

This submittal was compiled by HCOG from the best information available for submittal to the Nuclear Regulatory Commission. The submittal is believed to be complete and accurate, but it is not submitted on any plant specific docket. The information contained in this letter and its attachments should not be used for evaluation of any specific plant unless the information has been endorsed by the appropriate member utility. HCOG members may individually reference this letter in whole or in part as being applicable to their specific plants.

If you have any questions or require additional information, please contact me.

Sincerely,

S H Hobbs

S. H. Hobbs
Chairman, Hydrogen
Control Owners Group

SHH/mrd

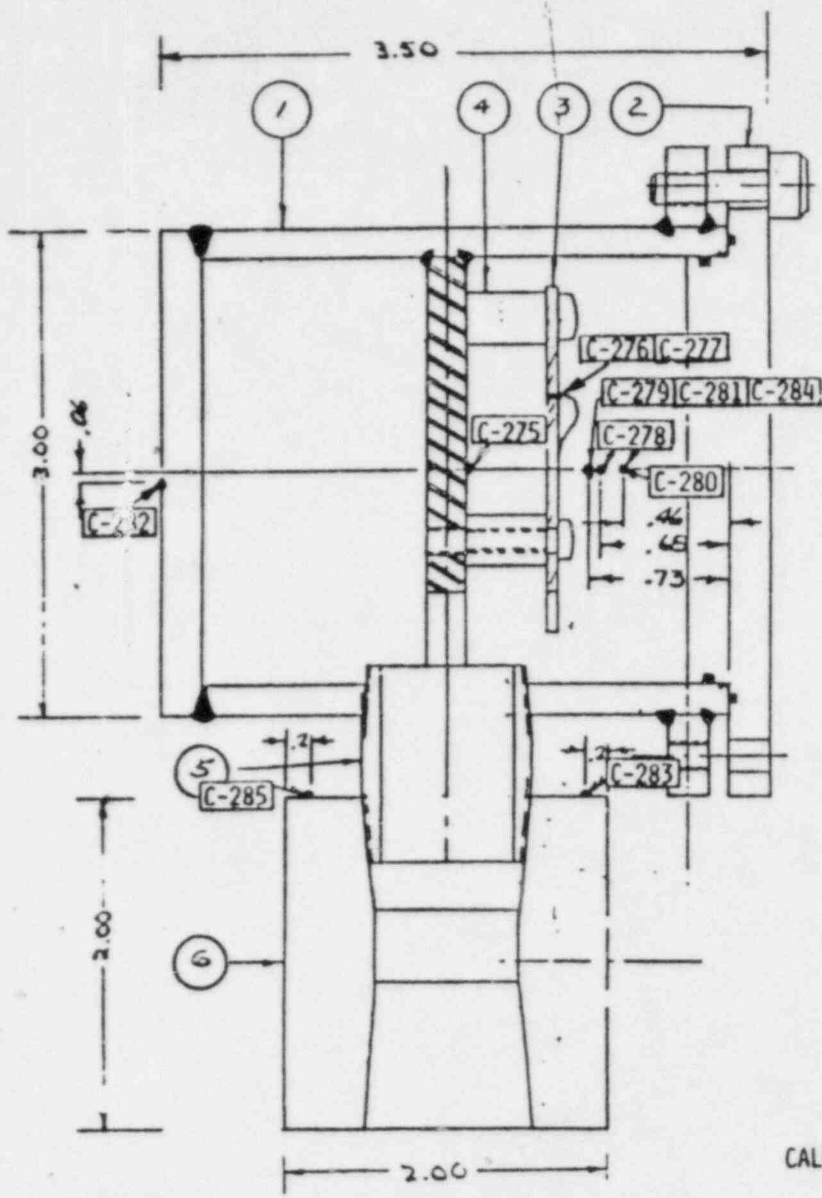
Attachments

cc: Mr. Carl R. Stahle (w/a)
Hydrogen Control Program Manager
U. S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Washington, D.C. 20555

Mr. Charles G. Tinkler (w/a)
Containment Systems Branch
U. S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Washington, D.C. 20555

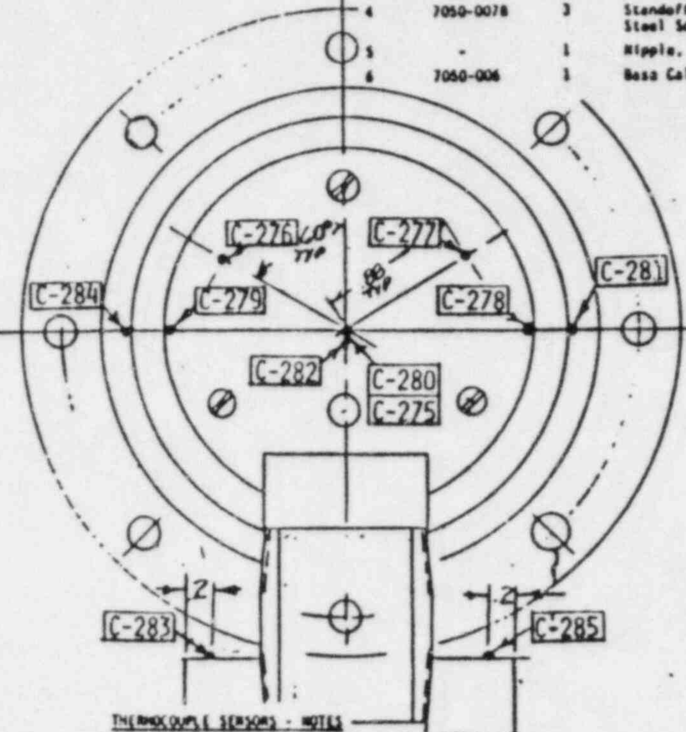
Mr. John Cummings (w/a)
Project Manager
Hydrogen Studies Division 4441
Sandia National Laboratory
Albuquerque, NM 87185

ATTACHMENT 1




PARTS

| ITEM NO. | PART NO. | QUANTITY | DESCRIPTION |
|---|---|---|---|
| 1 | 7050-002 | 1 | Body Sub-Assembly, 316 S.S. |
| 2 | 7050-005 | 1 | Cover Plate, 316 S.S. |
| 3 | 7050-007A | 1 | Circuit Plate, 6061 aluminum |
| 4 | 7050-007B | 3 | Standoff, 316 S.S., Mounted with 6-32 Steel Screws |
| 5 | - | 1 | Nipple, Close, 3/4" Pipe, S.S. |
| 6 | 7050-006 | 1 | Base Calorimeter, Mild Steel |

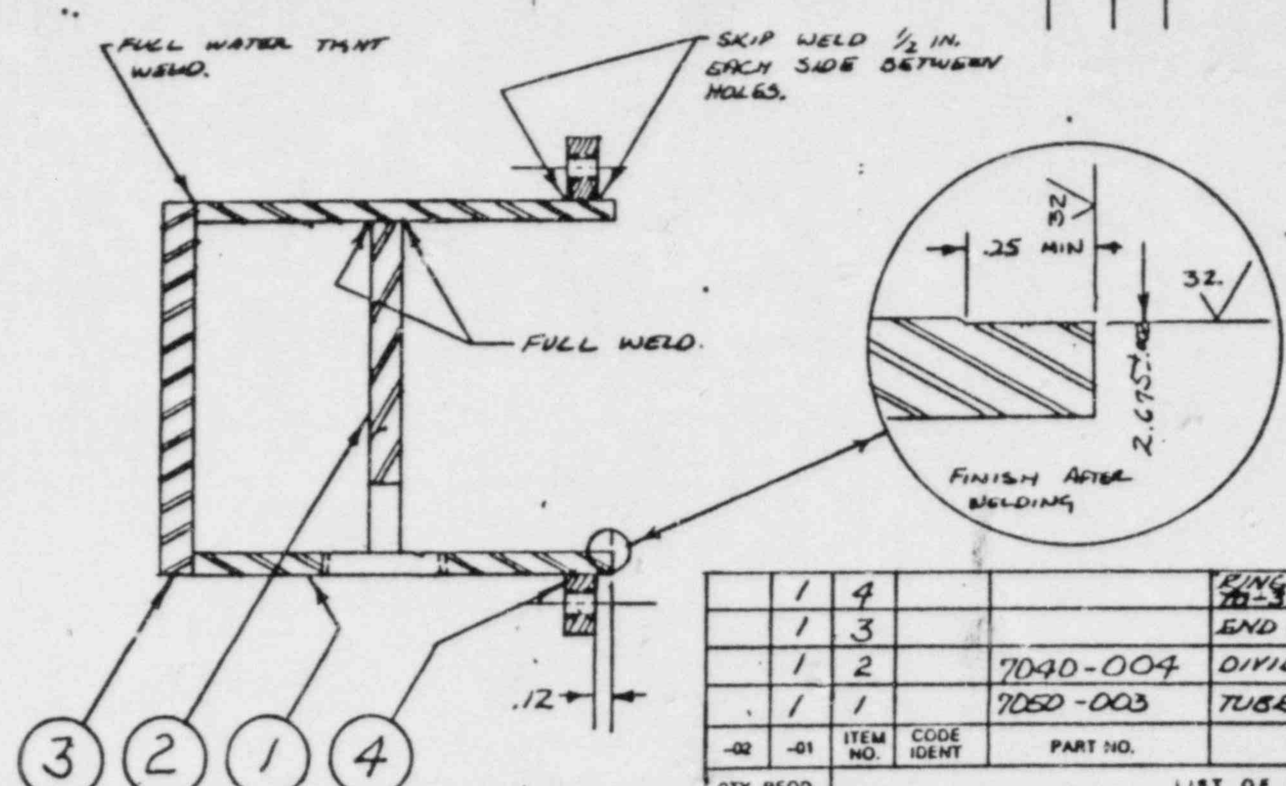



THERMOCOUPLE SENSORS - NOTES

1 C-275 Lead secured to divider plate with 6-32 STL screw and S.S. clip
2 C-276, C-277 are welded junctions inserted in small holes in plate. Holes are swaged closed around junctions using center punch
3 C-275, C-278, and C-284 are intrinsic type. Wires are separately welded to structure with approx. 0.5 in. seperation
4 Thermocouple lead wire is Omega 304-K-MO-125. 0.125 in. S.S. - clad cable
5 Feedthrough is Omega FT-18-7
6 C-285 is spare
7 Numbers in [ ] indicate thermocouple indentifiers

CALORIMETER ASSEMBLY

ASTRON RESEARCH AND ENGINEERING




| -02 | -01 | ITEM NO. | CODE IDENT | PART NO. | DESCRIPTION |
|---|---|---|---|---|---|
| | 1 | 4 | | | RING 3.01 ID x 4.00 OD x .25 THK W/ 10-32 TAPPED HOLES 8PL ON 3.50 DBC |
| | 1 | 3 | | | END PLATE 3.00 DIA x .25 THK 316 SS |
| | 1 | 2 | | 7040-004 | DIVIDER |
| | 1 | 1 | | 7050-003 | TUBE |
| QTY. REQD. | | | | | |

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
FRACTION DECIMALS .XX .XXX ANGLES
MACH COR—.005 TO .015 R OR CHAM
SH MATL—BREAK EDGES .005 MAX R
ALL √ SURFACES TO 63 √
DIM AND TOL APPLY BEFORE FIN. TREAT
DO NOT SCALE DRAWING
MATERIAL
FINISH

| | | DATE |
|---|---|---|
| DRAWN | D. RANDALL | 10/25/84 |
| CHECKED | | |
| ENGINEER | D. Randall | 10/25/84 |
| APPROVED | | |

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2028 Old Middlefield Way • Mountain View, CA 94043 • (415) 962-8165

BODY SUB-ASSEMBLY
CALORIMETER

| SIZE | CODE IDENT NO. | DRAWING NO. | REV. |
|---|---|---|---|
| B | | 7050-002 | 0 |

SCALE | WT | SHEET OF

| REVISIONS | | | | |
|---|---|---|---|---|
| ZONE | LTR | DESCRIPTION | DATE | APPROVED |
| | | | | |

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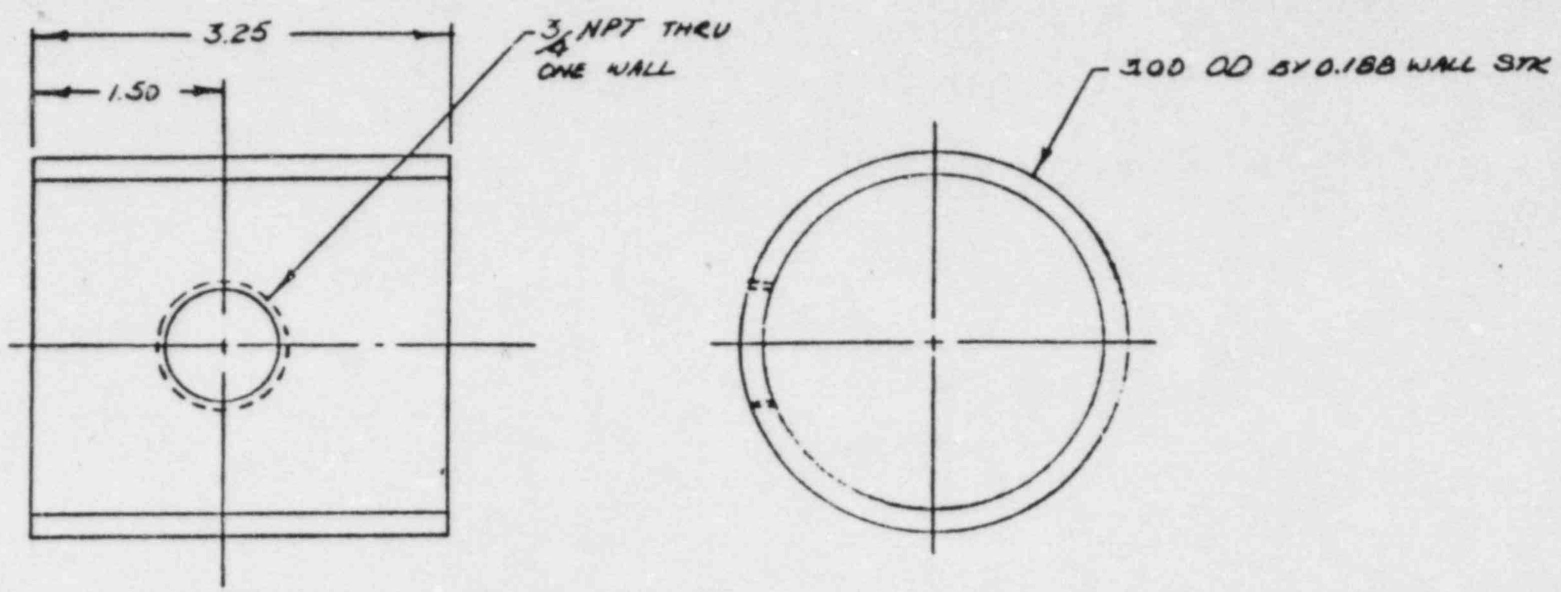


REVISIONS

| ZONE | LTR | DESCRIPTION | DATE | APPROVED |
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| -02 | -01 | ITEM NO. | CODE IDENT | PART NO. | DESCRIPTION |
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| QTY. REQD. | | | | | |

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
FRACTION DECIMALS .XX .010 .XXX .005 ANGLES
MACH COR—.005 TO .015 R OR CHAM SH MATL—BREAK EDGES .005 MAX R
ALL √ SURFACES TO BE 125
DIM AND TOL APPLY BEFORE FIN. TREAT.
DO NOT SCALE DRAWING
MATERIAL STAINLESS 304 OR 316
FINISH

DRAWN D. RANDALL DATE 10/25/84
CHECKED
ENGINEER D. RANDALL 10/26/84
APPROVED

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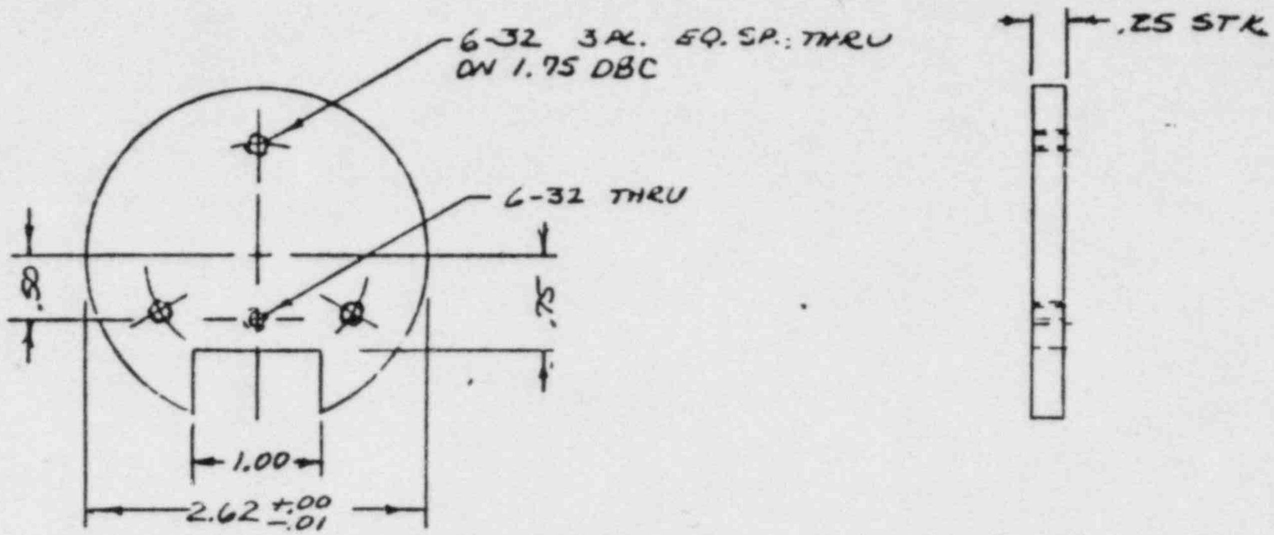
TUBE CALORIMETER

SIZE B | CODE IDENT NO. | DRAWING NO. 7050-003 | REV. 0
SCALE FULL | WT | SHEET 1 OF 1




| REVISIONS | | | | |
|---|---|---|---|---|
| ZONE | LTR | DESCRIPTION | DATE | APPROVED |
| | | | | |

| -02 | -01 | ITEM NO. | CODE IDENT | PART NO. | DESCRIPTION |
|---|---|---|---|---|---|
| QTY. REQD. | | LIST OF MATERIALS | | | |

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
FRACTION DECIMALS ANGLES
.XX .01 .XXX .005

MACH COR—.005 TO .015 R OR CHAM BY MATL—BREAK EDGES .005 MAX R

ALL √ SURFACES TO 63 √125

DIM AND TOL APPLY BEFORE FIN. TREAT.

DO NOT SCALE DRAWING

MATERIAL .25 THK 316 SS

FINISH

| | | DATE |
|---|---|---|
| DRAWN | D. Randall | [illegible] |
| CHECKED | | |
| ENGINEER | [signature] | 10/25/89 |
| APPROVED | | |

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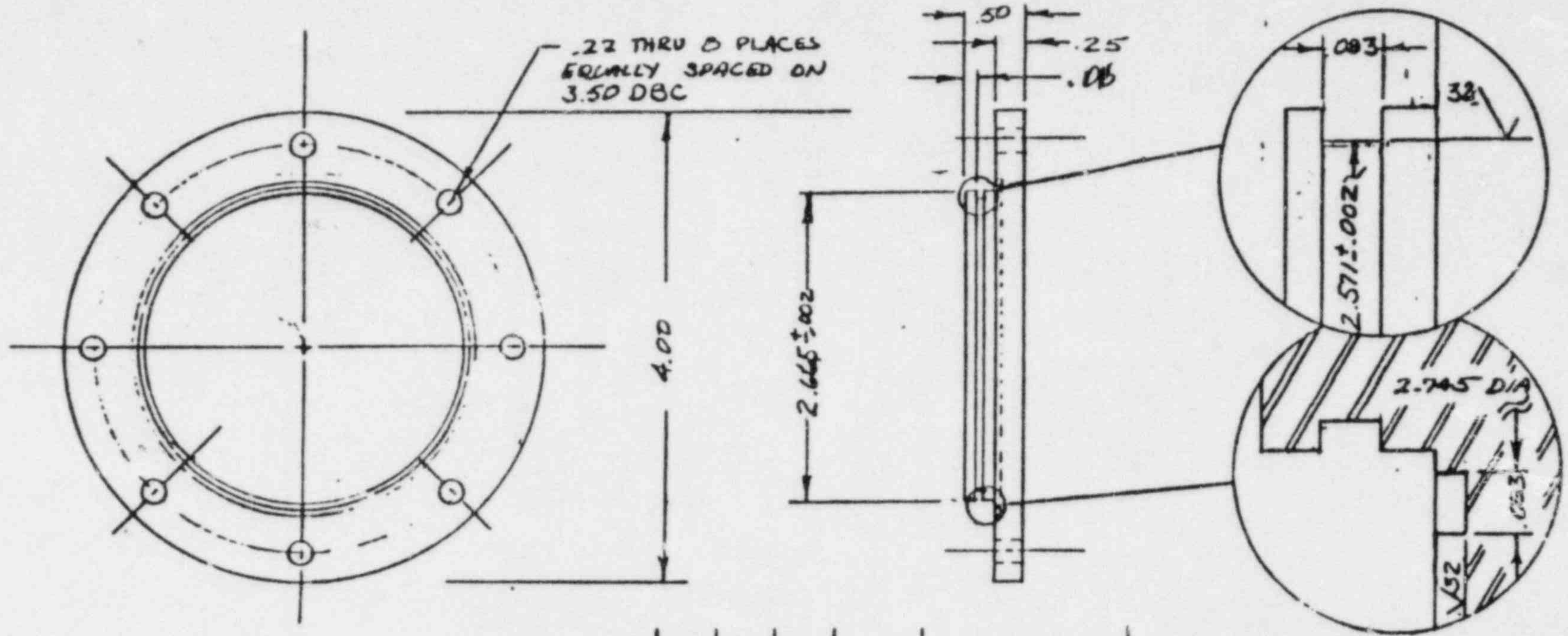
DIVIDER
CALORIMETER

| SIZE | CODE IDENT NO. | DRAWING NO. | REV. |
|---|---|---|---|
| B | | 7050-004 | 0 |
| SCALE FULL | | WT | SHEET 1 OF 1 |




| -02 | -01 | ITEM NO. | CODE IDENT | PART NO. | DESCRIPTION |
|---|---|---|---|---|---|
| QTY. REQD. | | | LIST OF MATERIALS | | |

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
FRACTION | DECIMALS .XX .01 .XXX .005 | ANGLES
MACH COR— .005 TO .015 R OR CHAM
SH MATL—BREAK EDGES .005 MAX R
ALL ✓ SURFACES TO 63 ✓125
DIM AND TOL APPLY BEFORE FIN. TREAT.
DO NOT SCALE DRAWING
MATERIAL 316 SS
FINISH

| | | DATE |
|---|---|---|
| DRAWN | D. RANDALL | 10/12/84 |
| CHECKED | | |
| ENGINEER | D. RANDALL | 10/12/84 |
| APPROVED | | |

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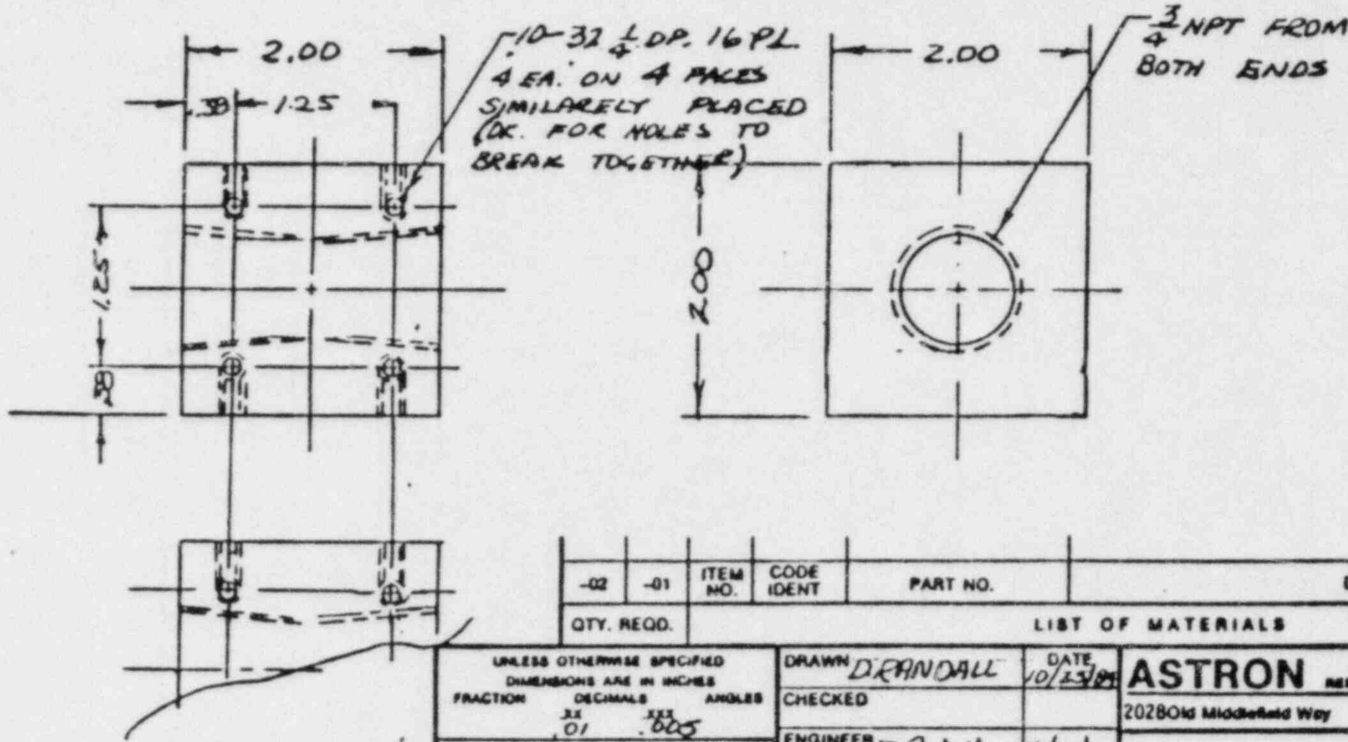
COVER PLATE
CALORIMETER

| SIZE | CODE IDENT NO. | DRAWING NO. | REV. |
|---|---|---|---|
| B | | 7050-005 | 0 |
| SCALE FULL | | WT | SHEET OF |

| REVISIONS | | | | |
|---|---|---|---|---|
| ZONE | LTR | DESCRIPTION | DATE | APPROVED |




| -02 | -01 | ITEM NO. | CODE IDENT | PART NO. | DESCRIPTION |
|---|---|---|---|---|---|
| QTY. REQD. | | | LIST OF MATERIALS | | |

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| UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES FRACTION DECIMALS .XX .01 .XXX .005 ANGLES | DRAWN D. RANDALL DATE 10/23/84 | **ASTRON** RESEARCH AND ENGINEERING 2028 Old Middlefield Way • Mountain View, CA 94043 • (415) 962-8166 |
| MACH COR—.005 TO .015 R OR CHAM SH MATL—BREAK EDGES .005 MAX R | CHECKED | BASE |
| ALL ✓ SURFACES TO BE ✓ | ENGINEER [signature] 10/23/84 | CALORIMETER |
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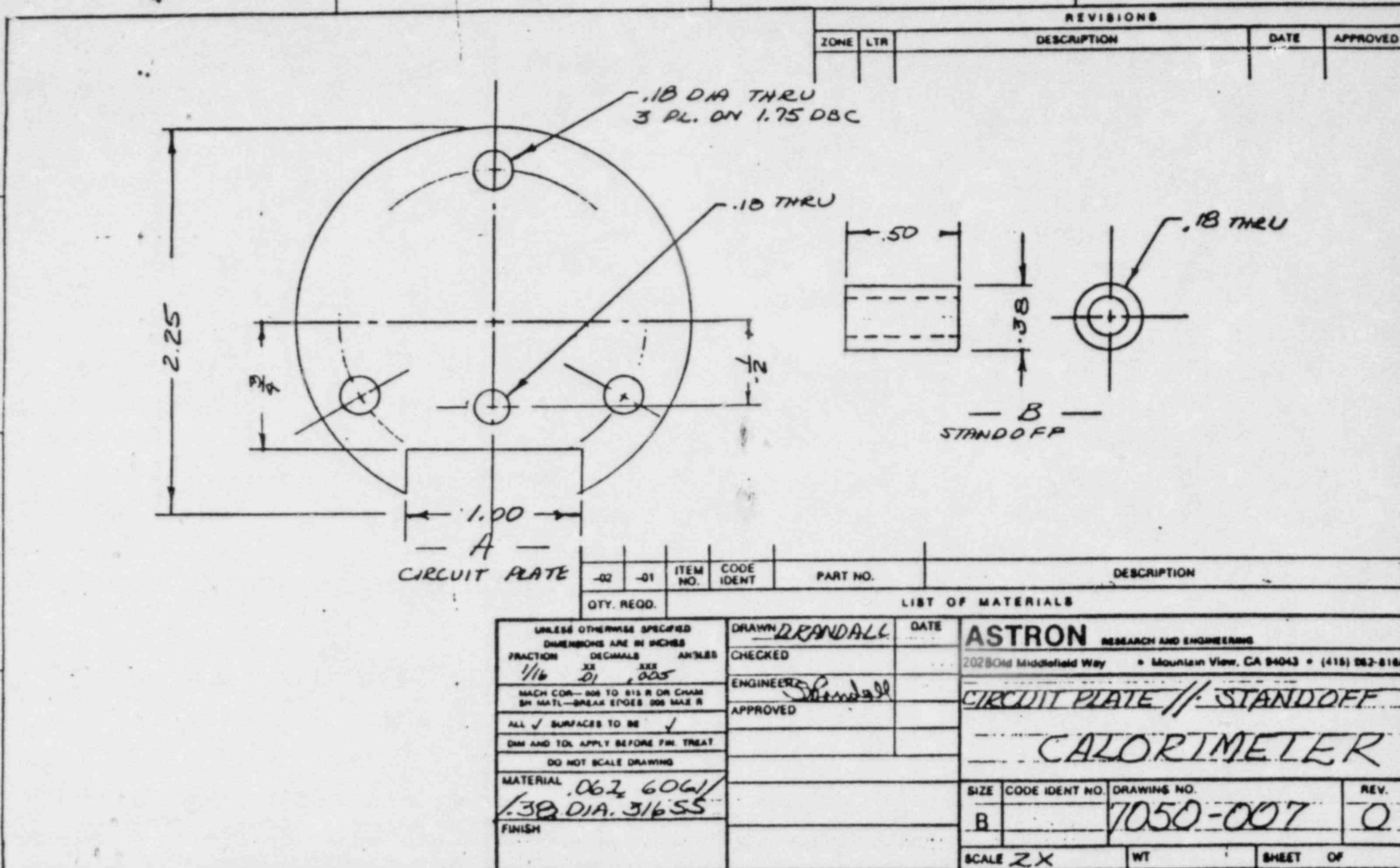

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APPROVED
ASTRON RESEARCH AND ENGINEERING
2028 Old Middlefield Way • Mountain View, CA 94043 • (415) 962-8186
CIRCUIT PLATE // STANDOFF
CALORIMETER
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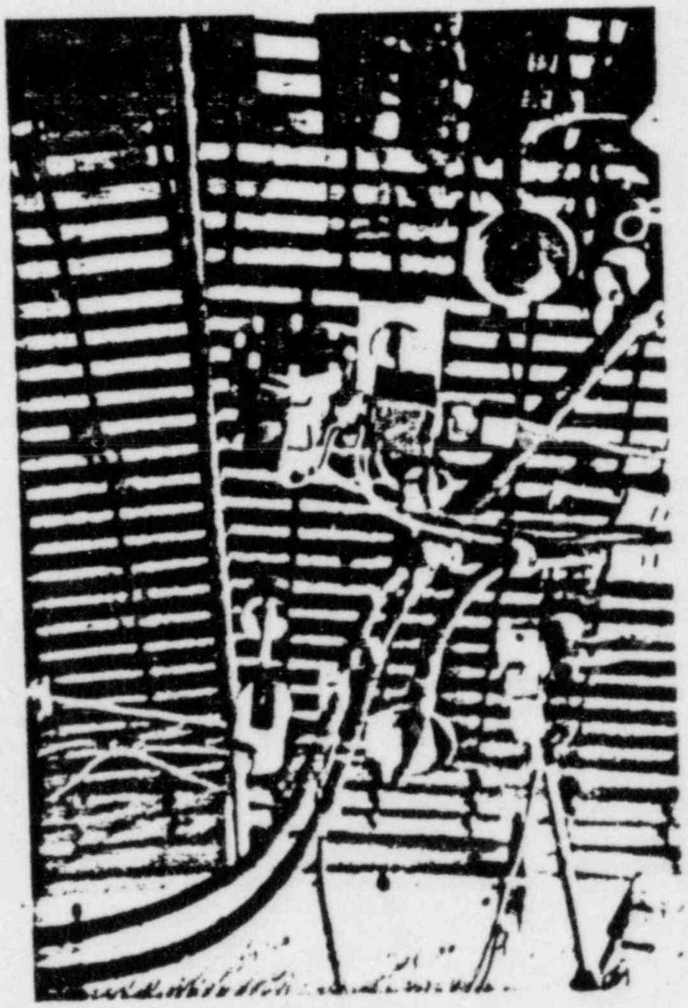

Figure 1

Complex Calorimeter Mounted to Underside of Grating at HCU (10 ft.) level (looking almost directly up).

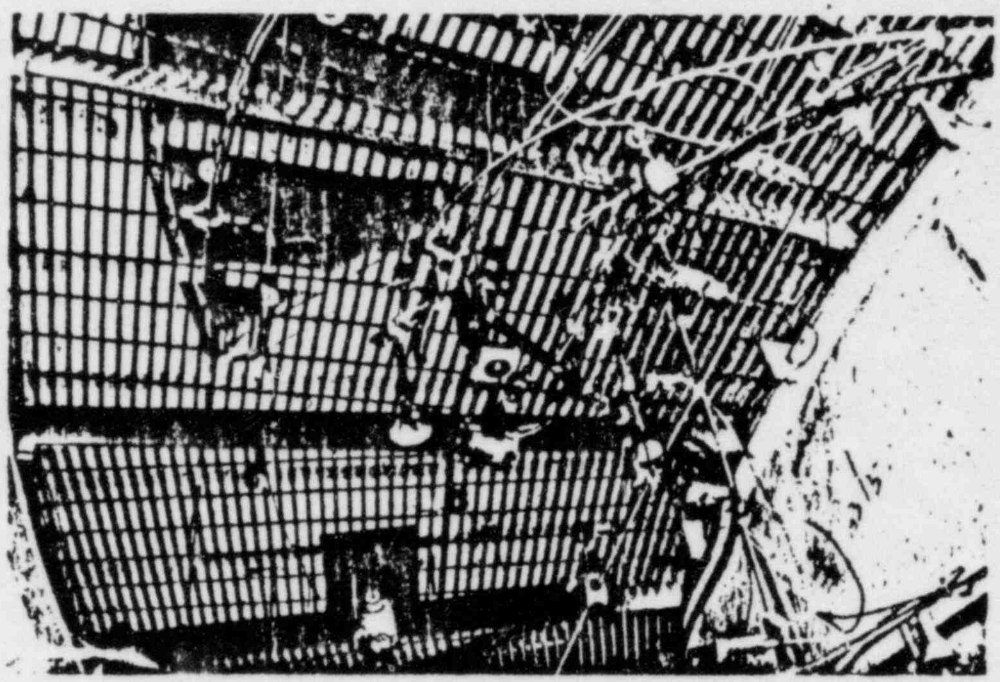

Figure 2

315° Chimney - View looking up at the complex calorimeter and other instruments attached to the underside of the grating at the HCU (10Ft) level.

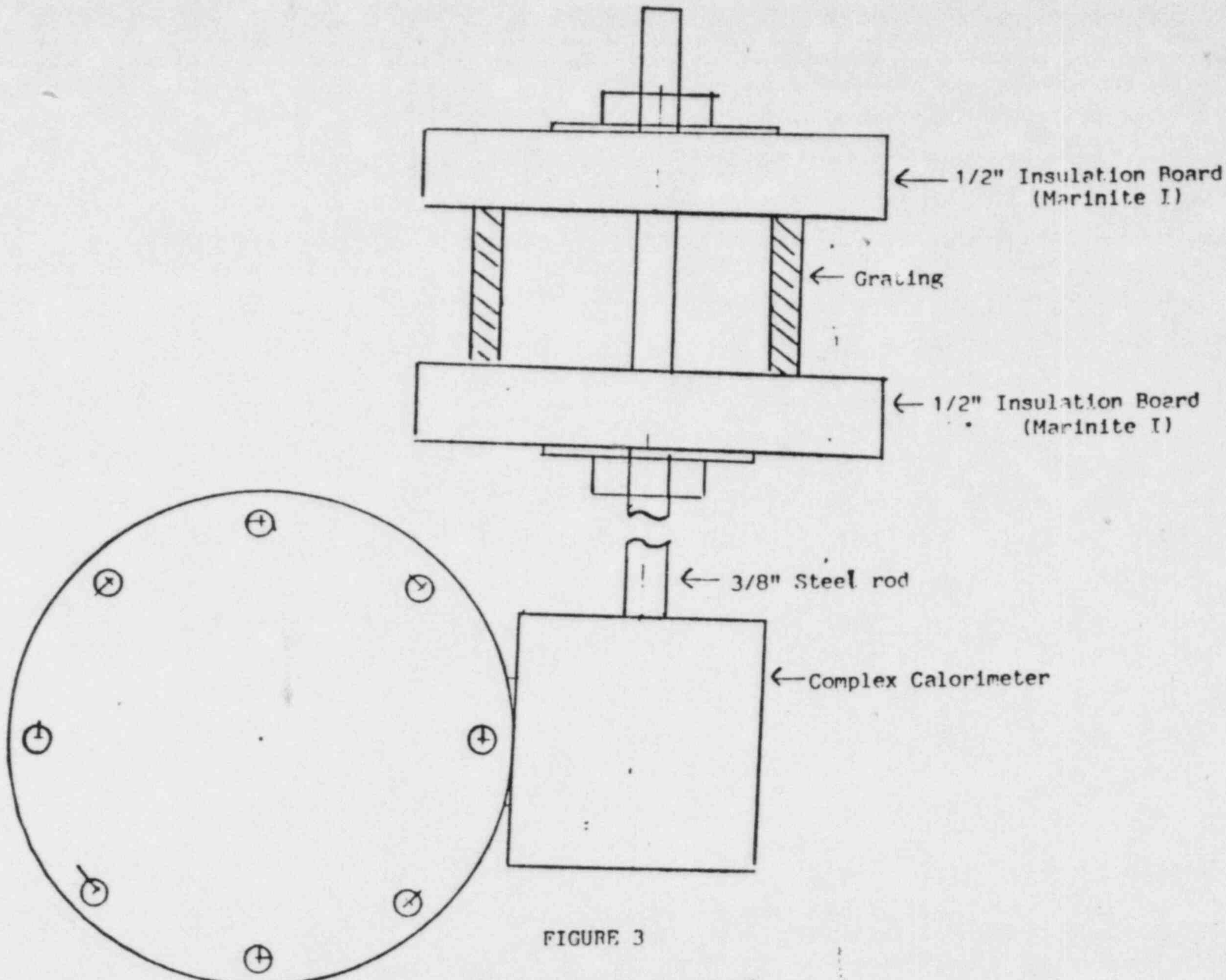


FIGURE 3

Mounting Arrangement
For Complex Calorimeter

PROPOSED AGENDA FOR
THE JANUARY 30 MEETING BETWEEN
THE HYDROGEN CONTROL OWNERS GROUP
AND NUCLEAR REGULATORY COMMISSION

| | |
|---|---|
| 8:30 - 9:00 | Introduction and Meeting Objectives |
| 9:00 - 10:00 | Discussion of MARCH Analysis |
| 10:00 - 11:00 | Discuss PBF Test Results |
| 11:00 - 12:30 | HCOG Comments<br>- BWR Core Heatup Code treatment of oxidation<br>- MARCH input assumptions<br>- Test data supporting irreversible oxidation cutoff |
| 12:30 - 1:30 | Lunch |
| 1:30 - 2:30 | Discuss Loss of Control Rod Integrity |
| 2:30 - 3:00 | Station Blackout as a Hydrogen Generation Event |
| 3:00 - 4:30 | Non-mechanistic hydrogen release histories |

The meeting will be held in room P110 of the Phillips Building in Bethesda, Maryland.

## TASK 9 - DIFFUSION FLAME THERMAL ENVIRONMENT

Requirements 10 CFR 50.44 (c)(3)(vi)

A hydrogen control system shall be provided and justified by a program of experiment and analysis.

### Task Description

The hydrogen combustion testing completed under Task 6 demonstrated that steady diffusion flames could exist at the suppression pool surface. This task involves completing a test program to define the thermal environment in the wetwell and upper containment produced by this type of combustion.

TASK 9 - DIFFUSION FLAME THERMAL ENVIRONMENT

MAJOR SUBTASKS

9.2 Design Test Facility

- Facility designed to simulate Mark III containment features (i.e. suppression pool, sprays or unit coolers, spargers)
- Floor geometry variable to simulate all four Mark III plants
- Heavily instrumented to provide data on thermal environment

9.7 Draft Test Matrix

- A matrix of tests to be completed in the facility was developed
- Covers range of hydrogen release locations
- Evaluates key parameters which might affect thermal environment

9.12 Complete Shakedown Testing

- Tests to check operation of facility systems
- Tests to verify instrument operability and responses
- Tests to evaluate integrated system performance

9.14 Prepare Final Test Facility Design Report

- Document final facility configuration
- Identify key facility characteristics

## TASK 9 - DIFFUSION FLAME THERMAL ENVIRONMENT

### MAJOR SUBTASKS (CONT)

9.17 Complete Scoping Tests

- o Test series to evaluate effects of varying important parameters
- o Potential impact on production tests
- o Utilize same hydrogen history as production tests

9.19 Production Test Matrix Acceptable

- o Review scoping test results
- o Determine if assumptions used in developing production test matrix are valid

9.23 Complete Production Tests

- o Execute tests in production test matrix
- o Record required data
- o Make necessary changes in test configuration

9.28 Prepare Final Test Report

- o Document test results
- o Discuss effect of important parameters on test results
- o Discuss reliability of data

## TASK 9 - DIFFUSION FLAME THERMAL ENVIRONMENT

### Status

- Subtasks 9.1 - 9.3, 9.7 - 9.8 and 9.11 complete
- Subtasks 9.5, 9.9, 9.10 and 9.12 in progress

### Remaining Work

- HCOG preparing responses to NRC questions on 1/4 scale facility design
- Final facility design report remains to be submitted
- Execute balance of shakedown and scoping tests
- Determine if production test matrix is adequate
- Schedule meeting to review scoping test results
- Schedule meeting to review production test progress
- Complete Production tests
- Reduce Data
- Schedule meeting to discuss production test data
- Submit final test Report

## TASK 9 - DIFFUSION FLAME THERMAL ENVIRONMENT

Acceptance Criteria

- o Obtain data to define thermal environment produced by steady diffusion flames
- o Scaling for test facility shall be conservative
- o Scaled test facility shall represent Mark III plants
    - capability to simulate each containment geometry
    - simulate major blockages
    - simulate containment cooling system including sprays and unit coolers
    - heat transfer characteristics shall be conservative compared to full scale parameters
    - simulate variable hydrogen and steam injection to facility
- o Testing in scaled facilities shall be consistent with accident progression based on operator actions in EPG
- o Parameters which could affect full scale thermal environment shall be evaluated in scaled test facility
- o A limiting thermal environment produced by diffusion flames shall be established for each area in wetwell and upper containment
- o Hydrogen distribution shall be measured throughout facility to resolve mixing
- o Data shall be obtained to validate analytical methods

# TASK 11 - EQUIPMENT SURVIVABILITY ANALYSIS PROGRAM

Requirements — 10 CFR 50.44 (c)(3)(iv)(V) and (c)(vi)(B)(5)(ii)

Equipment which is required to survive degraded core accidents shall be demonstrated to survive. Analyses shall account for local detonations unless probability of local detonations is demonstrated to be sufficiently low.

## Task Description

Certain pieces of equipment must be operable during and after accidents which produce large quantities of hydrogen. These components could potentially be exposed to deflagrations, diffusion flames or a severe environment in the drywell. This task involves defining equipment required to survive and verifying by analysis that the equipment will withstand the predicted environments.

## TASK 11 - EQUIPMENT SURVIVABILITY ANALYSIS PROGRAM

### MAJOR SUBTASKS

### 11.1 Criteria for Equipment Survivability

- o Equipment surface temperature remains below equipment qualification temperature
- o Critical component temperature remains below equipment qualification temperature
- o Component temperature remains below survivability temperature
- o Pressure produced by deflagrations remains below qualification pressure
- o Component can be shown to be insensitive to pressure

### 11.2 Identify Equipment Required to Survive

- o Review all safety related equipment in containment
- o Identify components required to survive
- o Identify support components

### 11.5 Develop Models of Equipment

- o A heat transfer code will be used to calculate thermal response of equipment
- o A generic set of equipment models will be developed using a common approach and assumptions on heat transfer coefficients

### 11.11 Analyze Equipment Thermal Response

- o Models developed in 11.5 will be used
- o Thermal environments produced by deflagrations, diffusion flames or in the drywell will be applied to equipment

TASK 11 - EQUIPMENT SURVIVABILITY ANALYSIS PROGRAM

MAJOR SUBTASKS (CONT)

11.12 Peak Pressure Exceeds Equipment Qualification Pressure

- The peak pressure produced by base case deflagrations will be compared to the pressure equipment can withstand

11.14 Peak Temperature Exceeds Equipment Qualification Temperature

- The peak component temperature resulting from hydrogen combustion shall be compared to the Equipment Qualification temperature

11.16 Critical Component Temperature Exceed Qualification Temperature

- If the decision point at 11.14 shows equipment temperature exceeding qualification temperature, the critical component will be identified

- The critical component temperature will be compared with its qualification temperature

11.17 Identify Survivability Enhancements

- HCOG will investigate various approaches to insuring equipment survivability

  - shielding equipment
  - active cooling
  - relocation
  - equipment replacement

11.21 Prepare Equipment Survivability Report

- Document modeling assumptions

- Document thermal profiles used for analysis

- Document analysis results

- Document equipment survivability

## TASK 11 - EQUIPMENT SURVIVABILITY ANALYSIS PROGRAM

Status

- o Subtasks 11.1 and 11.2 Complete
- o Subtasks 11.3 and 11.6 - 11.8 in progress

Remaining Work

- o Model equipment
- o Finalize thermal environments
- o Analyze equipment thermal response
- o Schedule meeting on thermal environment definition
- o Verify equipment survivability
- o Schedule meeting on survivability resolution
- o Submit equipment survivability report to NRC

## TASK 11 - EQUIPMENT SURVIVABILITY ANALYSIS PROGRAM

Acceptance Criteria

- o A list of equipment required to survive hydrogen combustion shall be prepared
- o Equipment thermal response shall be calculated using an acceptable thermal response analysis code
- o Number of components to be modeled and analyzed can be limited
  - If identical or similar component has been evaluated against a more limiting thermal environment
  - If a similar more thermally sensitive component has been modeled
- o Thermally limiting component shall be the component most likely to fail during or after combustion
- o Thermal environments in drywell and in containment due to deflagrations, diffusion flames or inverted diffusion flames as appropriate shall be defined
  - Deflagrations based on containment response analysis completed in Task 8
  - Diffusion flames based on experimental data in Task 9
  - Drywell environment based on results from analyses in Task 10
- o Equipment shall be judged to survive temperatures
  - If equipment surface temperature remains below qualification
  - If critical component temperature remains below qualification
  - If equipment surface temperature remains below survivability temperature

TASK 11 - EQUIPMENT SURVIVABILITY ANALYSIS PROGRAM

ACCEPTANCE CRITERIA (CONT)

- Equipment shall be judged to survive pressures
  - If peak pressure experienced by equipment is below qualification
  - Component can be shown to be insensitive to pressure
- Measures shall be identified to assure survivability
  - Protection
  - Demonstrate equipment can perform function
  - Replacement
  - Relocation

## TASK 12 - VALIDATION OF ANALYTICAL METHODS

Requirements — 10 CFR 50.44 (c)(3)(vi)

Analysis shall be submitted which demonstrates that systems and components necessary to establish and maintain safe shutdown and to maintain containment integrity, will perform their function during and after exposure to environmental conditions created by the burning of hydrogen.

Task Description

To demonstrate conservatisms of CLASIX-3 modeling assumptions, a prediction of a complex calorimeter thermal response will be made using CLASIX-3 thermal environment prediction as input. This prediction will be compared to the measured response of the actual calorimeter during a deflagration test in the 1/4 scale facility. It will be shown that the analytical method is conservative.

## TASK 12 - VALIDATION OF ANALYTICAL METHODS

### MAJOR SUBTASKS

12.3 Complete CLASIX-3 Prediction

- o Develop model of 1/4 scale facility
- o Specify input

12.4 Design Complex Calorimeter

- o Instrumented calorimeter with complex geometry
- o Movable in facility to validate methods in varying environment

12.5 Prepare Model of Complex Calorimeter

- o Heat transfer model developed
- o Same methodology as survivability thermal response models

12.7 Compare Measured Results With CLASIX-3/Heat Transfer

- o Evaluates analytical method for predicting response to deflagrations
- o Predicted response of complex calorimeter will be compared with measured response
- o If not acceptable, then modeling assumptions and techniques will be refined
- o Changes in assumptions and results will be documented

12.9 Compare Measured Results With Thermal Response Prediction

- o Measured thermal environment data from diffusion flame tests applied to model of complex calorimeter
- o Techniques and assumptions used to construct thermal response model will be confirmed

# TASK 12 - VALIDATION OF ANLAYTICAL METHODS

Status

- Task 12.4 complete
- Tasks 12.1 and 12.2 in progress

Remaining Work

- Complete CLASIX-3 model and prediction
- Prepare thermal response model of complex calorimeter
- Take measured response data and apply to thermal response model
- Compare measured response with predicted response using CLASIX-3 data
- Compare measured response with predicted response using 1/4 scale test data
- Schedule meeting to discuss methodology validation
- Submit final methods validation report

Acceptance Criteria

- Predicted response of model in a known thermal environment will be compared to measured response and shown to be conservative
- Thermal response methodology using deflagration data from CLASIX-3 will be shown to be conservative compared to measured response in a known deflagration environment

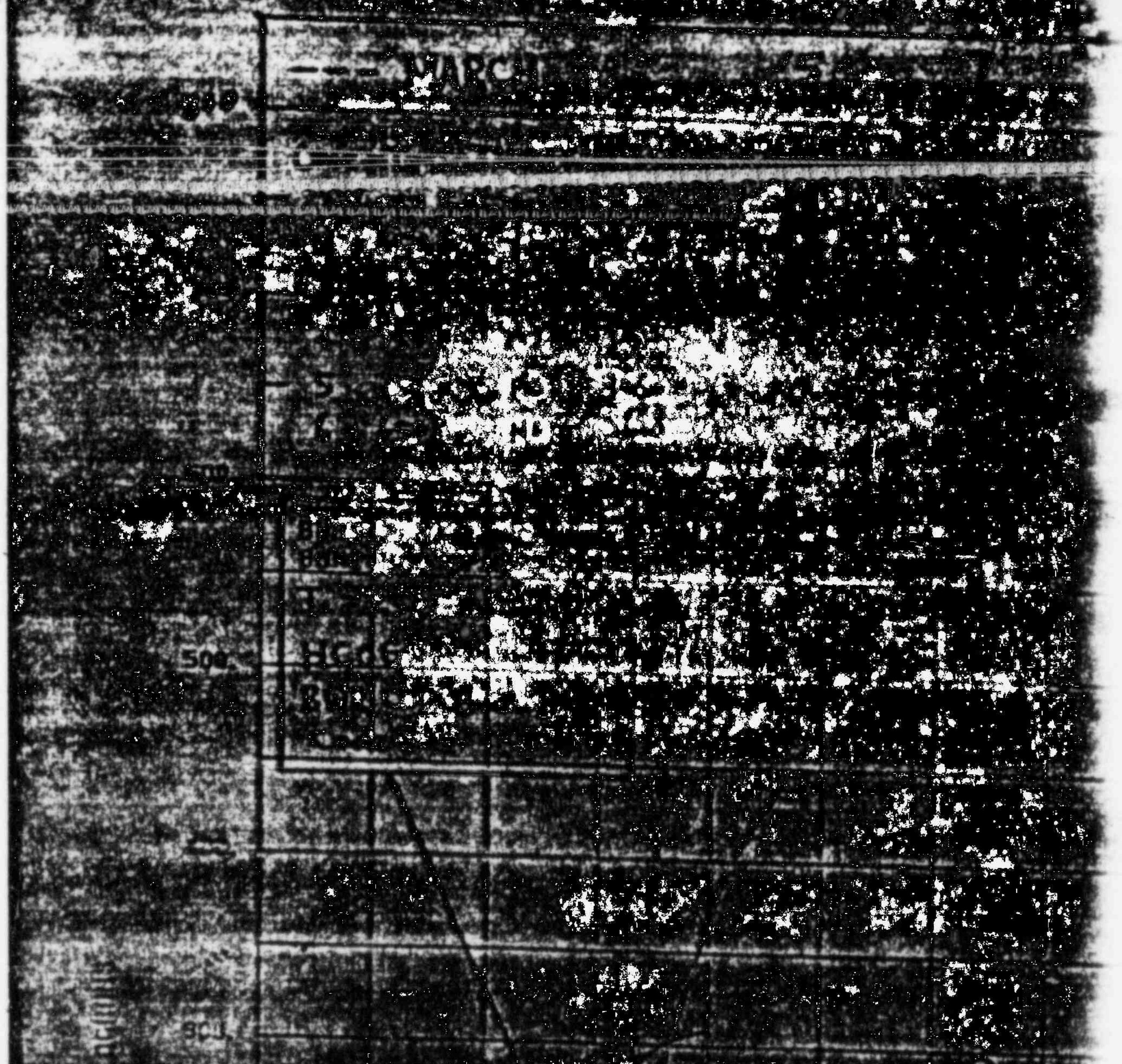


Fig. 1. CUMULATIVE HYDROGEN GENERATION

January 24, 1985

Docket No. 50-440, 50-416, 50-417,
50-458, 50-459, 50-461

MEMORANDUM FOR: Elinor G. Adensam, Chief
Licensing Branch No. 4
Division of Licensing

FROM: Carl Stahle, Project Manager
Licensing Branch No. 4
Division of Licensing

SUBJECT: Forthcoming Meeting with Hydrogen Control Owners Group for all Mark III Plants

DATE & TIME: Wednesday, January 30, 1985
9 a.m. - 11 a.m., 1 p.m. - 5 p.m.

LOCATION: Phillips Building
P-110

PURPOSE: Discuss Hydrogen Generation Rates

PARTICIPANTS:

| NRC | HCOG |
|---|---|
| M. Wigdor, et al | S. Hobbs, et al |

$

Carl Stahle, Project Manager
Licensing Branch No. 2
Division of Licensing

cc: See next page

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Docket No(s): 50-440, 416, 417, 458,459, 461

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