**NORTHEAST UTILITIES**

THE CONNECTICUT LIGHT AND POWER COMPANY
WESTERN MASSACHUSETTS ELECTRIC COMPANY
HOLYOKE WATER POWER COMPANY
NORTHEAST UTILITIES SERVICE COMPANY
NORTHEAST NUCLEAR ENERGY COMPANY

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April 15, 1988

Docket No. 50-213
B12882

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

Gentlemen:

Haddam Neck Plant
Additional Information Relating to
Small Break LOCA Analysis Model, NULAP5 (TAC No. 45830)

In a conference call with the NRC Staff on March 17, 1988, Northeast Utilities Service Company (NUSCO), on behalf of Connecticut Yankee Atomic Power Company (CYAPCO), agreed to provide the Staff and it's consultant additional information relating to the Small Break Loss of Coolant Accident (SB-LOCA) analysis model, NULAP5.

Attachment 1 contains information from NUREG-0065, "LOCA Temperature Criterion for Stainless Steel Clad Fuel". This information was previously provided informally to the NRC's consultant and is included to formally docket this information.

Attachment 2 contains information previously provided to the NRC's consultant regarding the response of the clad swell and rupture model in the SB-LOCA analysis. These calculations and plots show that the rupture model behaves as it should and is consistent with the internal tables of the SB-LOCA code.

Attachment 3 contains the information requested in the conference call of March 17, 1988. The information confirms that the oxidation calculation performs properly in the SB-LOCA model, NULAP5. This performance is verified by running the code for a constant surface temperature and observing the amount of metal that reacted. Since, at a constant temperature, the parabolic rate equation is linear with time, only two data points are required to provide the curve.

A001
1/1

If there are further questions please contact my licensing representative.

Very truly yours,

CONNECTICUT YANKEE ATOMIC POWER COMPANY

E. J. Mroczka

E. J. Mroczka
Senior Vice President

C. F. Sears

By: C. F. Sears
Vice President

cc: W. T. Russell, Region I Administrator
A. B. Wang, NRC Project Manager, Haddam Neck Plant
J. T. Shedlosky, Senior Resident Inspector, Haddam Neck Plant

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Attachment 1

Haddam Neck Plant

Information from NUREG-0065,
"LOCA Temperature Criterion for Stainless Steel Clad Fuel"

April, 1988

Sent to EG+G

1/8/78

JAC
G.A. Taylor

NUREG -0065

# LOCA TEMPERATURE CRITERION

# for

# STAINLESS STEEL CLAD FUEL


Franklin D. Coffman, Jr.
June 1976

Reactor Safety Branch
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission

the rate equation and generally all those evaluation model inputs which are directly dependent upon the alloy used for the fuel cladding are discussed and the reported calculations were adjusted appropriately. However, these adjustments are minor relative to most of the analytical refinements required by Appendix K.

2.0 Summary and Conclusion

The comparison of the response of Zircaloy and stainless steel cladding to a PWR Loss-of-Coolant Accident (LOCA) is presented in Table 1. The limiting material property for stainless steel cladding is its strength. By contrast, oxidation embrittlement is the limiting materials phenomenon for Zircaloy cladding. These material limitations have been translated into thermal performance units which facilitate the definition of safety margins. The safety differential of interest is between the Linear Heat Generation Rate (LHGR), for stainless steel cladding at a 2300 F Peak Cladding Temperature compared to the LHGR for Zircaloy cladding at a $2200^{o}$F Peak Cladding Temperature. The stainless steel clad fuel retains a favorable differential on the order of 3 kw/ft for the selected conditions calculated.

It is concluded that the behavior of stainless steel clad fuel under LOCA conditions would be conservative relative to Zircaloy clad fuel when considering the refinements of those evaluation models complying with 10CFR50, Appendix K. Furthermore, the $2300^{o}$F temperature criterion is applicable to stainless steel cladding even when these Emergency Core Cooling System Evaluation Models are used.

$H_2O$ and for the Zircaloy is about 3880 cal/g $H_2O$. For the same weight of water reacted the stainless steel will yield only about one tenth the heat of that yielded by Zircaloy.

Oxidation embrittlement is the limiting phenomenon for Zircaloy cladding. The potential for Zircaloy to absorb oxygen is quite large (29.7 atom percent) and is evident from the zirconium-oxygen phase diagram (Figure 5). The absorbed oxygen stabilizes the alpha-zirconium phase and can result in cladding which is friable and has very little ductility. The Zircaloy-water reaction is rapid and exothermic and appears to be unfavorably affected by a zirconia phase change which occurs around 2300°F.

Oxygen embrittlement is not limiting for stainless steel cladding. Examination of the binary equilibrium phase diagrams for the Fe-O and Ni-O system shows that the solubility of oxygen in stainless steel is insignificant when contrasted with the 29.7% absorbed by zirconium. The oxygen does not selectively stabilize a brittle phase in the stainless steel and there is no associated oxide phase change until melting temperatures are approached above 2400°F. Thus, the potential for oxygen embrittlement of stainless steel cladding during a postulated DBA is negligible.

3.3 Chemical Compatibility

All fuel system designs feature the cladding in close contact with some iron and nickel bearing, high temperature alloys (e.g., austenitic stainless steels, Inconels, Incoloys). The effects of compositional variations during a Design Basis Accident must be

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Attachment 2

Haddam Neck Plant

Information on
Clad Swell and Rupture Model
in NULAP5

April, 1988

Haddam Neck Plant, Clad Swell and Rupture Model

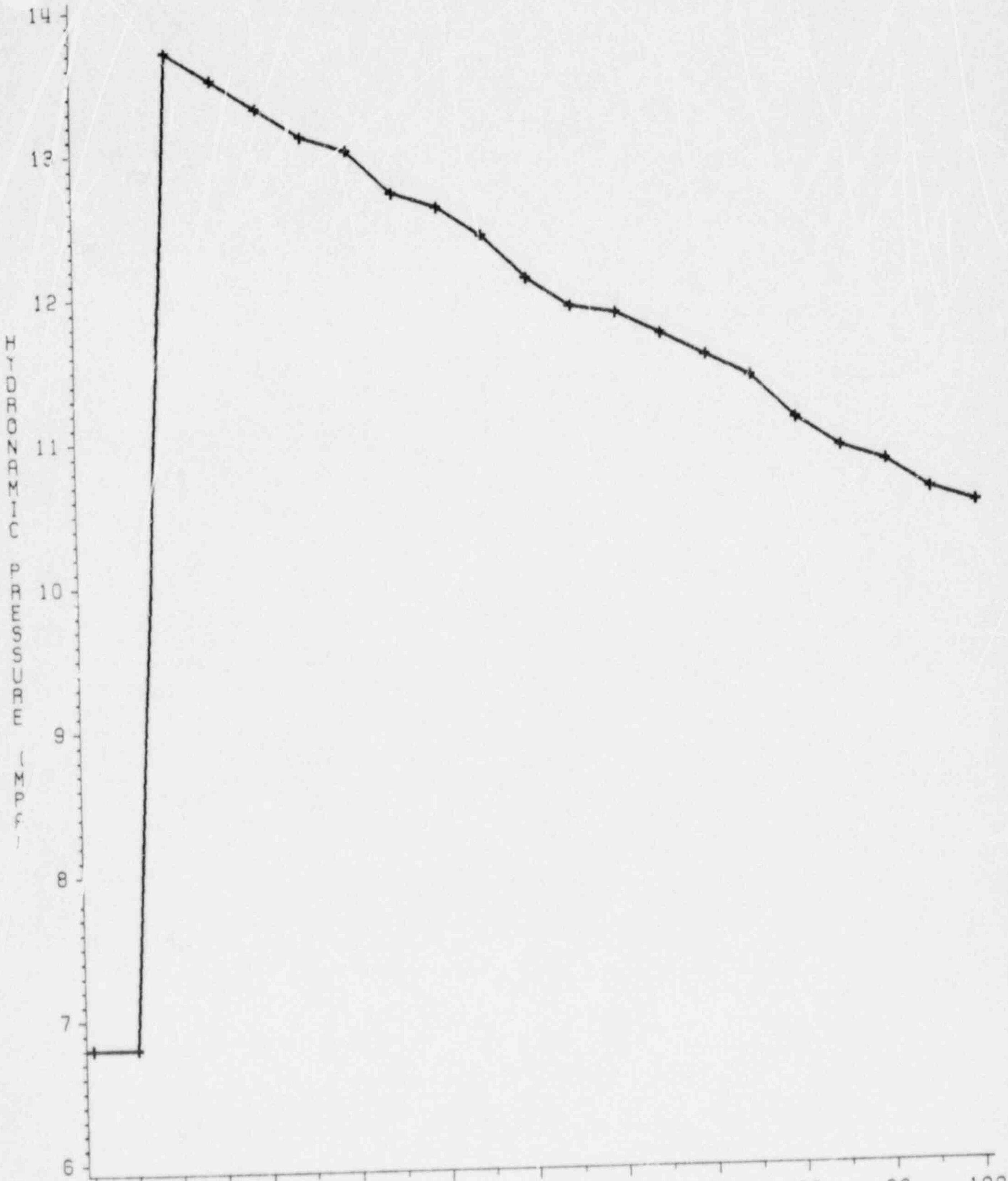
This attachment contains information regarding the response of the clad swell and rupture model in the SB-LOCA analysis. To provide this information tests were run with a pipe for the hydrodynamic boundary condition and heat structures to simulate a Haddam Neck fuel rod. Three tests were run at different initial pin pressures but all other initial conditions were kept unchanged. Table 1 of this attachment contains a summary of the results of the calculations. Plots of temperature vs. time and coolant pressures vs. time for the 1800 psi case are also included. All three test runs ended at about 102 seconds when the clad temperature caused a water property failure. These calculations show that the rupture model behaves as it should and is consistent with the internal table of the SB-LOCA.

TABLE 1

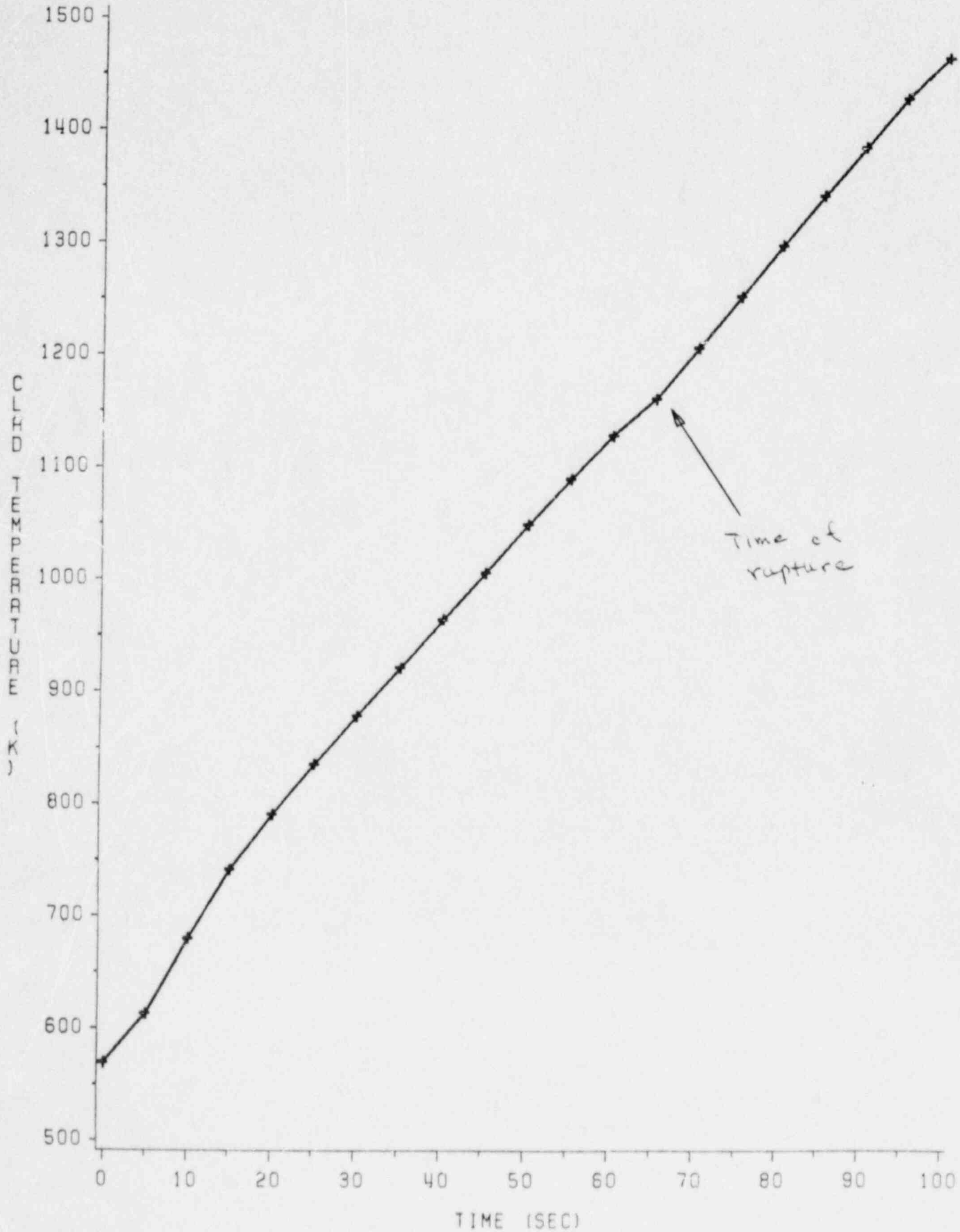
Test Results

| | | | | |
|---|---|---|---|---|
| Initial Rod Pressure | (psi) | 2800 | 1800 | 1000 |
| Calculated Hoop Stress | (psi) | 32480 | 19805 | 9598 |
| Table Hoop Stress | (psi) | 32355 | 19750 | 9596 |
| Temperature at Rupture | ($^{o}$F) | 1395 | 1641 | 2090 |
| % Blockage at Rupture | (-) | 3.0 | 26.6 | 90.1 |
| Time of Rupture | (sec) | 48.1 | 65.8 | 98.5 |

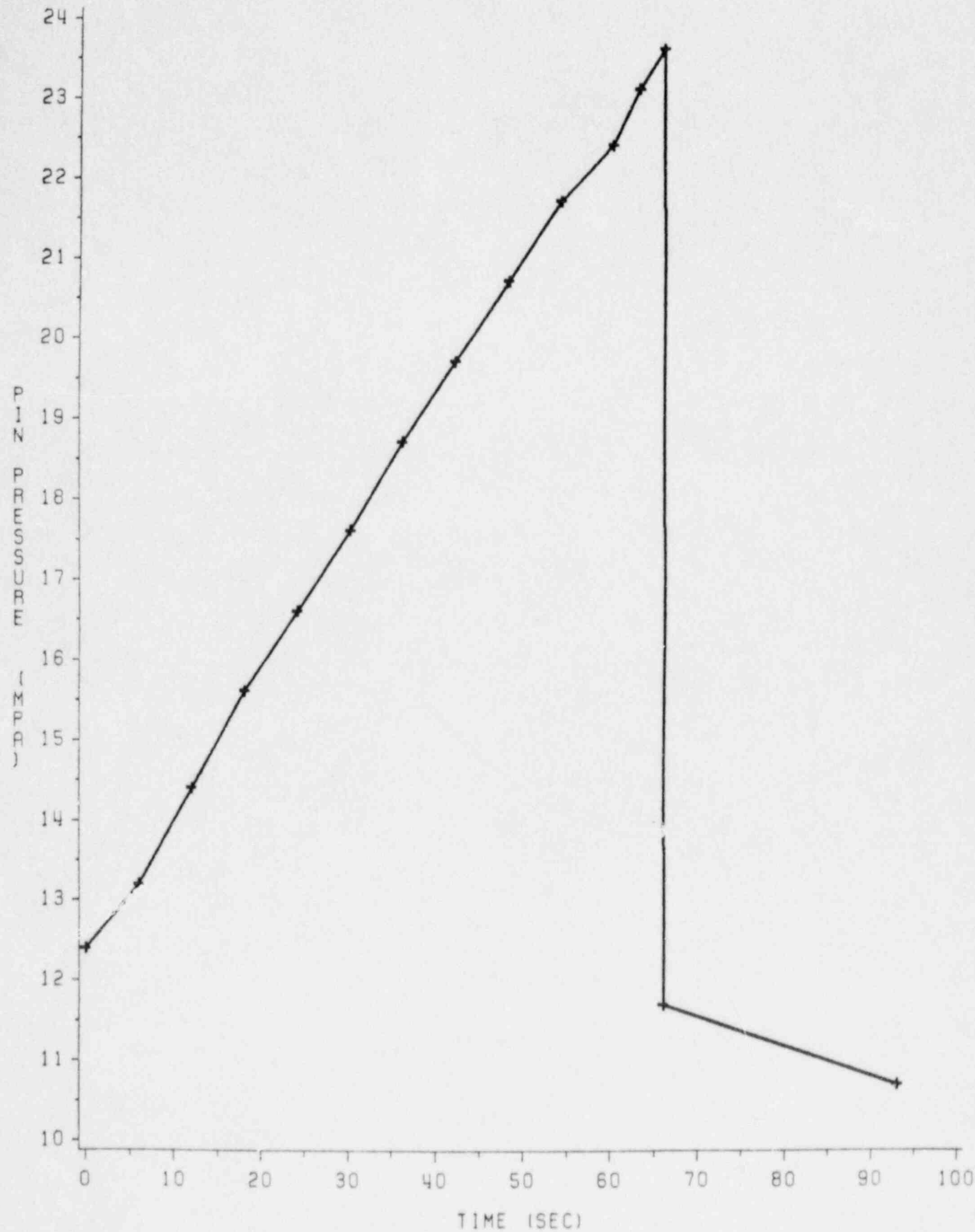
# HADDAM NECK SWELL AND RUPTURE MODEL



# HADDAM NECK SWELL AND RUPTURE MODEL



# HADDAM NECK SWELL AND RUPTURE MODEL



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Attachment 3

Haddam Neck Plant

Response to NRC Questions
About the
Oxidation Model in NULAP5

April, 1988

## Information on NULAP5 Oxidation Model

Request: Demonstrate that the oxidation calculation in NULAP5 predicts the appropriate metal-water reaction.

Response

The metal-water oxidation reaction is expressed by the parabolic rate equation.

$$W^2 = tk \exp(- E/RT)$$

W = weight of metal reacted per unit area, $mg/cm^2$

k = rate constant, $6.28 \times 10^{12}\ mg^2/cm^4$-5

E = activation energy, 84,300 cal/mole

R = gas constant, 1.987 cal/mole - K

T = temperature, K

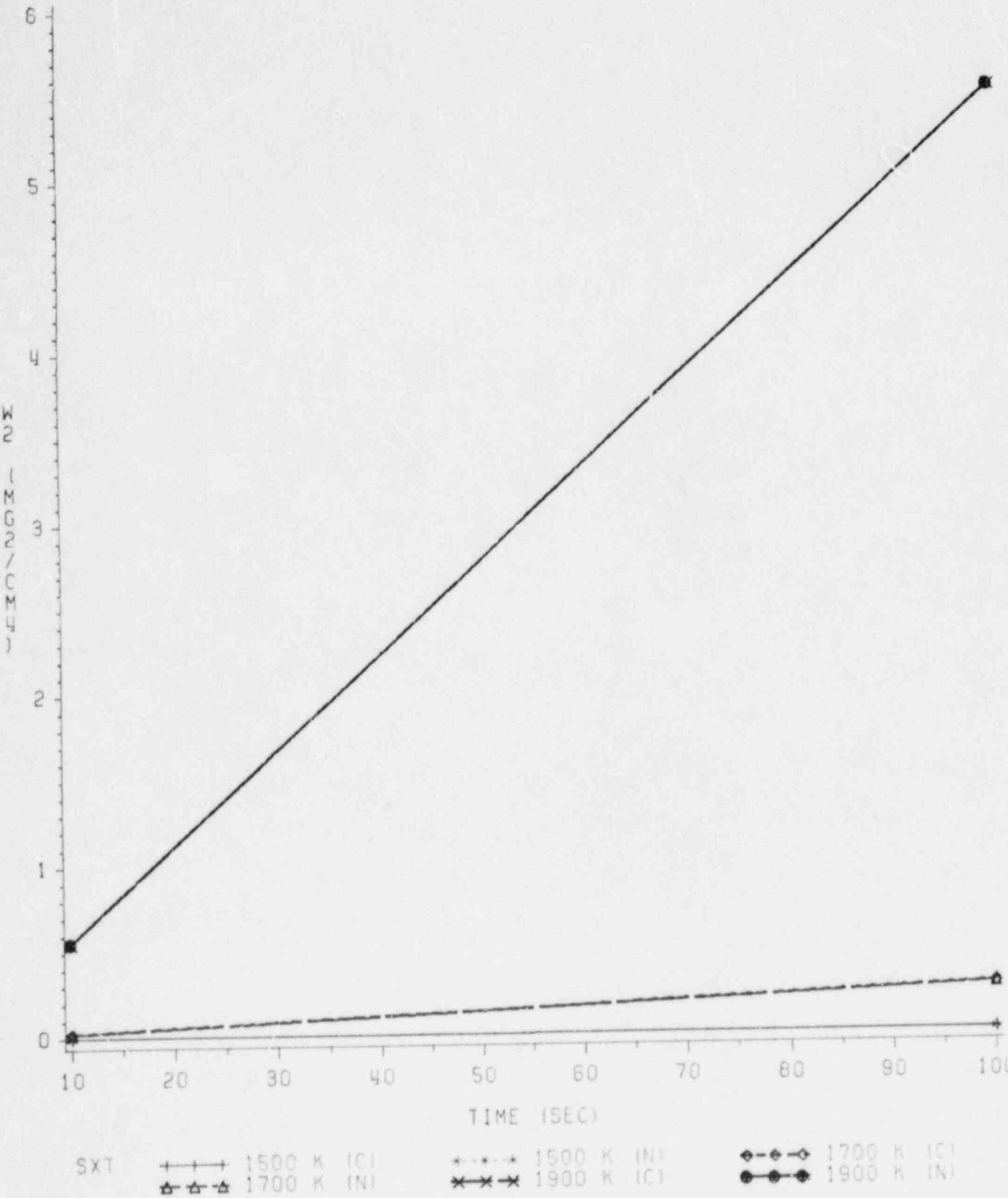
t = time, s

NULAP5 integrates this equation to give a clad thinning and heat calculation as described in previous submittals. The plots that follow show hand calculated values for $W^2$ and code calculated $W^2$ at various constant temperatures versus time. Only two points for each temperature are given since at a constant temperature $W^2$ is linear with time. The lines for the hand calculated plot and the NULAP5 calculated plot overlay each other since, at the same temperature, their values are the same. The plots confirm that the integration of the rate equation is properly implemented.

The temperature at which an appreciable amount of oxidation occurs is in excess of the peak integrated oxidation reported in the submitted topical report. Although the effect of oxidation is insignificant for stainless steel clad fuel during a small break LOCA, the calculation is included in the code. The following plots show that the oxidation calculation is consistent for a range of temperatures and would be consistent and correct for any other temperatures postulated.

# HADDAM NECK OXIDATION CALCULATION

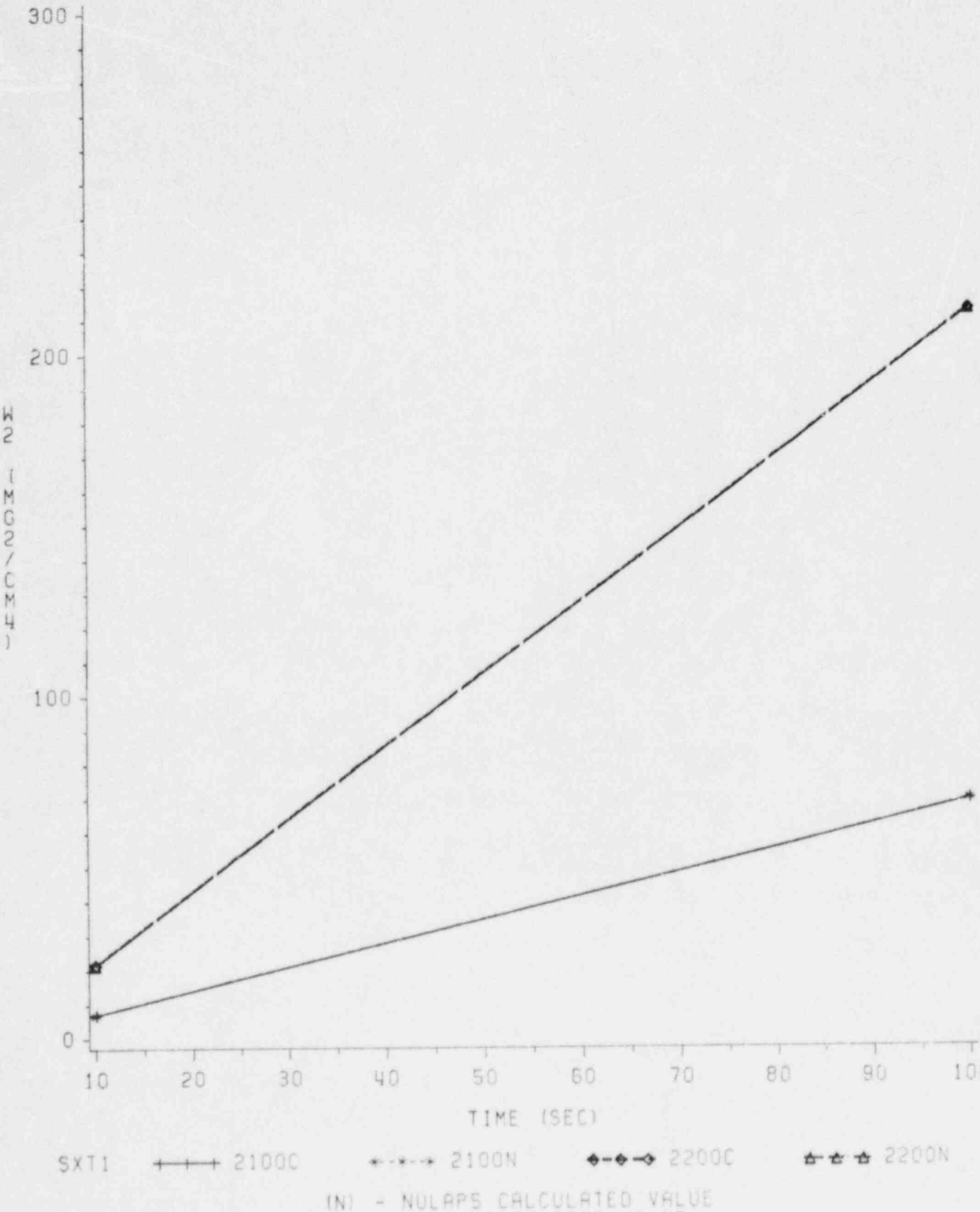
ISOTHERMS




(N) - NULAPS CALCULATED VALUE
(C) - HAND CALCULATED VALUE
ISOTHERMS IN DEGREES KELVIN

# HADDAM NECK OXIDATION CALCULATION

ISOTHERMS




(N) - NULAPS CALCULATED VALUE
(C) - HAND CALCULATED VALUE
ISOTHERMS IN DEGREES KELVIN