HEDL-TME 77-18
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CONTAINMENT MARGINS IN FFTF FOR POSTULATED FAILURE OF IN-VESSEL POST-ACCIDENT HEAT REMOVAL

HANFORD ENGINEERING DEVELOPMENT LABORATORY
Operated by Westinghouse Hanford Company
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PRELIMINARY REPORT

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SAFETY ANALYSIS DEPARTMENT

Principal Contributors

S. F. Bankert
J. P. Hale
W. P. Kunkel
H. C. Martin
R. D. Peak
A. O. Rock
P. R. Shire
D. E. Simpson
D. D. Stepnewski

April 1977

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ABSTRACT

This study was performed to complete the assessment of potential melt-through consequences for the postulated failure of post-accident heat removal following a hypothetical core disruptive accident (HCDA) in the FFTF.

The SPRAY, SOFIRE, CACECO, HAA-3B, and COMRADEX codes were used to determine potential site boundary radiation doses. Parametric comparisons were made to evaluate the effects of natural hydrogen-oxygen recombination, reactor cavity liner failures and containment coolers. Containment pressure relief, vent/purge options, and the effects of exhaust filtration were also included in the study.

The potential site boundary radiation exposures for all options considered were within 10 CFR 100 guideline values.

CONTENTS

		Page
	List of Figures	ix
	List of Tables	xiii
1.0	Introduction	1-1
2.0	Summary	2-1
	2.1 Results	2-3
	2.1.1 Consequences for Passive Containment Response	2-3
	2.1.2 Effect of Hydrogen-Oxygen Recombination	2-9
	2.1.3 Effect of Cavity Liner Failures	2-10
	2.1.4 Effects of Engineered Systems on Site Boundary Exposures	2-11
	2.1.4.1 Effect of Operation of RCB Coolers	2-12
	2.1.4.2 Effect of RCB Vent/Purge or Pressure Relief	2-12
	2.1.4.3 Effect of Exhaust Filtration	2-14
	2.1.4.4 Effects of Structural Failure	2-14
	2.2 Conclusions	2-17
3.0	Physical Description and Models	3-1
	3.1 Reactor Containment Building	3-1
	3.2 Reactor Cavity	3-6
	3.3 Reactor Subcavity	3-10
	3.4 H&V Cooler Room	3-11
	3.5 Reactor	3-12
4.0	Basis for Cases Analyzed	4-1
	4.1 HCDA In-Vessel PAHR Assessment	4-1
	4.2 Expulsion Source for Sodium and Radioactive Materials	4-2

		Page
4.3	Postulated Failure Modes for In-Vessel PAHR	4-3
4.4	Definition of Conditions for Analyses	4-3
4.4.1	In-Vessel Cases	4-4
4.4.2	Ex-Vessel Cases	4-6
5.0	Calculational Methods	5-1
5.1	Initial Conditions for Containment Transients	5-1
5.2	Initial Aerosol Behavior	5-6
5.3	CACECO Code Analysis	5-8
5.3.1	In-Vessel Case Analysis	5-9
5.3.2	Ex-Vessel Case Analysis	5-15
5.4	HAA Code Analysis	5-21
5.5	COMRADEX Analysis	5-22
5.5.1	Radioactivity Release Model	5-22
5.5.2	Radiological Exposure Models	5-30
5.5.2.1	Direct Dose	5-30
5.5.2.2	External Dose	5-30
5.5.2.3	Internal Dose	5-31
5.5.2.4	Total Dose	5-31
5.5.3	Initial Source Term Model	5-31
5.5.4	Biological Dose Model	5-32
5.5.5	Meteorological Model	5-33
6.0	Results of Analysis	6-1
6.1	Case 654	6-2
6.1.1	Containment Transients	6-2

		Page
	6.1.2 Radiological Evaluations	6-10
6.2	Case 655	6-16
	6.2.1 Containment Transients	6-16
	6.2.2 Radiological Evaluations	6-19
6.3	Case 656	6-22
	6.3.1 Containment Transients	6-22
	6.3.2 Radiological Evaluations	6-22
6.4	Case 657	6-27
	6.4.1 Containment Transients	6-27
	6.4.2 Radiological Evaluations	6-27
6.5	Case 658	6-33
	6.5.1 Containment Transients	6-33
	6.5.2 Radiological Evaluations	6-36
6.6	Case 659	6-40
	6.6.1 Containment Transients	6-40
	6.6.2 Radiological Evaluations	6-43
6.7	Case 675	6-46
	6.7.1 Containment Transients	6-46
	6.7.2 Radiological Evaluations	6-49
6.8	Case 681	6-52
	6.8.1 Containment Transients	6-52
	6.8.2 Radiological Evaluations	6-55
6.9	Case 677	6-58
	6.9.1 Containment Transients	6-58

	Page
6.9.2 Radiological Evaluations	6-58
6.10 Case 678	6-63
6.10.1 Containment Transients	6-63
6.10.2 Radiological Evaluations	6-63
6.11 Case 682	6-69
6.11.1 Containment Transients	6-69
6.11.2 Radiological Evaluations	6-69
6.12 Case 683	6-75
6.12.1 Containment Transients	6-75
6.12.2 Radiological Evaluations	6-79
6.13 Case 688	6-83
6.13.1 Containment Transients	6-83
6.13.2 Radiological Evaluations	6-87
6.14 Effect of Filtration on Releases and Doses	6-90
7.0 References	7-1
Appendices	
A. Calculational Bases for Containment Conditions	A-1
CACECO Case Summaries	A-27
CACECO Case Figures	A-41
B-1 FFTF Core Inventory Library	B-1
B-2 Suspended Concentration Plots	B-13
B-3 Filtration Effects	B-27
C. Calculations of Penetration of Containment Structures by Fuel Debris	C-1
D. Fission Product and Radioactive Material Release and Transport	D-1
E. Structural Analysis	E-1

FIGURES

Figure		Page
2-1	In-Vessel Boil-Up Cases	2-4
2-2	Ex-Vessel Boil-Up Cases	2-5
3-1	Fast Flux Test Facility	3-2
3-2	Reactor Containment Building (RCB)	3-4
3-3	Reactor Cavity Structures	3-8
5-1	Spray Pressure Transient	5-2
5-2	SOFIRE Pressure Transient	5-4
5-3	RCB Leak Rate Vs. Time	5-5
5-4	HAA Suspended Concentration	5-7
5-5	Case 654 Sodium Inventories (0-83 hours)	5-11
5-6	Case 654 Sodium Inventories (83-526.5 hours)	5-13
5-7	Case 683 Sodium Inventories (0-3 hours)	5-17
5-8	Case 683 Sodium Inventories (3-384 hours)	5-18
5-9	Case 683 Sodium Inventories (384-428.7 hours)	5-20
5-10	Case 681 CACECO Leak Rate Data For Reactor Cavity	5-25
5-11	Fission Product - Sodium Equilibrium Vaporization	5-26
5-12	Case 681 - Leak Rate	5-28
5-13	Case 681 - Fallout Rate	5-29
5-14	Comparison of Diffusion Models	5-35
6-1	Case 654 Building Atmosphere Conditions	6-3
6-2	Case 654 Building Average Vent Rate	6-5
6-3	Case 654 Average Pool Temperature	6-9
6-4	Case 654 HAA Suspended Concentration	6-11

FIGURES (Cont'd)

Figure		Page
6-5	Case 654 Radioactivity Release	6-12
6-6	Case 654 Dose Vs. Distance Curves	6-14
6-7	Case 654 Whole Body Dose	6-15
6-8	Case 655 Building Atmosphere Conditions	6-17
6-9	Case 655 Building Average Vent Rate	6-18
6-10	Case 655 Radioactivity Release Curves	6-20
6-11	Case 655 Dose Vs. Distance Curves	6-21
6-12	Case 656 Building Atmosphere Conditions	6-23
6-13	Case 656 Building Average Vent Rate	6-24
6-14	Case 656 Radioactivity Release Curves	6-25
6-15	Case 656 Dose Vs. Distance Curves	6-26
6-16	Case 657 Building Atmosphere Conditions	6-28
6-17	Case 657 Building Average Vent Rate	6-29
6-18	Case 657 Radioactivity Release Curves	6-30
6-19	Case 657 Dose Vs. Distance Curves	6-31
6-20	Case 657 Building Atmosphere Conditions	6-34
6-21	Case 658 Building Average Vent Rate	6-35
6-22	Case 658 Radioactivity Release Curves	6-38
6-23	Case 658 Dose Vs. Distance Curves	6-39
6-24	Case 659 Building Atmopshere Conditions	6-41
6-25	Case 659 Building Average Vent Rate	6-42
6-26	Case 659 Radioactivity Release Curves	6-44
6-27	Case 659 Dose Vs. Distance Curves	6-45

FIGURES (Cont'd)

Figure		Page
6-28	Case 675 Building Atmosphere Conditions	6-47
6-29	Case 675 Building Average Vent Rate	6-48
6-30	Case 675 Radioactivity Release Curves	6-50
6-31	Case 675 Dose Vs. Distance Curves	6-51
6-32	Case 681 Building Atmosphere Conditions	6-53
6-33	Case 681 Building Average Vent Rate	6-54
6-34	Case 681 Radioactivity Release Curves	6-56
6-35	Case 681 Dose Vs. Distance Curves	6-57
6-36	Case 677 Building Atmosphere Conditions	6-59
6-37	Case 677 Building Average Vent Rate	6-60
6-38	Case 677 Radioactivity Release Curves	6-61
6-39	Case 677 Dose Vs. Distance Curves	6-62
6-40	Case 678 Building Atmosphere Conditions	6-64
6-41	Case 678 Building Average Vent Rate	6-65
6-42	Case 678 Radioactivity Release Curves	6-67
6-43	Case 688 Dose Vs. Distance Curves	6-68
6-44	Case 682 Building Atmosphere Conditions	6-71
6-45	Case 682 Building Average Vent Rate	6-72
6-46	Case 682 Radioactivity Release Curves	6-73
6-47	Case 682 Dose Vs. Distance Curves	6-74
6-48	Case 683 Building Atmosphere Conditions	6-76
6-49	Case 683 Building Average Vent Rate	6-77
6-50	Case 683 Pool Temperature Vs. Time	6-80

FIGURES (Cont'd)

Figure		Page
6-51	Case 683 Radioactivity Release Curves	6-81
6-52	Case 683 Dose Vs. Distance Curves	6-82
6-53	Case 688 Building Atmosphere Conditions	6-84
6-54	Case 688 Building Average Vent Rate	6-85
6-55	Case 688 Radioactivity Release Curves	6-88
6-56	Case 688 Dose Vs. Distance Curves	6-89
6-57	Case 654F Radioactivity Release Curves	6-91
6-58	Case 654F Dose Vs. Distance Curves	6-92

TABLES

Table	Title	Page
2-1	Summary of Cases	2-6
2-2	Radiological Consequences Summary	2-8
2-3	Passive Containment Response Consequences	2-9
2-4	Effect of H_2/O_2 Recombination	2-10
2-5	Effects of Liner Failures	2-11
2-6	Effect of Cooler Operation (In-Vessel Case)	2-13
2-7	Effect of Vent/Purge	2-13
2-8	Effect of 10 PSIG Relief of RCB	2-14
2-9	Timing of Pertinent Events - In-Vessel	2-16
2-10	Timing of Pertinent Events - Ex-Vessel	2-17
3-1	RCB Equipment	3-5
3-2	Reactor Weights	3-13
5-1	CACECO Analysis of Case 656	5-10
5-2	CACECO Analysis of Case 683	5-16
5-3	Comparison of Meteorological Constants	5-34
6-1	Case 675 Vs. Case 683	6-49

CONTAINMENT MARGINS IN FFTF FOR POSTULATED FAILURE
OF IN-VESSEL POST-ACCIDENT HEAT REMOVAL

1.0 Introduction

This report presents an analysis of predicted consequences and the sensitivity of those consequences to variations in phenomenology and engineered equipment operation for a postulated failure of post-accident heat removal (PAHR) following a hypothetical core disruptive accident (HCDA) in the Fast Flux Test Facility (FFTF).

Extensive HCDA analyses for FFTF, based on energy releases in excess of predictions for hypothesized core disruptive accidents, have established that the heat transport system would remain intact.(1)(2) Further, it has been shown that fuel configurations resulting from mechanistic analyses of such accidents would be coolable and permanently retained in the reactor vessel, with cooling by either forced or natural convection flow.(3)

In order to assess the availability of still further safety margins, a number of evaluations of postulated reactor core melt-through consequences have been documented in the following reports:

(1) PAHR Containment Transients - November 1974.(4)

(2) Radiological Assessment of Ex-Vessel PAHR Containment Transients - November 1974.(5)

(3) Analyses of FFTF Postulated Failure of In-Vessel Post-Accident Heat Removal, HEDL-TI-76028, June 1976.

Item (1) reports the investigation of a range of reactor cavity liner failure conditions, including cases where sodium contacted bare concrete. These cases provided a basis for a parametric radiological assessment, Item (2), and guidance in choosing among alternatives for the disposition of the reactor building subcavity, which was incorporated in the FFTF as space for for a core retention system, should need for such a system be established. References 4 and 5 supported a conclusion that no ex-vessel core retention system would be needed. The analyses in Item (1) also showed the desirability of avoiding contact between sodium and bare concrete and for minimizing concrete liner failures. Subsequent analyses were made which showed that liner plates can withstand conditions associated with an ex-vessel PAHR event.[6] Item (3) is a more realistic evaluation of PAHR conditions, including an evaluation of assumed loss of primary heat removal capability as an alternative assumption to core melt-through. That study considered two circumstances, one in which the core material remains in the reactor vessel, and one in which melt-through into the reactor cavity is postulated.

This report extends previous studies and completes the evaluation of containment margins for postulated core melt-through for FFTF. This study has two objectives:

a. To complete the assessment of potential melt-through consequences with considerations of all applicable phenomena including structural failures and possible additional radioactivity release following boiling away of all sodium.

b. To evaluate the effects of containment operational conditions, including possible additional design features such as venting, purging, cooler operation, and effects of filtration.

The calculations reported here reflect updated analytical models and data based on results of ongoing experimental and analytical development programs associated with post-accident heat removal technology. In particular, the calculations use a new concrete water release model, hydrogen-oxygen recombination, and a revision of water release from the reactor containment building (RCB) floor, all based on experimental data. Also, modeling of physical structures has been expanded to include additional energy absorbing areas which are available in the design.

2.0 SUMMARY

Since mechanistic HCDA evaluations predict in-vessel post-accident heat removal (PAHR) for the FFTF, the postulation of failure of in-vessel PAHR is arbitrary. Consideration of such circumstances provides an insight into additional containment safety margins.

Two general conditions of in-vessel PAHR can be postulated:

- Coolable core debris within the reactor vessel, but failure of the heat transport system (HTS) to carry away the decay heat.
- Core debris in an uncoolable configuration, resulting in melt-through into the reactor cavity.

Both classes of conditions, identified as in-vessel and ex-vessel cases, respectively, have been investigated.

In the in-vessel cases, the fuel debris is assumed to remain in a coolable configuration in the reactor vessel, with heat transfer to stagnant sodium in the vessel. The ex-vessel cases assumed that at an arbitrary time of three hours, sodium and core debris melted through the reactor vessel bottom into the reactor cavity. The effects of structural failures of the reactor vessel support arms and the reactor cavity floor were included in the investigation.

The effect of arbitrary reactor cavity liner failure was studied by introducing several cases in which the extent of liner failure in the cavity was varied. This is an important consideration because it affects the extent of sodium reaction with the concrete structure.

The effect of free hydrogen accumulation in the containment atmosphere, as well as the use of experimental evidence of the natural recombination of hydrogen and oxygen, was evaluated. The natural recombination of hydrogen and oxygen is expected, and absence of that phenomenon was included for comparison.

In addition to investigation of phenomenological variations, analyses were performed to evaluate the effects of certain operational conditions or engineered equipment operation. For analysis of the passive containment response, containment pressure was allowed to increase to a maximum of 20 psi; at that pressure, blowdown to atmospheric pressure was assumed to occur. Alternate relief concepts were studied. For one of these, venting to atmospheric pressure and subsequent fresh air purge were provided when the building pressure reached 10 psig or when hydrogen concentration reached a level of 4 percent. Another case considered that building pressure would be relieved and regulated near 10 psig.

Two other options were evaluated: the effect of RCB atmosphere cooler operation, and the effect of filtration on the effluent discharged in either the purge/vent case or the regulated relief case.

Conditions were studied up to the time of sodium temperature stabilization or sodium boil-dry (whichever occurs first). In addition, the study included an evaluation of post-boil-dry conditions. It was postulated that fuel debris beds would reform into a consolidated layer and melt into the structural concrete. The depth of concrete penetration was calculated to be about 13 feet for the ex-vessel case, and about 7 feet for the in-vessel case. Additional radioactivity release at this stage was concluded to be negligible.

Each accident scenario was divided into several analytical phases for calculational convenience. Computer codes SPRAY, SOFIRE, CACECO, HAA-III, and COMRADEX were used to evaluate the details of these phases. Post-boilup fuel conditions and concrete penetration were analyzed using the AYER code. Structural failure predictions were made by separate stress analyses.

2.1 Results

Because of the variety of parametric evaluations which were performed (23 COMRADEX cases, for example), it is convenient to divide the cases into two groups for clarity in considering results. The first of these groups is shown on the event tree in Figure 2-1 and represents the conditions which were evaluated for the in-vessel cases. Figure 2-2 presents similar information for the ex-vessel cases.

The containment analysis summary for all cases is shown in Table 2-1, and resulting site boundary doses are presented in Table 2-2. General conclusions from these calculational results are summarized in the following paragraphs.

2.1.1 Consequences for Passive Containment Response

Consequences for passive response of the containment were calculated for both in-vessel and ex-vessel cases. A comparison of these conditions can be made considering Case 658 (in-vessel) and Case 688 (ex-vessel). Case 688 is conservative in assuming nonmechanistic failure of 346 ft^2 of reactor cavity floor liner at the time of postulated melt-through. Both cases assume natural H_2/O_2 recombination, RCB failure and blowdown at 20 psig pressure, no RCB cooler operation, and no filtration. Both cases include mechanistic treatment of the reactor cavity floor. For the in-vessel case, floor failure occurs after sodium boil-dry and subsequent interaction of core debris and the floor. For the ex-vessel case, floor failure is calculated at 1,008 hours.

The calculated site-boundary whole body, thyroid and bone dose for the two cases are given in Table 2-3. With the exception of the thyroid dose for Case 658, all doses are well below guideline values of 10 CFR 100, and the dose from 658 was overestimated by neglecting the rainout effect caused by condensation of sodium vapor.

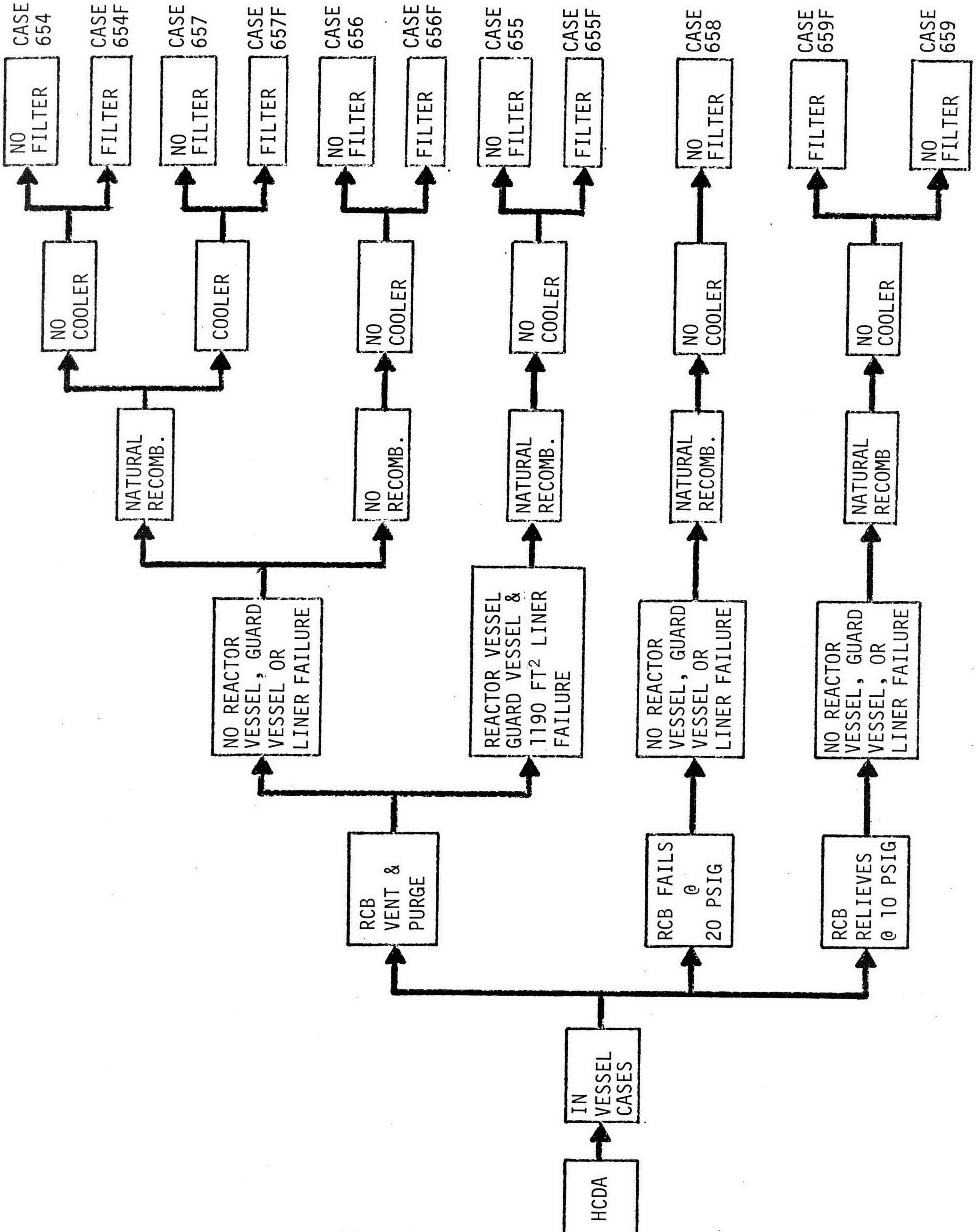

FIGURE 2-1. In-Vessel Boil-up Cases.

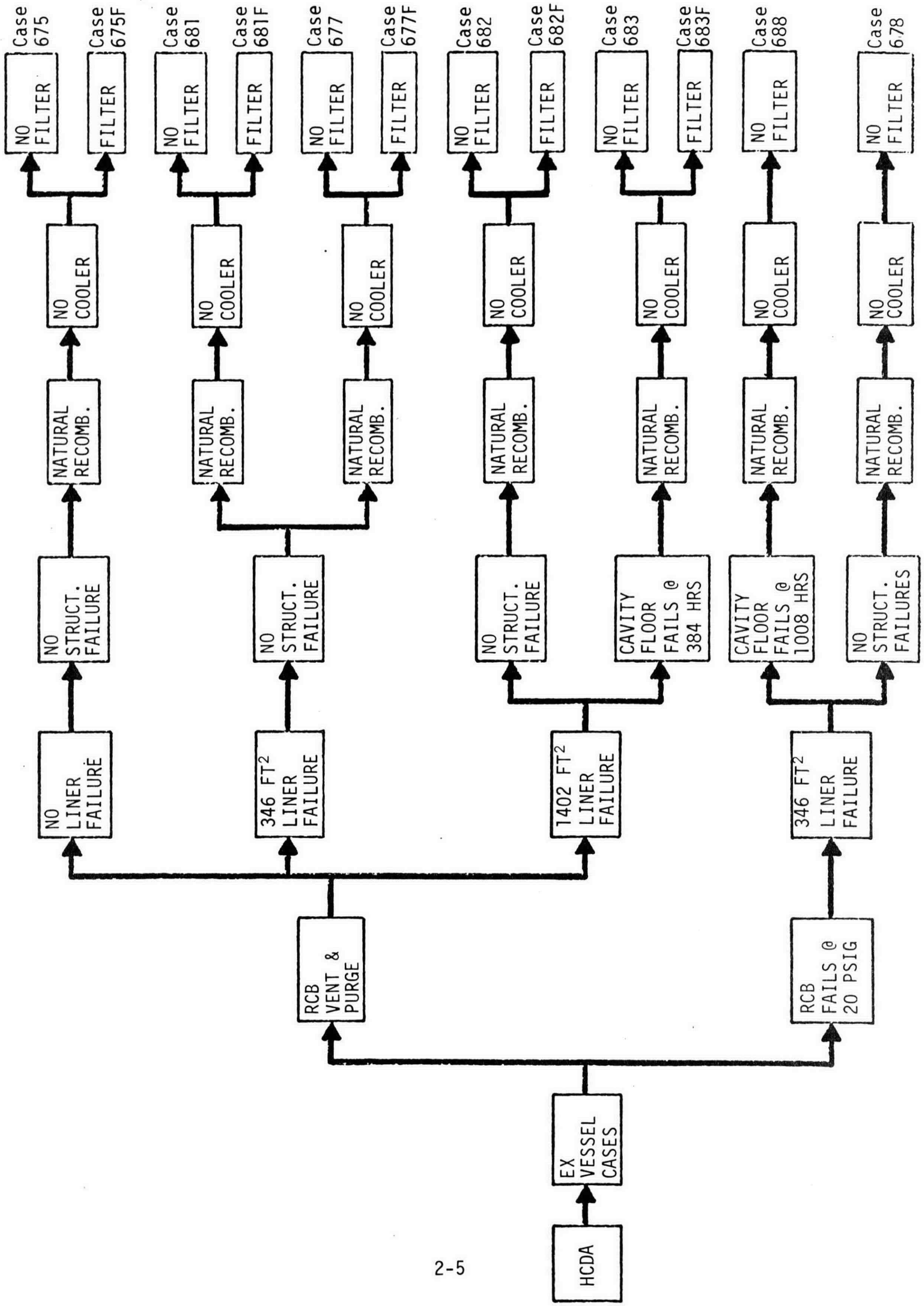

FIGURE 2-2. Ex-Vessel Boil-up Cases.

TABLE 2-1

SUMMARY OF CASES

Case Number	Reactor Bldg. H&V Coolers	Hydrogen Recombination	Reactor Bldg. Ventdown & Air Purge	Reactor Bldg. Ventdown		Reactor Vessel Failure	
				Pressure (psig)	Time (Hrs)	Sodium Spill (lbs)	Time (Hrs)
654	none	natural	yes	10.0	82.0	none	526.5
656	none	none	yes	10.2	83.0	none	527.8
657	continuous	natural	yes	7.9	91.0	none	541.8
658	none	natural	No, "do nothing"	20.0	123.0	none	572.9
659	none	natural	No, Bldg. relief at 10 psig	---	---	none	590.2
655	none	natural	yes	10.0	82.0	125,966	384.0
675	none	natural	yes	10.0	229.0	619,998	3.0
681	none	natural	yes	9.4	200.0	619,998	3.0
677	none	none	yes	5.1	42.2	619,998	3.0
678	none	natural	No, "do nothing"	20.0	960.0	619,998	3.0
682	none	natural	yes	6.4	55.1	619,998	3.0
683	none	natural	yes	6.4	55.1	619,998	3.0
688	none	natural	No, "do nothing"	20.0	960.0	619,998	3.0

TABLE 2-1

SUMMARY OF CASES (Cont'd)

Case Number	Reactor Cavity Failed Liner Area (Sq. Ft.)	Reactor Cavity Floor Failure Time (Hrs)	Maximum Sodium Temperature		Sodium Boiloff to Reactor Building		Maximum Reactor Bldg. Temp.	
			Value (°F)	Time Attained (Hrs)	Amount (lbs)	Boil Dry Time (Hrs)	Value (°F)	Time Attained (Hrs)
654	---	526.5	1729	82.	619,392	526.5	1012	180
656	---	527.8	1730	83.	619,520	527.8	1013	84
657	---	541.8	1708	91.	619,347	541.8	1000	180
658	---	572.9	1806	123.	621,327	572.9	1140	124
659	---	590.2	1728	120.	619,197	590.2	822	120
655	1190	---	1729	82.	494,041	---	1016	150
675	0	---	1472	1370.	123	---	212	1632
681	346	---	1427	1200.	1,655	---	212	1632
677	346	---	1478	1320.	2,477	---	222	1632
678	346	---	1479	1270.	1,796	---	217	1632
682	1402	---	1479	900.	29,501	---	266	360
683	1402	384	1618	392.	203,932	428.7	1461	428.7
688	346	1008	1653	1011.	247,800	1062.4	1203	1062.4

TABLE 2-2

RADIOLOGICAL CONSEQUENCES SUMMARY

Case	Site Boundary Doses (REM)*			
	Bone	Thyroid	Lung	Total Body
654	2.1	135.3	3.9	0.78
655	2.2	136.9	4.1	0.80
656	2.3	152.8	4.3	0.88
657	2.6	94.0	5.4	0.49
658	1.7	304.0	3.0	1.07
659	2.0	38.4	4.3	0.19
675	1.4	0.30	3.1	0.04
677	7.7	1.8	17.4	0.20
678	1.4	0.30	3.2	0.02
681	1.5	0.38	3.3	0.05
682	1.5	5.1	3.0	0.30
683	2.2	78.4	3.8	0.81
688	2.0	2.7	3.2	0.46
654F	1.7	1.8	3.8	0.12
655F	1.7	1.8	3.9	0.12
656F	1.8	2.0	4.1	0.12
657F	2.4	1.5	5.3	0.12
659F	1.9	1.6	4.3	0.07
675F	1.4	0.29	3.1	0.04
677F	1.5	0.31	3.3	0.13
681F	1.5	0.31	3.3	0.05
682F	1.2	0.31	2.8	0.12
683F	1.5	1.1	3.5	0.14

*Doses were calculated for the duration of the event (68 days), for a distance of 7,240 m (4 1/2 miles) from the FFTF.

TABLE 2-3

PASSIVE CONTAINMENT RESPONSE CONSEQUENCES

	Off-Site Exposure (Rem)		
	Whole Body	Thyroid	Bone
In-Vessel (658)	1.1	304	1.7
Ex-Vessel (688)	1.3	2.7	2.0

2.1.2 Effect of Hydrogen-Oxygen Recombination

Hydrogen is produced as a result of sodium-water reactions. In order to prevent excessive hydrogen accumulation it was considered necessary, in previous studies, to vent the building and to control hydrogen concentration to ~4 percent by an air purge. The air purge, however, increases release of radioactivity from the building, thus increasing the contribution to the site boundary dose.

One purpose of this study was to consider the effect of natural hydrogen-oxygen recombination on containment transients and the potential effect on subsequent site boundary doses. Experimental results at HEDL have established that under conditions typical of these accident conditions, hydrogen would combine with oxygen to form water vapor.

The results of hydrogen-oxygen natural recombination are shown in Table 2-4. The comparison cases both assume RCB vent and purge commencing at 10 psig or 4 percent H_2. There is little difference between potential doses for the in-vessel cases.

In the ex-vessel case, there was a decrease by a factor of 5 in both bone dose and thyroid dose. The decreased hydrogen concentration in the natural recombination case delays RCB pressure buildup and the vent/purge, and results in a significantly lower site boundary dose.

TABLE 2-4

EFFECT OF H_2/O_2 RECOMBINATION

	Site Boundary Dose (Rem)	
IN-VESSEL	BONE	THYROID
Natural H_2/O_2 Recombination (Case 654)	2.1	135
No H_2/O_2 Recombination (Case 656)	2.3	153
EX-VESSEL		
Natural H_2/O_2 Recombination (Case 681)	1.5	0.4
No H_2/O_2 Recombination (Case 677)	7.7	1.8

2.1.3 Effect of Cavity Liner Failures

Short of structural collapse of the reactor cavity floor, no liner failures would be predicted mechanistically. The margins associated with possible liner failure were investigated by arbitrarily postulated failures.

For the in-vessel case, the effect of failure of the floor liner at the time of reactor vessel support failure (384 hours) is assessed by comparison of Case 654 (no failure) and Case 655 (1,190 ft^2 failure).

For the ex-vessel case, initial failure areas of zero (Case 675), 346 ft^2 (Case 681), and 1,402 ft^2 (Case 682) were analyzed. Structural failure was not included.

All of these cases assume RCB vent at 10 psig, purge, natural H_2/O_2 recombination, no coolers and no filters.

TABLE 2-5

EFFECTS OF LINER FAILURES

	Thyroid	Bone
In-Vessel		
No failure (Case 654)	135	2.1
Failure - 1,190 ft^2 at 384 hours (Case 655)	137	2.2
Ex-Vessel		
No failure (Case 675)	0.3	1.4
Failure - 346 ft^2 (Case 681)	0.4	1.5
Failure - 1,402 ft^2 (Case 682)	5.1	1.5

2.1.4 Effect of Engineered Systems on Site Boundary Exposures

Analysis of the present design of FFTF has resulted in calculated doses from the postulated HCDA which identify large safety margins for extremely low probability events.

Another purpose of this study was to evaluate the additional safety margin which could result from building air cooler operation, the addition of venting or relief devices, or filtration of building exhaust from venting or relief. These effects are summarized as follows.

2.1.4.1 Effect of Operation of RCB Coolers

The FFTF design does not include the provision for assured cooler operation for post-accident conditions.

The effect of postulated cooler operation is shown in Table 2-6 for in-vessel conditions with RCB vent and purge. In this case, there was no significant change in the bone dose, and the thyroid dose decreased by 30 percent when cooler operation was assumed.

2.1.4.2 Effect of RCB Vent/Purge or Pressure Relief

Two containment options considered to control H_2 concentration or pressure in the RCB are the vent/purge or regulated pressure relief at 10 psig.

The effects of each of these, as compared with the case in which the pressure is allowed to increase to twice the design pressure and the building is then assumed to vent ("Do-Nothing" case), are shown in Tables 2.7 and 2-8.

For the vent/purge case, no difference in site boundary dose was noted for the ex-vessel case. In the in-vessel case, the thyroid dose was reduced by a factor of about 2.3 by venting the building. The bone dose remained essentially the same.

For the regulated pressure relief at 10 psig, the bone dose, as shown in Table 2-8, remained essentially the same as for the "Do-Nothing" case, but the thyroid dose was reduced by a factor of 8.

TABLE 2-6

EFFECT OF COOLER OPERATION (IN-VESSEL CASE)

	Site Boundary Dose (Rem)	
	Bone	Thyroid
RCB Cooler In Operation (Case 657)	2.6	94
No Cooler In Operation (Case 654)	2.1	135

TABLE 2-7

EFFECT OF VENT/PURGE

	Site Boundary Dose (Rem)	
	Bone	Thyroid
IN-VESSEL		
"Do-Nothing" Case (Bldg. fails at 20 psig) (Case 658)	1.7	304
Vent/Purge Case (Case 654)	2.1	135
EX-VESSEL		
"Do-Nothing" Case (Bldg. fails at 20 psig) (Case 678)	1.7	0.4
Vent/Purge Case (Case 681)	1.5	0.4

TABLE 2-8

EFFECT OF 10 PSIG RELIEF OF RCB

	Site Boundary Dose (Rem)	
	Bone	Thyroid
IN-VESSEL		
"Do-Nothing" Case (Bldg. fails at 20 psig) (Case 658)	1.7	304
10 psig RCB Relief Case (Case 659)	2.0	38

2.1.4.3 Effect of Exhaust Filtration

Ten pairs of cases were calculated for which the only difference was incorporation analytically of a filter for the RCB exhaust from venting and/or purging. No specific filter medium or design was identified, and a representative filtration efficiency of 99 percent was used for all materials except noble gases. The effect of filters is shown in Table 2-2 for case numbers with the suffix "F".

The assumed filtration reduced thyroid exposures by between one and two orders of magnitude for cases where the unfiltered dose exceeded a few tens of Rem. Whole Body exposures were reduced a lesser amount, up to about a factor of 7. Lung and bone exposures calculated were predominantly the result of an initial assumed 1 percent core inventory release to containment, and subsequent leakage prior to venting and/or purging. This leakage was not filtered, so these doses are not affected by the filtration.

2.1.4.4 Effects of Structural Failures

Structural failures of significance in this study are collapse of the reactor cavity floor and failure of the reactor support ledge. The analyses of these failures are described in Appendix E. The predicted structural failures were not specifically included in the analyses, but analyzed conditions adequately bound the structural failure effects.

For in-vessel conditions, cavity floor collapse is predicted at 600 hours, with calculated loss of reactor vessel support arms at 384 hours and postulated sodium release at that time. Support ledge failure is estimated at 1,500 hours. For cases analyzed without floor collapse, sodium boil-dry occurred near or before 600 hours. (See Table 2-9.) Therefore, floor collapse at 600 hours would not significantly affect sodium boiling or sodium reactions; the main effect would be in interaction of fuel, molten steel, and concrete. These interactions were involved in the analyses at the time sodium boiled dry. Differences due to floor collapse would be expected to be relatively small, and of little significance with respect to radiological evaluation. The steel-water reaction is completed for all cases within a total elapsed time of 1,120 hours from start of the incident. This time is well in advance of the projected ledge failure time of 1,500 hours, and no effect of this failure on the scenario has been identified. Case 655 is an exception to the foregoing discussion. In this case the steel-fuel-concrete interaction never occurred because the sodium had not boiled dry by the end of the case. However, by 600 hours the activity release was essentially completed and equal in both Case 655 and Case 654, a typical floor failure case. Thus, failure of the floor would not materially alter consequences in this case.

For ex-vessel cases, structural failures of the floor and support ledge are both predicted at approximately 1,000 hours or longer. Most ex-vessel cases analyzed did not consider structural failure, as discussed in Section 4.4.2, and were included in the report for comparative effects up to 1,000 hours. Two ex-vessel cases considered failure of the cavity floor, but not failure of the support ledge. Timing of pertinent events is given in Table 2-10. For Case 683, all reactants have been consumed prior to support-ledge failure and no effect on the scenario would be expected. For Case 688, the containment building atmosphere was already self-inerted, so collapse of the support ledge would not accelerate sodium-air reactions. The potential significance of ledge failure could be increased bare concrete surface for sodium attack. However, sodium available for reaction was already nearly consumed and, considering ledge design and failure mode, it is not likely that failure would have a significant effect on the reactions. Radiological consequences have been bounded by Case 683, as shown in Table 2-2, in which early floor failure was postulated nonmechanistically for investigation of the safety margin for such a case. The thyroid dose for Case 683 was strongly influenced by effects prior to floor failure, namely a large failed liner area.

TABLE 2-9

TIMING OF STRUCTURE RELATED EVENTS-IN-VESSEL

Case No.	Boil-dry Time, Hrs	Floor Failure Time, hrs	Time Steel Consumed, hrs
654	526.5	888	1056
656	527.8	888	1056
657	541.8	912	1056
658	572.9	936	1080
659	590.2	948	1120

TABLE 2-10

TIMING OF STRUCTURE RELATED EVENTS - EX-VESSEL

Case No.	Floor Failure Time, hrs	Boil-dry Time, hrs	Time Steel Consumed, hrs
683	384	429	777
688	1008	1062	1620

2.2 Conclusions

The potential site boundary radiation exposures for all the cases studied were significantly below 10 CFR 100 guideline values. Although the computed thyroid dose for case 658 was essentially equal to the guideline, the dose was overestimated by neglecting the rainout effect caused by condensation of sodium vapor. Also, the thyroid doses for the in-vessel cases (unfiltered exhaust) and the most severe ex-vessel case (Case 683) were overestimated by 20-40 percent by the use of a 1.7 m/sec rather than 3.0 m/sec wind speed for times beyond four days.

The in-vessel cases produce higher calculated doses because of more rapid sodium boiling from the reactor vessel. In the ex-vessel cases, the greater heat sink of the building structures overrides additional heating from chemical reaction even when liner failures are postulated.

Passive response cases assume containment failure if a pressure of 20 psig is calculated. Subsequent pressure blowdown from 20 psig causes rapid sodium flashing and corresponding rapid release of volatile fission products, a major factor in the increased doses calculated for those cases. Subsequent to blowdown, reaction of sodium and, later, molten steel with water from the concrete produces hydrogen which accumulates in the RCB after oxygen is depleted.

Of the engineered equipment items studied, containment coolers offer limited potential for reduction of site boundary doses. Regulated pressure relief reduces potential exposure but could result in high hydrogen concentrations in the RCB. Reductions are calculated for an RCB vent/purge system, with additional reduction of potential exposures by filtration of the vent/purge exhaust. These conclusions do not imply any need for such systems for FFTF because of the extreme nature of postulated conditions and the existence of substantial safety margins without such features.

3.0 PHYSICAL DESCRIPTION AND MODELS

The FFTF consists of the Fast Test Reactor (FTR), closed loop systems, and supporting facilities. The reactor uses Pu-U oxide fuel and sodium coolant and has a power rating of 400 MWt. The primary coolant system consists of three circulating loops. Each loop has an intermediate heat exchanger (IHX) which is part of the primary coolant boundary and through which heat is transferred from the primary to the secondary coolant loop. The secondary coolant system transports the heat to dump heat exchangers (DHX) which reject thermal energy to the atmosphere.

Fuel handling machines within the reactor vessel are used to transfer core subassemblies between the reactor core and in-vessel storage or transfer positions during reactor shutdown. Additional shielded fuel handling equipment is used to transfer subassemblies from in-vessel transfer positions to interim storage within the containment building and to positions for transfer out of containment.

The reactor and primary coolant loops are located in separate inert atmosphere cells below the operating floor within a steel containment building. Service and auxiliary buildings and facilities are provided for control of the plant, receiving and shipping of fuel and equipment, secondary coolant system equipment, service systems and other operating and administrative services.

Figure 3-1 identifies the principal components of the FFTF and their layout.

3.1 Reactor Containment Building

The Reactor Containment Building (RCB) is a steel enclosure with vertical cylindrical walls (135 ft diameter, 1.38 inches thick) and an ellipsoidal roof (1 inch thick). The top of the roof is 108.8 ft above the operating floor level (at grade level of 550 ft above sea level). The RCB air volume

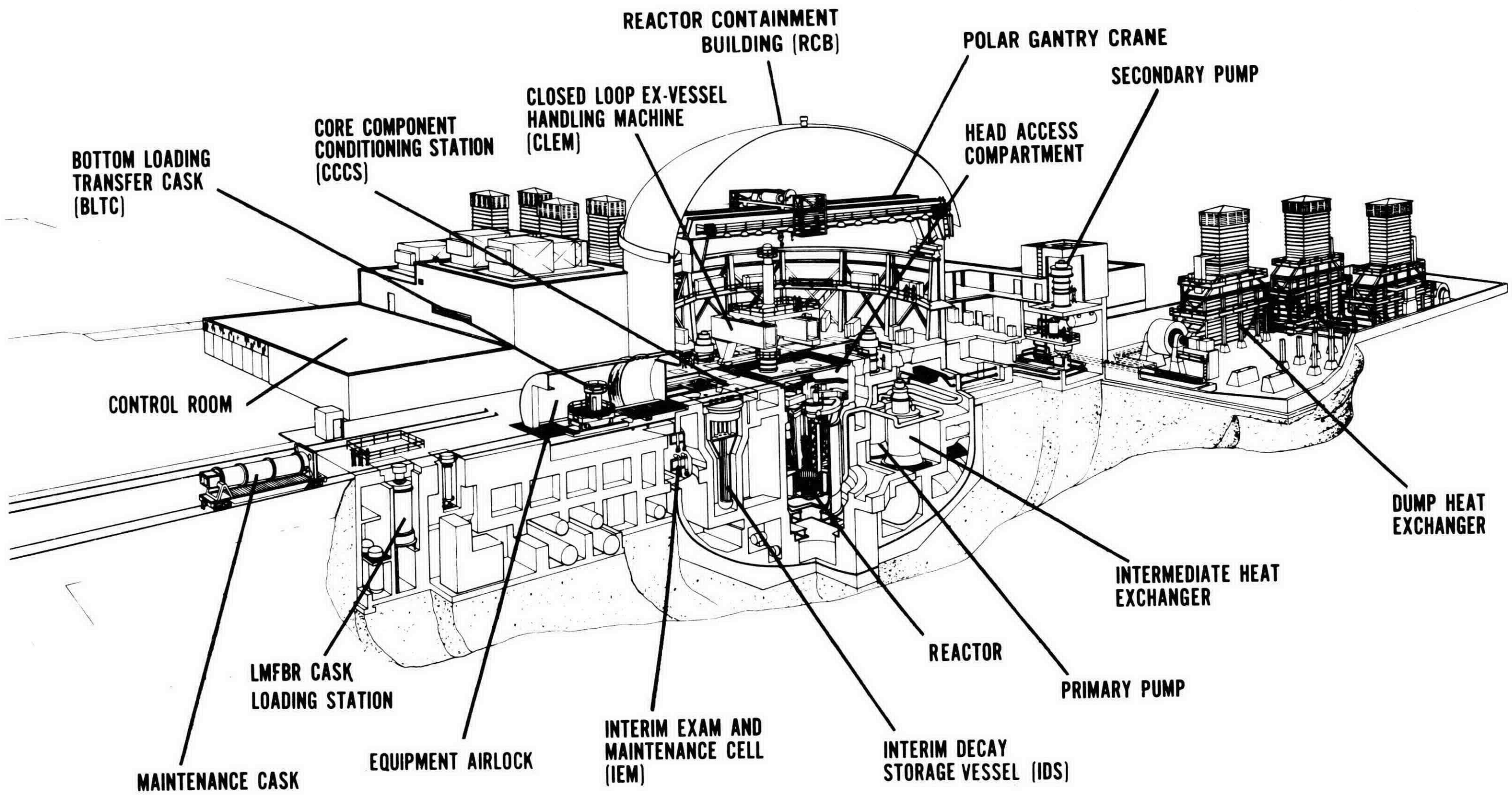

FIGURE 3-1. Fast Flux Test Facility.

between the roof and operating floor is approximately $1.4 \times 10^6 ft^3$. The volume of air spaces below the operating floor is small. These spaces are neglected except for the H&V cooler room which is described later.

The RCB is a pressure-tight structure with a nominal leak rate of 0.1 vol %/day at its 10 psig design pressure and 76°F operating temperature. This leak rate amounts to 7.3 lb/hr or 1.5 scfm. The leak rate from the building is assumed to vary inversely as the square root of the pressure.

The major characteristics of the RCB, as modeled for these analyses, are summarized in Figure 3-2. Insulation on the $3.4 \times 10^4 ft^2$ area of roof and outside walls inhibits heat loss to the outside air. The outside air was represented by an input table of temperature and heat transfer coefficients. The temperature varied from 77.5 to 102.°F over each 24-hour cycle. Coefficients were appropriate for stagnant air with no wind convection.

Service buildings attached to the remaining $1.0 \times 10^4 ft^2$ area of walls also inhibit RCB heat loss. Heat transfer through these walls to outside air is calculated with an overall heat transfer coefficient that combines the parallel and series resistances of natural convection circulation and of roof and wall insulation of service buildings.

The $1.3 \times 10^4 ft^2$ floor area noted in Figure 3-2 represents the entire operating floor. It includes stairways but excludes the head compartment. This floor has high density (225 lb/ft^3) magnetite concrete over cells and pipeways of the heat transport system and closed loops. This floor surface is sealed by a thick epoxy coating. A drying test performed at HEDL on a concrete cylinder covered with this epoxy coating showed that the epoxy modifies release of water as the concrete is heated but does not significantly delay or reduce the release. The analyses of this study neglected this epoxy floor surface.

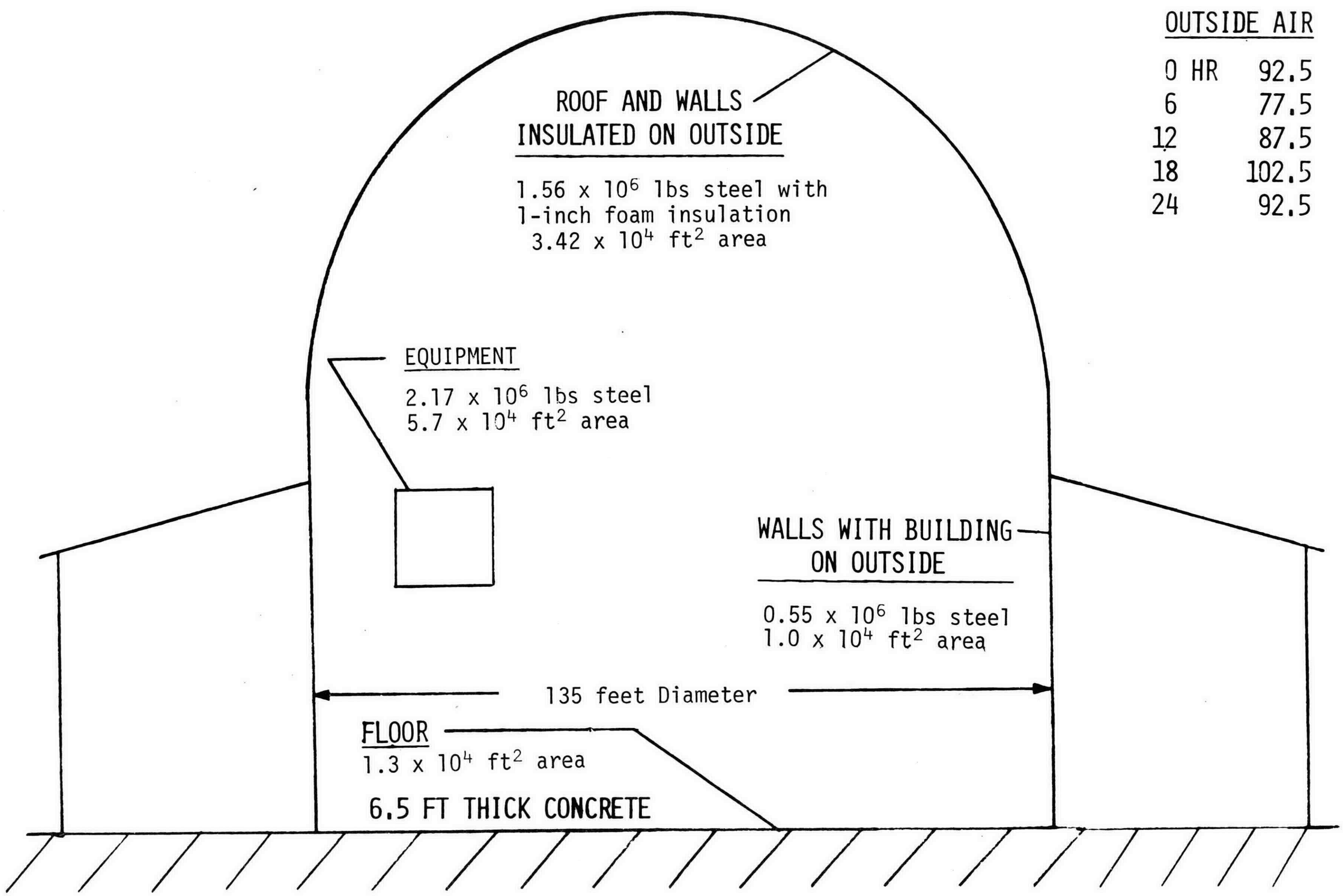

FIGURE 3-2. Reactor Containment Building (RCB).

The heat capacity of the RCB includes the major equipment and fixtures located in the RCB. This equipment consists of the following:

TABLE 3-1

RCB EQUIPMENT

NAME		MASS
Polar crane and supports		1.17×10^6 lbs
Head compartment grating		0.254×10^6
Head compartment off-head shielding		0.297×10^6
Head compartment on-head shielding		0.237×10^6
CLEM and transporter		0.112×10^6
Miscellaneous		0.104×10^6
	Total	2.174×10^6

The RCB atmosphere is normally ventilated by a flow of approximately 20,000 cfm of air which is supplied and exhausted through 36" openings, each equipped with dual containment isolation valves. Ventilation is maintained by operation of supply and exhaust blowers. In addition to the ventilation, the RCB atmosphere is normally heated or cooled to maintain normal operating temperature. Coolers for this purpose have a capacity of 1.8×10^6 Btu/hr.

In the event of a major radioactivity release into the RCB, the containment isolation system (CIS) would automatically cause closure of the ventilation containment isolation valves and shutdown of the supply and exhaust fans. The building coolers could continue to operate; however, no specific design features are provided to assure their operation or to permit their remote startup or shutdown.

Instrumentation is provided for monitoring temperature, pressure and radiation level within the containment.

The studies documented in this report investigated two areas:

1. The containment safety margins existing and inherent in the FFTF.

2. The effect of alternative containment atmosphere treatments on containment safety margins.

For investigation of the first area, the passive response of the plant was analyzed for the various hypothesized circumstances. In this analysis, RCB pressures were allowed to increase to 20 psig before release and blowdown to atmospheric pressure. For the second area, operation of equipment or systems of interest was assumed in order to determine the effect on containment margins. The equipment operations which were investigated, singly or in appropriate combinations, were the following:

- overpressure relief (without blowdown to lower pressure) at essentially 10 psig whenever RCB pressure reached this value,

- vent and blowdown to atmospheric pressure, followed by forced air ventilation (purge) to limit hydrogen concentration to 4 percent,

- continued operation of the RCB atmosphere coolers,

- filtration of exhaust from RCB venting.

3.2 Reactor Cavity

The reactor cavity is a cylindrical cell which encloses the reactor vessel. The atmosphere volume of the cavity is approximately $2.2 \times 10^4 ft^3$, and roof, wall and floor surface area totals approximately 6,800 ft^2. This space interconnects through sodium piping penetrations with the upper auxiliary pipeway which surrounds the top part of the reactor cavity. The pipeway atmosphere volume is approximately $1.9 \times 10^4 ft^3$. The interconnection between the spaces is sufficient for the two volumes to pressurize and vent together, at essentially equal pressures, but not for the atmospheres to mix. In this study, the heat capacity of the pipeway was neglected.

The reactor cavity and upper auxiliary pipeway have a design pressure of 35 psig. There are no design communication paths between the cavity-pipeway atmosphere and the three HTS cell atmospheres, nor between the reactor vessel atmosphere, the cavity-pipeway atmosphere, and the RCB atmosphere. However, in this study, the sodium is assumed to boil out of the reactor vessel or out of the cavity into the RCB atmsphere through an opening. This opening is a nonmechanistic representation of leakage paths assumed to be created as a consequence of the HCDA. The size of the opening is unimportant; the study assumes that the sodium boils away from the vessel or cavity without significant vessel or cavity pressurization.

A concrete shield collar surrounds the reactor vessel in the top part of the reactor cavity. This shield collar is assembled from steel cans containing a total of about 800 ft^3 of basalt concrete. Each can is vented through piping to the adjacent cavity liner venting system. This shield collar represents a significant heat sink, equivalent to the concrete 1.8 inches deep on the roof, walls and floor, and was included in the analysis.

The major characteristics of the reactor cavity, as modeled for this study, are shown in Figure 3-3.

The cavity roof is cantilevered inward from the cavity inner diameter to provide a circular support for the reactor vessel and reactor vessel head. The roof structure also accommodates the geometrical transition from the circular cross section of the reactor cavity to the square cross section of the head compartment.

The cavity roof is 6.2 ft thick and composed of magnetite concrete and heavy reinforcing steel. This concrete-steel roof has an effective thermal

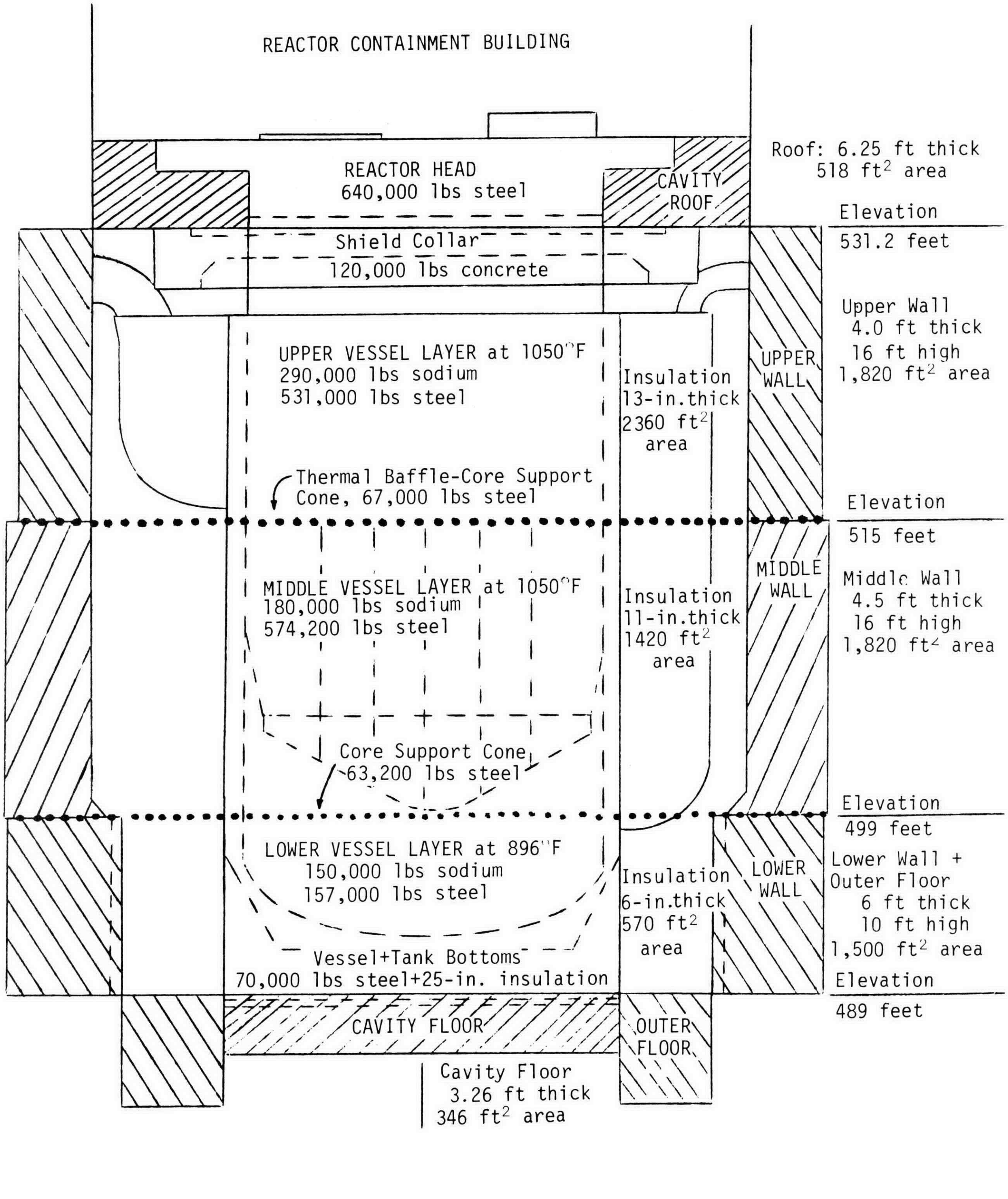

FIGURE 3-3. Reactor Cavity Structures.

conductivity higher than that of concrete itself. The cavity side of the roof is protected by steel plate 0.50 inches thick, a "cold liner" design.

The cavity upper wall is 4.0 ft thick and composed of magnetite concrete. The cavity side of this wall is protected by steel plate 0.25 inches thick, a "cold liner" design. The steel embedments to support these liners penetrate 3 inches into the concrete wall. This embedment-concrete layer has an effective thermal conductivity higher than that of concrete itself. Two different types of cold liners are used, with the transition at an elevation of 24.3 ft above the cavity floor. The characteristics of the two liner types are sufficiently similar that they were represented by one model.

The cavity lower wall, up to 6.5 ft above the floor, is 6.0 ft thick and composed of a layer of firebrick and then magnetite concrete. The cavity side of this wall is protected by steel plate 0.38 inches thick, a "hot liner" design. The cavity outer floor, outside the circle of the skirt of the reactor vessel guard tank, is quite thick and composed of a layer of firebrick and then magnetite concrete. The cavity floor center, under the reactor vessel (over the subcavity), is 3.3 ft thick and composed of layers of firebrick, insulating brick, and then ordinary basalt concrete. The whole floor is protected by steel plate 0.62 inches thick, a "hot liner" design.

The cold and hot liners on the cavity roof, walls and floor are vented through special piping into the H&V cooler equipment room in the lower levels of the RCB. A sodium spill into the cavity would heat the cavity roof, wall, and particularly the floor concrete, and drive out water vapor (steam). This steam would vent into the H&V cooler room and there condense on the cold concrete and equipment surfaces. The vent piping eliminates buildup of steam pressure, behind the liners, that would otherwise lead to liner failure.

A sodium spill, even a massive spill, is not expected to strain these cold and hot liners to failure. For purposes of investigating the containment safety margins, however, several different conditions of liner failures have been postulated for analysis.

In case of core melt-through from the reactor vessel and guard vessel, if the cavity floor liner should suffer localized penetration, the concrete below the liner would be exposed to sodium attack. Since the floor design is discontinuous at the circumference of the guard vessel support skirt, the area within this skirt would be the only area affected if reaction products prevented the passage of sodium through the narrow steam vent paths at this circumference. Accordingly, an exposed area of 346 ft^2, equal to the area within the support skirt, is one liner failure condition analyzed.

For a maximum liner failure condition, the sodium attack on concrete behind the liners on the entire cavity floor and the walls to a height of 5.6 ft was analyzed. This represents flooding of the concrete surface up to the height of the steam vent system outlet elevations. This flooding is limited by the buildup of steam pressure from the wall above the vent system outlets. The exposed concrete area for this condition is 1,402 ft^2.

In case of core retention in the reactor vessel, without heat removal, structural failure of vessel supports can be predicted at about 384 hours. If failure of the vessel and guard vessel are assumed at that time, the quantity of sodium released would flood the reactor cavity to a depth of 3-1/2 feet. If gross failure of liners were postulated, a surface area of 1,190 ft^2 behind hot liners could be exposed. This alternate condition was also analyzed.

3.3 Reactor Building Subcavity

The reactor building subcavity is the space below the reactor cavity floor. This subcavity has an atmosphere volume of about $3.7 \times 10^3 ft^3$ filled with air at 80°F. The subcavity roof is the 3.3 ft thick central floor of the reactor cavity. The roof, walls and floor have a total area of about 1,390 ft^2. The upper 6.67 ft of the subcavity wall is of magnetite concrete, while the lower 4.0 ft is of basalt concrete. These walls are 12 ft thick.

The subcavity floor is of basalt concrete. This concrete is about 33 inches thick to the steel shell of the reactor containment building. Below the steel shell is an additional 4 ft of concrete, for a total thickness of 6.8 ft of concrete.

The roof, walls and floor surfaces are of bare concrete. This subcavity is vented to the adjacent H&V cooler room by two pipes through the wall, each 1-1/2 inches in diameter and 9.9 ft above the subcavity floor.

The subcavity is of significance in the analysis of post-accident consequences for cases having structural failure of the reactor cavity floor.

3.4 H&V Cooler Room

The H&V cooler room contains heating and ventilating equipment for the reactor cavity, HTS cells, closed loop cells and various pipeways. It fills the lower regions of the reactor containment building and surrounds the subcavity and lower part of the reactor cavity. The floor follows the ellipsoidal shape of the bottom of the steel containment building. This room has an atmosphere volume of about $6.4 \times 10^4 ft^3$, filled with air at 80°F. The H&V cooler room roof, walls and floor have a total area of about 19,800 ft^2.

The roof-wall-floor concrete is about 43 percent magnetite; the remainder is basalt. The magnetite portions include the outer surfaces of the lower wall of the reactor cavity and the upper wall of the subcavity. All of this concrete is bare.

The H&V cooler room is important because the cavity liners and the subcavity vent into it. As the cavity concrete heats under the postulated accident conditions, the water release, as steam, vents through the liner vent system into the H&V cooler room. The cool surfaces of the room condense this steam, forming a pool on the floor. The maximum amount of water collected, 1.6×10^5 lbs (Case 659), would form a pool on the floor about 4.5 inches deep, if the floor were flat.

The H&V cooler room is connected to the RCB atmosphere (above the operating floor) by stairways. The cooler room was included in the analysis because it would collect and hold much of the steam and energy driven out of the heated concrete of the reactor cavity and subcavity. That is, this room delays and reduces the heating and pressurization of the RCB atmosphere. Also, the room reduces the amount of steam introduced into the RCB atmosphere and, thereby, the amount of sodium (boiled out of the reactor vessel) and water which could react in the RCB atmosphere.

The arrangement, shape and dimensions of the H&V cooler room are not optimum for natural convection cooling of the steam venting from the cavity liner and subcavity atmosphere vent pipes. For this reason, the effective volume and area of this room were reduced to half for the purposes of this analysis. That is, the room volume was taken as $3.2 \times 10^4 ft^3$, the roof and walls were taken as 6,350 ft^2 of 3 ft thick basalt concrete, and the floor was taken as 3,550 ft^2 of 3 ft thick basalt concrete.

3.5 Reactor

The reactor includes the reactor head, the reactor vessel, the reactor internals and guard tank. The weights of these items are summarized as follows:

TABLE 3-2

REACTOR WEIGHTS

Items	Weight (lbs)
Reactor Head	0.759×10^6
Reactor Vessel	0.478×10^6
Reactor Internals	0.743×10^6
Guard Tank	0.242×10^6

The modeling of the reactor and reactor cavity is summarized in Figure 3-3. The reactor and cavity were divided into three layers:

(a) The upper vessel and wall layer, 16 feet high,

(b) The middle vessel and wall layer, also 16 feet high,

(c) The lower vessel and wall layer, 10 feet high.

The three-layer model permitted the top part of the vessel to be hotter than the bottom part, so that the sodium could boil first from the upper vessel layer, then from the middle vessel layer, and finally from the lower vessel layer. However, the CACECO code dimensions permitted only two "cell spaces". Therefore, a common sodium temperature was defined for the bottom two layers. The sequence for combining layers is described in Section 5.

The three-layer model was used to distribute heat-generating core debris, in accordance with PAHR predictions.[(3)] For example, as an upper limit, 90 percent of the core debris was distributed on the core outlet thermal baffles used to bound the top layer.

The sodium inventory of the reactor and adjacent, drainable pipes is approximately 6.2×10^5 lbs. Initially, some 83 percent of this sodium is at the nominal outlet temperature of 1050°F and the rest is at the inlet temperature which for this study was postulated as 830°F, slightly above the design-rated temperature of 792°F. The reactor vessel and reactor vessel head are supported independently on a steel ring structure ("Z-ring") which is in turn supported by the reactor cavity roof (also called the reactor support ledge). The guard vessel is supported by a steel skirt which rests on the reactor cavity floor.

The reactor vessel above the guard vessel and outer surface of the guard vessel are covered with calcium silicate insulation, and the adjacent inlet and outlet pipes are covered with refractory fiber insulation. The insulation thickness varies from 1.5 inches on the skirt of the guard tank to 13 inches on the upper part of the reactor vessel. The total outside area of this insulation is about 5,000 ft^2. The space between the bottom of the guard vessel and the reactor cavity floor is also insulated with calcium silicate.

4.0 BASIS FOR CASES ANALYZED

4.1 HCDA In-Vessel PAHR Assessment

Whole core accidents have been studied at length and detailed analyses and evaluations show no realistic basis for initiation of an HCDA.[7] For purposes of evaluation of containment safety margins, however, certain mechanistic core disruptive events have been hypothesized: loss of flow (LOF) without scram, and transient overpower (TOP) without scram.

The predicted course of an LOF hypothetical core disruptive accident (HCDA) in FFTF is a meltdown and core dispersal with little or no energy release. Nevertheless, mechanical consequences of LOF-HCDA's have been assessed using highly conservative recriticality and energy conversion assumptions. Results of the mechanical consequence assessment show that the entire primary boundary would remain intact for conditions beyond those of a 100$/sec re-criticality.[1] Sodium circulation in the primary loops would continue, with forced convection by operable pony motors as predicted, and natural convection if pony motors were to fail. The reactor vessel and its support system would remain intact. Also, the reactor head would retain its integrity, and seals would remain generally effective, so that no substantial expulsion of sodium or core materials into the containment building would be predicted.

The TOP-HCDA has also been investigated in detail. It was concluded that the TOP event would be terminated by nonenergetic fuel removal such that in-place cooling of the core would follow the transient. Even if meltdown or disassembly conditions were to occur, consequences are considered to be bounded by the 150 MW-sec evaluation or the pessimistic LOF-HCDA evaluations. A comprehensive evaluation of mechanical consequences of a 150 MW-sec HCDA concluded that, as in the case of the LOF-HCDA, the primary boundary would remain intact and the primary HTS loops would be available to perform in-vessel decay heat removal either by forced or natural circulation.

The condition of a reactor core disrupted in an energetic HCDA has been examined in detail, with the conclusion that fuel configurations are coolable and permanently retained in-vessel.[3] The most severe test of in-vessel cooling occurs for the loss-of-flow HCDA. For this case, it is projected that 70-90 percent of the core inventory would be ejected upward and form particulate beds in the upper sodium plenum on the thermal baffle and upper plenum components. Between 10-30 percent would form a bed or molten pool in the original core location or at some location within the support structure. For the TOP case, in-vessel post-accident heat removal would be predicted, with only a few percent of the core swept out to form beds on surfaces in the upper plenum and in the upper outlet piping.

4.2 Expulsion Source for Sodium and Radioactive Materials

Potential leakage paths for sodium and radioactive materials are limited, and have been identified in the HCDA mechanical consequences evaluation.[7] In a 150 MW-sec TOP HCDA it was concluded that sodium leakage would not occur from reactor head-mounted components, with the exception of the closed loop in-reactor assembly (CLIRA) spoolpiece seals. Potential leakage from that source was estimated at 240 lbs, released into the inerted center island enclosure. No leakage is predicted at the head peripheral seal, and the head omega seal is predicted to remain intact.

For the case of a 100$/sec LOF-HCDA, the CLIRA seal leakage would be similar to the 150 MW-sec results, since reactor head response is similar for both cases. However, vessel motion would be greater in the LOF case and the integrity of the complex-shaped omega seal, while predicted, is less certain. If the omega seal failed, an estimated 133,000 lbs of sodium would be released to the inerted reactor cavity. Release to the head compartment would be prevented by the head peripheral seal.

For the evaluation of additional safety margins by the analyses treated in this report, the assumption is made that seals will fail, either from loss of gas pressure in the case of inflatable seals or from the effects of sodium vapor and elevated temperatures. For conservatism, 100 percent of the noble gas inventory of the fuel pins is assumed to escape into the RCB head access compartment at the start of the accident, along with 300 lbs of sodium. One percent of the fuel and fission products is also assumed to be released into the RCB at time zero, although no mechanistic path for this release has been identified.

4.3 Postulated Failure Modes for In-Vessel PAHR

As previously discussed, a disrupted core would be predicted to remain within the reactor vessel, coolable as a debris bed by the primary HTS loops. There are three independent primary loops: any one loop has sufficient capability to cool the core. If, however, all three loops failed, then the sodium coolant would heat up, reach its boiling point, and eventually boil away into the RCB. This scenario forms the basis for the "in-vessel" cases treated in subsequent sections of this report.

If, for any reason, HCDA core debris assumed a noncoolable configuration, the fuel could melt its way through successive barriers consisting of the core shield-orifice assemblies, core basket region, and lower dome of the core support structure. If a coolable configuration did not develop in the reactor vessel inlet plenum, the lower vessel head would presumably be penetrated, releasing molten material to the guard vessel. Even if melting should progress to the guard vessel, it is probable that fuel fragmentation would occur at that location, resulting in a coolable configuration. This conclusion is supported by the ANL M-5 test.[8] If further progression occurred, with penetration of the guard vessel, sodium and core materials would be released to the reactor cavity floor. This scenario is the basis for "ex-vessel" cases treated in this report.

4.4 Definition of Conditions for Analyses

The cases analyzed are divided into two main categories, in-vessel and ex-vessel. In both categories the initial containment conditions are the initial stages of the transient based on the initial reactor releases postulated to result from the HCDA; that is, the release of 300 lbs of Na, 100 percent of the noble gas inventory, and 1 percent of the fuel and all fission products. The resulting containment pressurization, aerosol concentrations, and leakage are calculated as contributors to the offsite effects.

Beyond the initial release effects, the two basic loss of in-vessel PAHR scenarios, and case variations, are as described below.

4.4.1 In-Vessel Cases

The in-vessel cases have the core debris distributed in the vessel as particulate beds in the same configuration as the coolable in-vessel PAHR assessment.[3] With the assumption of no coolant circulation in HTS loops, the vessel sodium heats and boils out of the vessel into the RCB. The boilup phase was analyzed with the CACECO code.[9] The sodium boilup rate was input to the HAA-3 code[10] to compute aerosol fallout within the containment vessel. Radiological consequences were computed based on containment leakage using the COMRADEX program.[11]

The basic scenario for in-vessel cases, typified by Case 654, is as follows. The reactor containment building (RCB) is pressurized by sodium boilup effects. Hydrogen is formed by the reaction between sodium and water vapor released from the concrete containment floor. The hydrogen forms only if water vapor concentration is greater than the oxygen concentration, as evidenced by tests performed at HEDL.[12]

After the sodium is boiled out of the reactor vessel, fuel debris is assumed to consolidate and melt through the supporting structures, eventually penetrating the reactor vessel and guard vessel and spreading onto the floor of the reactor cavity as a mixture of stainless steel and fuel. This mixture melts into the concrete floor, releasing water vapor as the attack progresses. The water vapor reacts with the steel to form iron and chromium oxides and hydrogen. The quantity of molten steel available for oxidation was taken at 114,000 lbs. This quantity of steel represents the mass of components directly below the reactor core to a diameter of 10 ft. The steel comes from fuel assemblies, core basket, lower core support plate dome, reactor vessel, and guard vessel.

The attack of the reactor cavity floor is computed with the AYER code.(16) When only 6 inches of reinforced concrete remain, the floor is assumed to collapse and release the molten concrete-fuel pool to the subcavity, where water vapor-steel reaction continues until the remainder of the steel is consumed. Thereafter, the molten concrete-fuel pool continues spreading radially and downward until heat dissipation and heat generation are balanced.

The final disposition of the core has been calculated for one in-vessel case (and one ex-vessel case to be described later). The CACECO calculations of feedback effects to the upper regions of the containment building have been arbitrarily terminated at 1,632 hours. Prior to that time, all sodium has boiled away, all molten steel has reacted (usually by about 1,100 hours), and the radioactive releases have been completed.

Variations on this basic in-vessel scenario are as follows:

Case 656 -- Same as Case 654, except that hydrogen forms at all water vapor concentrations.

Case 657 -- Same as Case 654, except that building coolers are assumed to remove 1.8×10^6 Btu/hr from the RCB atmosphere.

Case 659 -- Same as Case 654, except that when RCB reaches 10 psig, gas is bled off as required to maintain that pressure. No purge is used.

Case 658 -- Same as Case 654, except that no purge nor vent is used. The building is pressurized by hydrogen and thermal effects until the failure pressure, taken as 20 psig, is reached. Then the building vents to atmospheric pressure and continues to vent as required to remain at essentially zero pressure. This case required no active components nor operator action. It is essentially a "do-nothing" case.

The final case (655) in the in-vessel series considers effects of thermal creep failure of the reactor vessel support system. A structural analysis[13] (Appendix E) indicates that the vessel support arms may fail after 384 hours exposure to the boiloff temperatures, causing the vessel to drop and become supported by the reactor guard vessel and cavity floor. Although this failure does not necessarily mean sodium release to the reactor cavity, the assumption is made in Case 655 that sodium spillage does occur. It is also assumed in this case that all liner area contacted by sodium, 1,190 ft^2, will fail. The sodium is cooled by cavity structures and boiling is stopped.

4.4.2 Ex-Vessel Cases

In the ex-vessel cases, the assumption is made that core debris and sodium coolant are released to the reactor cavity on a nonmechanistic basis 3 hours after the HCDA. This time is arbitrary; it corresponds approximately to early estimates of the time required for a consolidated layer of core debris to melt through the core basket and core dome. The space beneath the reactor guard vessel and above the reactor cavity floor is nearly filled with calcium silicate thermal insulation. This insulation may be mildly reactive with sodium. The heating effect of this reaction has not been included in the calculations and the insulation is assumed not to delay the release of the vessel contents to the cavity.

The basic assumption for the ex-vessel cases is that the fuel debris would refragment in the reactor cavity and that the liners would maintain their integrity, even though in most of the analyses liner failure is assumed. The assumption of liner integrity is based on structural analyses.[6,14] The assumption of molten fuel fragmentation and dispersal in liquid sodium is supported by the ANL M-5 test,[8] even for conditions in which molten fuel is released ahead of the sodium. From this general beginning, the subsequent scenario can be discussed.

Seven ex-vessel cases were analyzed in this study. Five cases are parametric variations valid until structural failures were calculated to occur. Two cases considered effects of structural failure and the analysis of one of these cases includes meltdown of the core into the earth. The basis for this last case will be described first.

In Case 683, sodium containing fuel debris fills the reactor cavity to a depth of 16.5 ft above the cavity floor. The floor liner and wall liners are assumed to fail such that 1,402 ft^2 of concrete react with sodium for a period of 4 hours in accordance with small-scale experimental data on Na-concrete reactions through failed liners.[15] Water is released from this same area into the sodium pool. The water reacts to form sodium oxide, which remains in the cavity, and hydrogen, which reacts to form sodium hydride, or leaks to the RCB. Hydrogen released from the reactor cavity recombines with oxygen in the RCB to form water vapor, so long as the effluent mixture contains sodium aerosol, and oxygen concentration in the RCB is greater than 11 vol%.

At 384 hours, the assumption is made that the reactor cavity floor fails and sodium flows into the subcavity. This failure time is arbitrary and corresponds to vessel support arm failure calculated for the in-vessel case. In this present case, vessel support arms are cooler and do not fail. A more realistic estimate[13] places the floor failure at 1,000 hours, and that failure time is used in the analysis of another case.

When the floor fails, sodium remaining in the cavity drains into the subcavity where it rapidly heats to its boiling point by reaction with the bare concrete surfaces. Sodium boilup forms sodium oxide in the RCB and accumulates on the building floor. The heating effect of the sodium-air reaction eventually heats the RCB concrete floor until it starts releasing water. This water reacts with the oxide deposit, converting it to hydroxide. When all sodium oxide has been thus reacted, water released into the RCB has the potential for forming more hydrogen with the sodium boilup, in accordance with O_2 concentration limits described in connection with Case 654.

When the sodium has boiled dry, attack of the concrete structures by molten fuel commences. Floor penetration calculations were made with the AYER code, as in Case 654, except that in Case 683 the attack starts on the subcavity floor, owing to the main cavity floor-failure assumption. Molten steel present in the debris reacts with water, releasing hydrogen to the RCB. When the steel has been consumed, any further water release reacts with sodium oxide remaining in the subcavity to form sodium hydroxide and release additional heat energy. The AYER code calculation was terminated when penetration showed no further progress. The CACECO code calculation of feedback effects to the RCB terminated at 1,632 hours. This termination time represents the same arbitrary choice used in the in-vessel cases, and, as in those cases, all radioactive releases are considered to be complete.

The second ex-vessel structural failure scenario analyzed is Case 688. This case starts out the same as Case 683, except that initial liner failure is limited to the area directly beneath the guard vessel, 346 ft^2. Also, rather than vent and purge, this case allows the RCB to pressurize until its assumed failure pressure of 20 psig is reached. The reactor cavity floor slab is assumed to collapse at 1,008 hours, corresponding to a structural analysis given in Appendix E and Reference (13). When the floor fails, the scenario is similar to Case 683 except, of course, for the displacement in time and the absence of the air purge.

Parametric variations were tested in five cases valid to 1,000 hours, as follows:

Case 675 -- This case starts out the same as Case 683, except that no cavity liner failure is assumed, and no structural failures are considered. The building is vented after reaching 10 psig. Hydrogen recombination is operative.

Case 677 -- Same as Case 675, except that 346 ft^2 of floor liner area is assumed to be failed, and there is no hydrogen recombination.

Case 678 -- Same as Case 675, except that 346 ft^2 of floor liner failure is assumed and the building is permitted to pressurize to 20 psig and then vent down. No air purge is used. This case is the analog to in-vessel Case 658 and is the same as the first 960 hours of ex-vessel Case 688, described previously.

Case 681 -- Same as Case 677, except that hydrogen recombination is used.

Case 682 -- Same as Case 675, except that a failed liner area of 1,402 ft^2 is used.

5.0 CALCULATIONAL METHODS

5.1 Initial Conditions for Containment Transients

The starting point for containment transients was established by using the SPRAY Code[17] to compute the temperature and pressure resulting from the assumed HCDA sodium and fuel release in the Head Compartment. Then the SOFIRE code[18] was used to compute the initial pressurization and corresponding leak rate from the RCB. Subsequent containment conditions and leakage were calculated by CACECO.

The SPRAY code was used to calculate the temperature and pressure rise resulting from an HCDA release of 30 kg of fuel (1 percent of the core) and 300 lbs of sodium. Input to SPRAY assumed that the fuel release mixed adiabatically with air in the reactor head compartment, heating it and producing an initial pressure which was equalized between the head compartment and the RCB. Sodium spray release consequences then were calculated using a mean droplet size of 0.01 inch diameter. SPRAY calculated that 96 lbs of sodium was consumed, producing 130 lbs of Na_2O. The balance of the sodium was deposited on the head compartment floor and equipment, and reacted as a pool. The 130 lbs of Na_2O was input to the HAA-3B code for aerosol computations.

The SPRAY pressure transient is shown in Figure 5-1. The atmosphere temperature increased to a maximum of 842°F in the head compartment. A pressure of 0.09 psig resulted from fuel heating; this increased to a peak of 0.14 psig in 6 sec. due to sodium spray combustion in the air atmosphere. The pressure in the head compartment was in equilibrium with that in the RCB due to the large opening ($\sim$500 ft^2) for flow through the operating deck.

The 0.14 psig peak pressure and corresponding temperatures in the head compartment and in the RCB from the SPRAY analysis were used as initial conditions in the SOFIRE code. Decay heat calculated by RIBD[3] for 100 percent noble gases and 1 percent of all other fission products was assumed to be

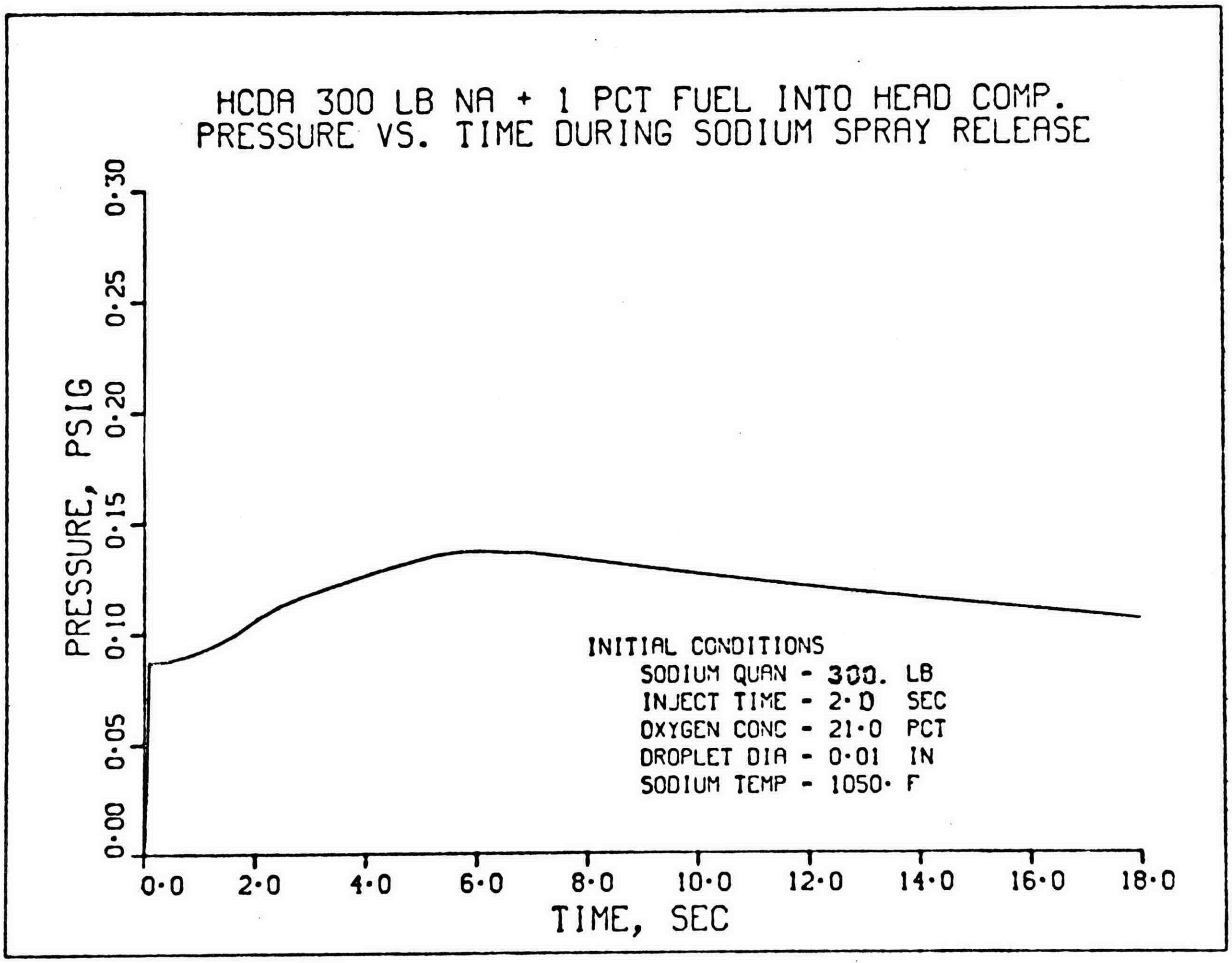

FIGURE 5-1. Spray Pressure Transient.

released in the RCB atmosphere. This was conservative, because fission products other than noble gases would dissolve in or be agglomerated with sodium oxide, the majority of which would be deposited on the RCB floor, and thus some decay heat would be absorbed directly in the concrete floor.

SOFIRE calculated pressures and temperatures resulting from the sodium pool fire in the head compartment plus fission product decay heat. The pressure history curve from the SOFIRE analysis for the RCB is shown in Figure 5-2. A corresponding leak rate history is shown in Figure 5-3. This follows the pressure rise on the basis of a design leakage of 0.1 vol% per day at 10 psig and leakage at lower pressures proportional to $\sqrt{\Delta p}$.

These transient curves apply to analyses of consequences of an HCDA with effective in-vessel PAHR. In the present study, the initial effects calculated with these transient curves were soon superseded by the more severe transients calculated for the postulated conditions of loss of in-vessel PAHR. Leak rate from the containment building in the initial stage of the transient was calculated by SOFIRE based on the RCB initial pressurization calculated by SPRAY, and subsequent pressure decay computed by SOFIRE. Sodium oxide aerosol formation in the RCB was obtained from CACECO and added to the fuel and sodium oxide aerosol concentration computed by SPRAY from the HCDA release. A few hours into the transient, heat and mass transport from the reactor vessel/cavity resulted in a higher RCB pressure and leakage than the SOFIRE results, which were based on the initial HCDA release only. At that time, transfer to the CACECO leakage data was made and used throughout the remainder of the transient. This leakage along with the sodium transport from the reactor vessel/cavity computed by CACECO was used as input to HAA-3B to compute aerosol behavior in the RCB.

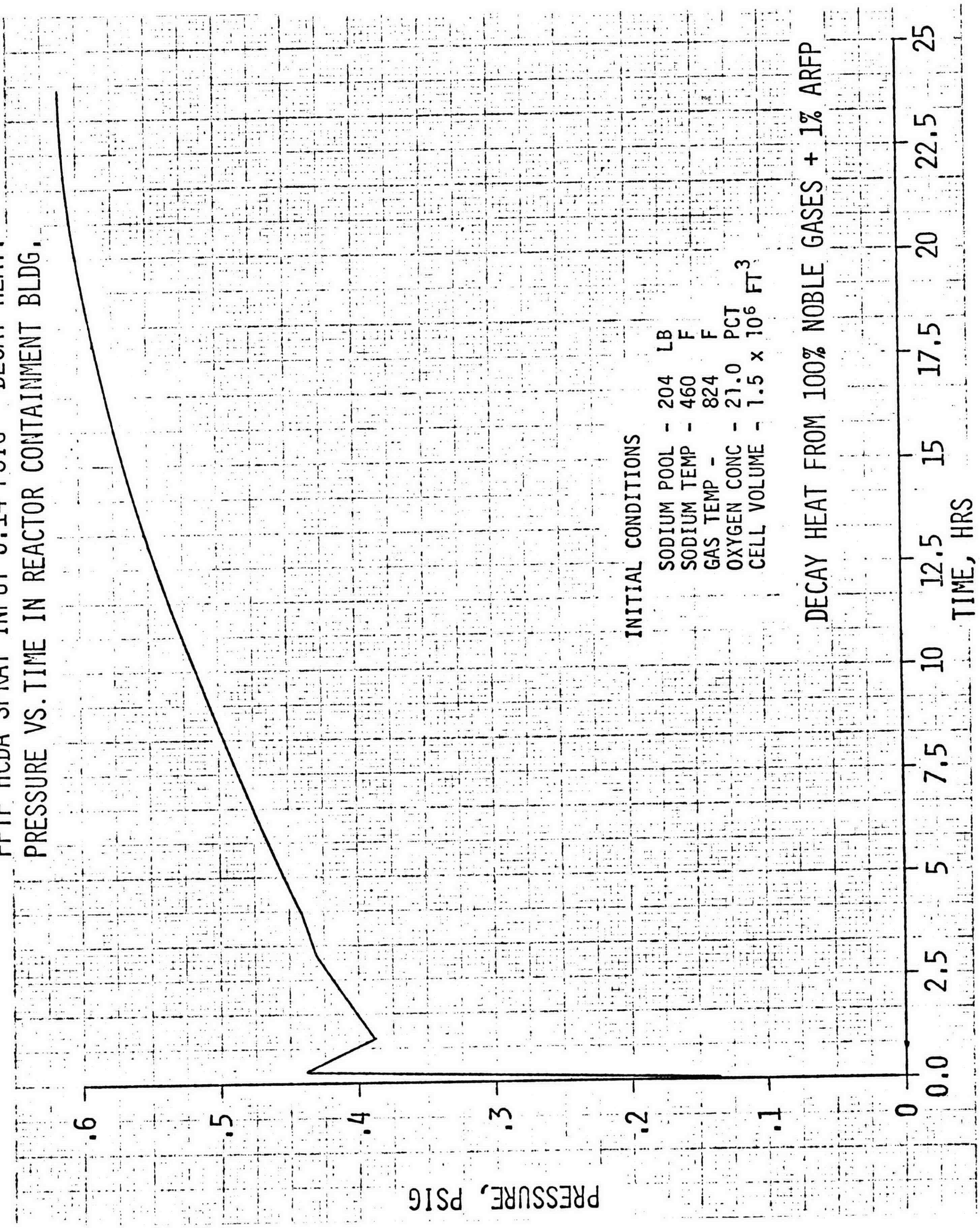

FIGURE 5-2. SOFIRE Pressure Transient.

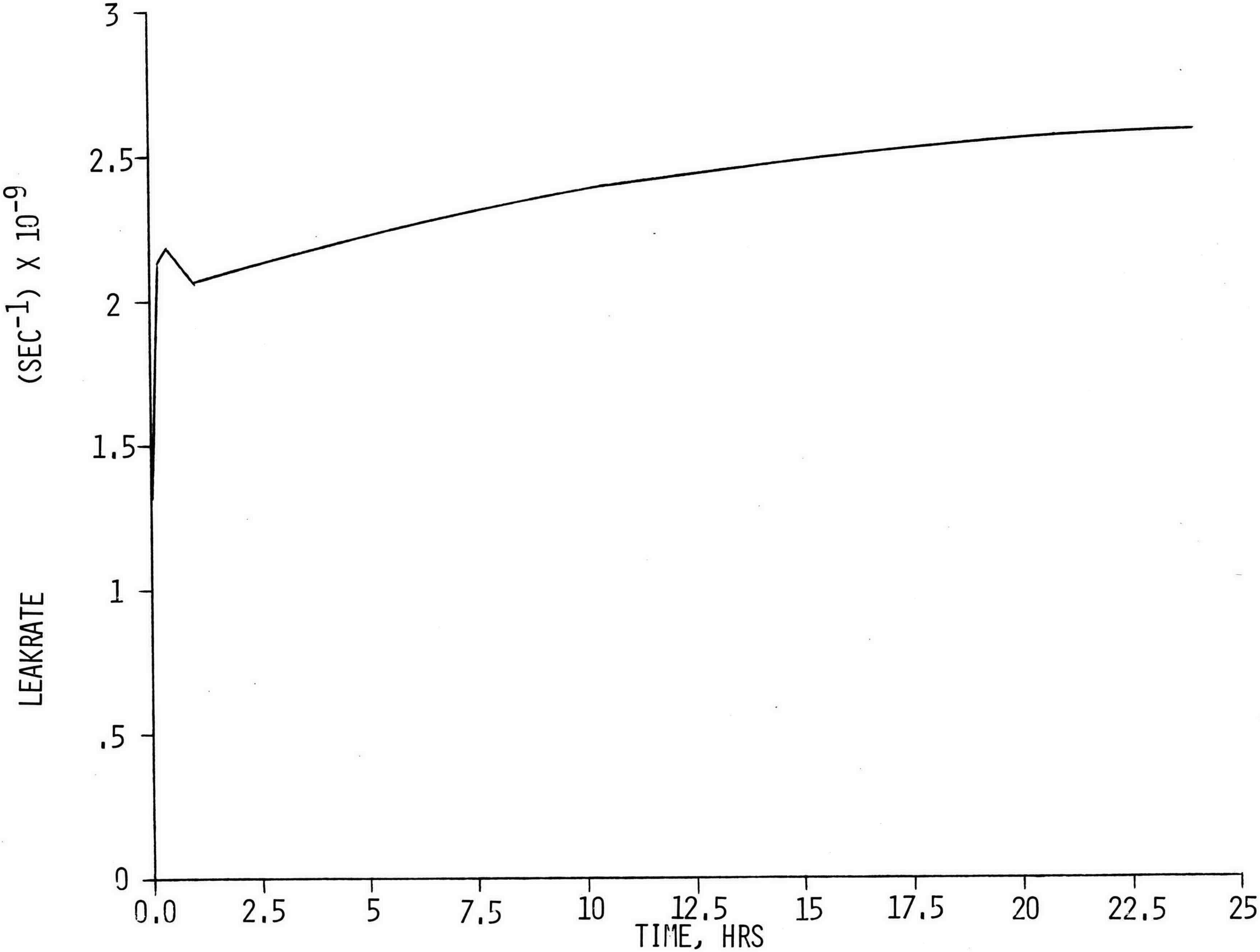

FIGURE 5-3. RCB Leakrate Vs. Time.

5.2 Initial Aerosol Behavior

The behavior of the aerosol in the RCB resulting from the assumed HCDA release of one percent of fuel and 300 lbs of sodium was calculated with the HAA-3B code. Here, 100 percent of fission product noble gases is assumed to be released to the RCB atmosphere at HCDA time zero along with one percent of the fuel and fission products. The fuel with UO_2 and PuO_2 was assumed to mix homogeneously with the sodium oxide and to agglomerate with it. This aerosol then settled, plated, or leaked out of the RCB.

The suspended concentration of sodium oxide, fuel and fission products vs. time is shown in Figure 5-4. The inital concentration, ~2 μg/cc, began to decrease significantly after 2 hours. Total aerosol concentration had decreased to 1/2 its initial value at 5 hours and was less than 10^{-5} μg/cc at 1,000 hours. Fuel and plutonium fractions of the total aerosol mass were 33.7 percent and 7.8 percent, respectively; assuming fuel with an average Pu enrichment of 23 percent. Plutonium concentration vs. time is also shown on Figure 5-4. Approximately 2 gms of Pu remained suspended at 200 hours. The plutonium concentration was initially 0.25 μg/cc and decreased to 7×10^{-7} μg/cc at 720 hours (30 days).

The foregoing fuel aerosol behavior was used as initial conditions for all of the cases analyzed. When sodium release from the reactor cavity caused an aerosol concentration in excess of the HCDA initial aerosol release, HAA-3 was used to recalculate suspended concentrations from that time until the end of the boilup transient. HAA-3B also calculated fractional rates of aerosol deposition in the RCB. This value closely followed the aerosol concentration transient. The deposition rate calculated by HAA-3B was used as a removal coefficient for suspended radioactivity in calculations of radiological consequences.

Figure 5-4 shows that even if no additional Na_2O were available to scavenge the fuel aerosol, suspended concentration would decrease to the

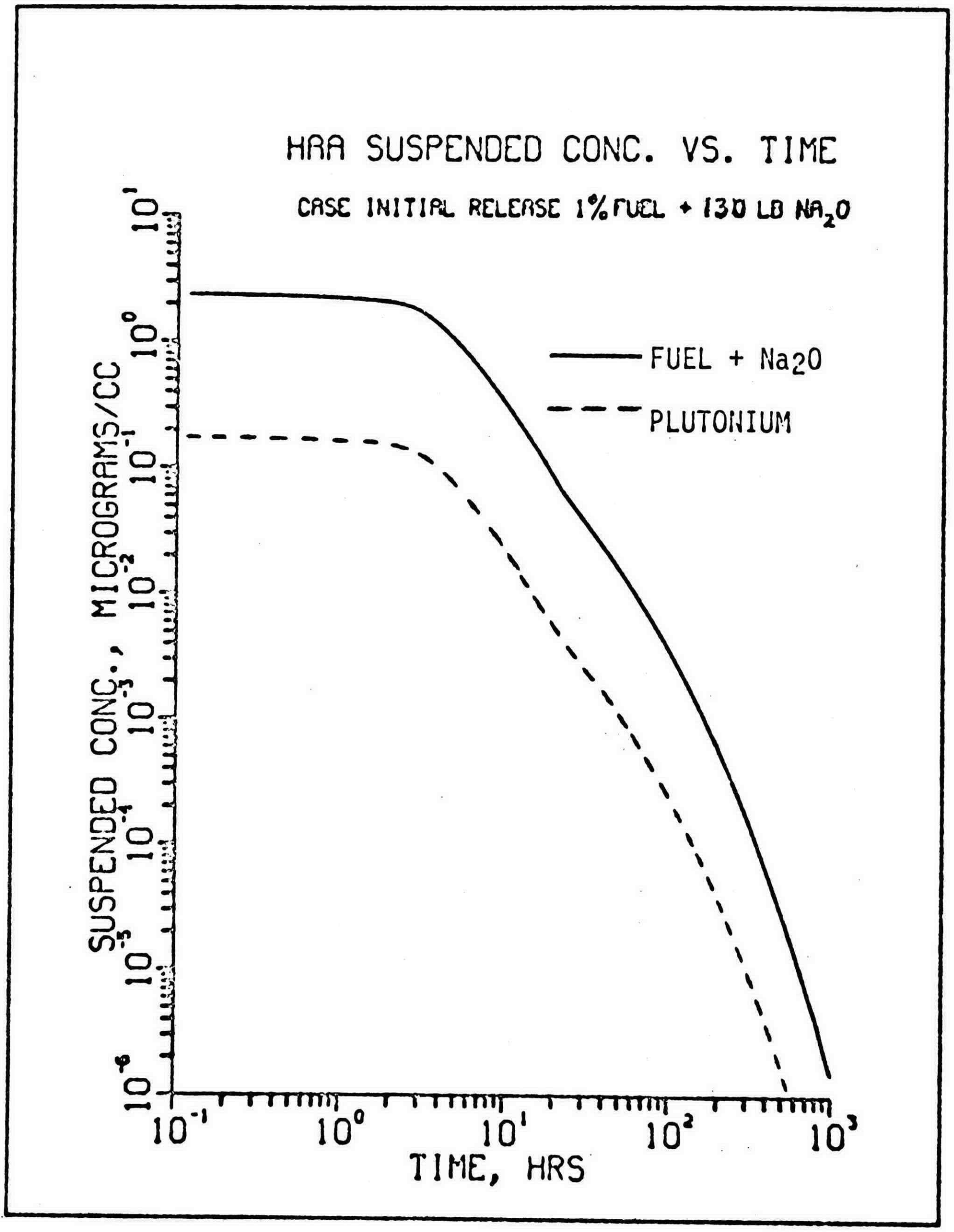

FIGURE 5-4. RCB Leakrate Vs. Time.

low levels shown at 1,000 hrs. The additional aerosol generation caused more rapid deposition of the suspended fuel.

5.3 CACECO Code Analysis

The containment conditions following the initial HCDA effects were calculated by using the CACECO code. The code analyzes the conditions in the reactor vessel, reactor cavity, adjacent cells and reactor building. It calculates conditions such as temperatures and pressures from mass and energy balances that include leakage and chemical reactions. The chemical reactions include the following:

In the reactor cavity during the sodium boiloff:
- sodium + oxygen to form sodium oxide
- sodium + concrete
- sodium + water vapor to form hydrogen
- sodium + hydrogen to form sodium hydride

In the cavity after sodium has boiled dry:
- stainless steel + water vapor to form hydrogen

In the RCB:
- sodium oxide + Water vapor to form sodium hydroxide
- sodium + oxygen to form sodium oxide
- sodium + water vapor to form hydrogen
- hydrogen + oxygen to form water vapor (hydrogen recombination)

The code calculates temperature transients for equipment, roofs, walls, and floor structures, which act as heat sources and sinks in the analysis.

All cases analyzed, both in-vessel and ex-vessel, used the RCB model described in Section 3.1. All cases started with the reactor vessel and cavity model described in Sections 3.2 and 3.5. The RCB atmosphere was heated by the decay power of the IDS fuel storage and of the HCDA release of one percent of core debris and all noble gas fission products. The reactor vessel permitted the top layer of the sodium to heat faster and become hotter than the middle and bottom layers. The top layer of the vessel was heated by the decay power of 9/10 of the core debris (actually 89.1 percent, since 1 percent was released into the building). The middle layer of the vessel was heated by the decay power of the in-vessel fuel storage and of 1/10 of the core debris.

The CACECO analysis of Case 654 is described in detail to illustrate the calculational method for in-vessel cases, and the analysis of Case 683 is described to illustrate the ex-vessel cases.

5.3.1 In-Vessel Case Analysis

Case 654 held the HCDA core debris in-vessel. Briefly, the vessel sodium heated and boiled away. The sodium boiloff heated and pressurized the building. The building was vented to prevent over-pressure and an air purge was begun to limit the hydrogen concentration. When the vessel boiled dry, the core debris melted through the vessel bottom onto the cavity floor and thence, after the floor collapsed, onto the subcavity floor. The CACECO analysis was stopped after the radioactivity release had ceased.

The code permits the user to redefine any of the four cells analyzed by the code, and this code feature was used to carry the analysis through successive stages. The CACECO analysis of this in-vessel case is outlined in Table 5-1. The successive steps of the containment scenario that use cell redefinition occur at 83 hours, 526.5 hours and 888 hours. At 83 hours, the building ventdown was finished and an air purge begun. At 526.5 hours the vessel boiled dry and the core debris melted through the vessel bottom. At 888 hours the cavity floor failed and core debris spilled into the subcavity.

The analysis situation at the beginning of Case 654 is shown in Figure 5-5. The upper vessel layer began with 290,000 lbs of sodium at

TABLE 5-1

CACECO Analysis of Case 654

Time After HCDA	Scenario	CACECO Code Cell Definition			
		Code Cell A	Code Cell B	Code Cell C	Code Cell D
0 to 83 hours	Upper Vessel heats and boils off into RCB which heats and pressurizes to 10 psig at 82 hrs. RCB ventdown to 0 psig at 83 hrs.	Upper Reactor Vessel	Reactor Cavity	Reactor Containment Building	Lower Reactor Vessel
At 83 hr restart	Combine upper and lower vessels. Introduce H&V cooler equipment room.	--	--	--	--
83 to 526.5 hrs	Boil reactor vessel dry. Purge RCB with air to limit hydrogen concentration. Accumulate water in H&V cooler room.	Reactor Vessel	Reactor Cavity	RCB	H&V Cooler equipment room
At 526.5 hr restart	Assume core debris melts thru vessel bottom into cavity. Combine vessel and cavity. Introduce subcavity. Use code version that has steel-water reaction.	--	--	--	--
526.5 to 888 hrs	Use 2600°F heat source to simulate core debris attack into cavity floor. Water release from floor reacts with steel making hydrogen. Continue RCB air purge.	Reactor vessel-Reactor cavity	Subcavity under the reactor cavity	RCB	H&V Cooler room
At 888 hr restart	Assume core debris collapses cavity floor into subcavity. Combine vessel, cavity and subcavity. Eliminate Code Cell B from analysis.	--	--	--	--
888 to 1632 hrs	Continue use of 2600°F heat source to simulate core debris attack into subcavity floor. Water release from floor consumes all the steel associated with debris. Stop RCB air purge	Reactor vessel-reactor cavity-subcavity	Not used	RCB	H&V Cooler room

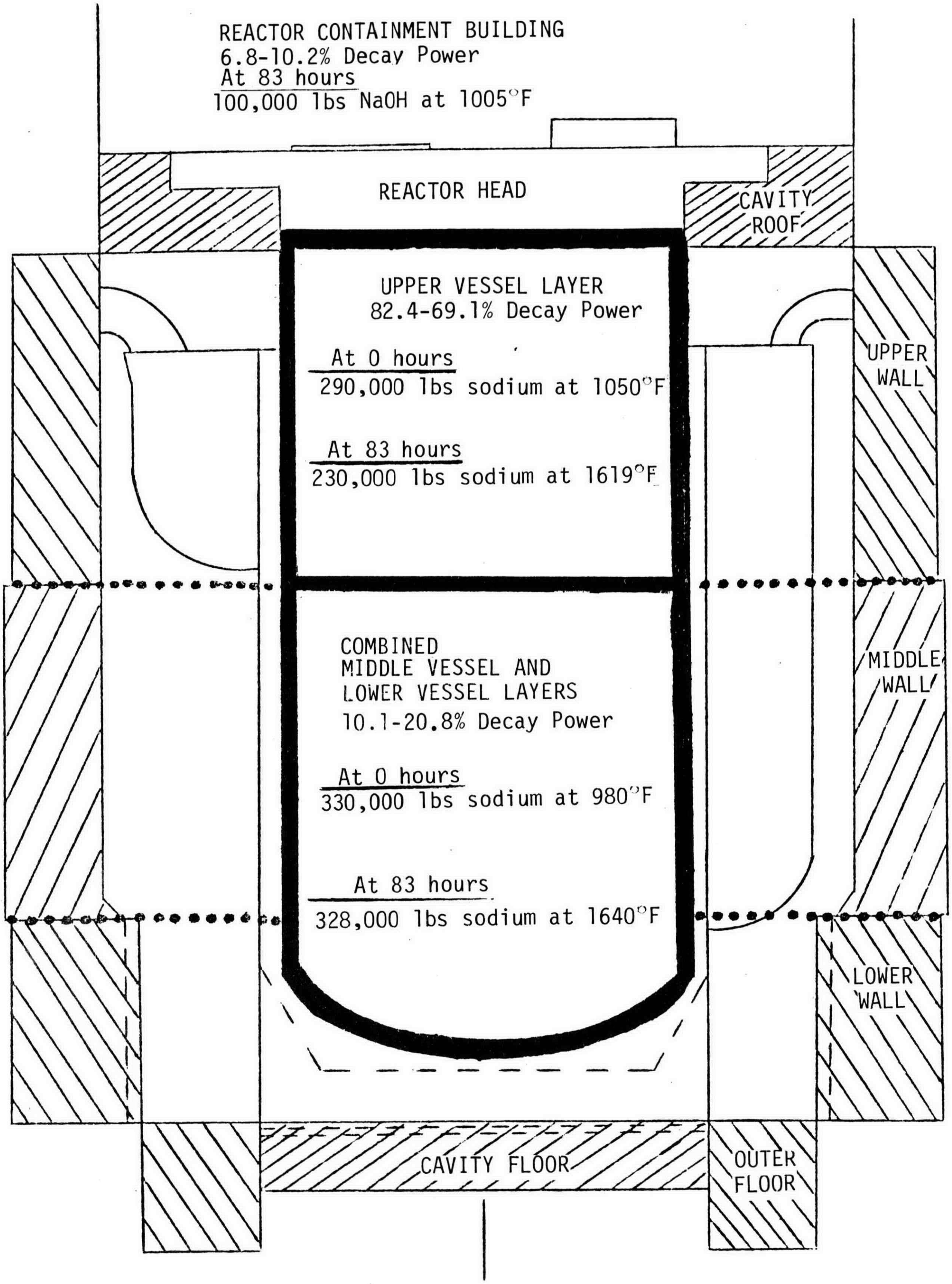

FIGURE 5-5. CACECO Case 654 - Sodium Inventories, 0 to 83 Hours.

1050°F and heated to 1620°F at 20 hours. The combined middle and lower layers began with 330,000 lbs of sodium at 980°F and heated to 1216°F in the same time period. The combined layers required 75 hours to heat to 1620°F.

The RCB was vented at 82 hours to prevent pressurization above 10 psig. The ventdown (also called blowdown) to near atmospheric pressure was assumed to take one hour (to 83 hours); then operation of the H&V ventilation blowers was simulated to provide the air purge to limit hydrogen concentration.

The analysis situation from 83 to 526.5 hours is shown in Figure 5-6. At 83 hours, the combined layers of the reactor coolant had 558,200 lbs of sodium at 1636°F. The air purge of the RCB, beginning at 83 hours, cooled the building atmosphere to 782°F but it heated again to the maximum value of 1015°F at 185-189 hours. Also, the RCB roof steel heated to 820°F. The analysis assumed that these high temperatures would degrade insulation on the outside of the roof to the extent of tripling its thermal conductivity. The decay power caused the vessel to boil dry at 526.5 hours.

Following sodium boil-dry, fuel debris was assumed to melt through the reactor vessel as discussed in Section 4.4.1. The CACECO simulation of the post-boil-dry period used two new features. One feature introduced the stainless steel-water reaction to produce hydrogen which had to be controlled by the building air purge. The source of the stainless steel is described in Section 4.4.1. The second feature used a 2600°F heat source on the cavity floor, and later in the subcavity, to represent heating caused by the molten pool of core debris and basalt concrete.

The CACECO analysis of the cavity floor and subcavity concrete heating is the basis for the concrete water release which reacted with the stainless steel to produce hydrogen. By 888 hours, water release from the cavity floor had reacted 51 percent of the stainless steel. By 1,056 hours, water release from the subcavity walls and floor had reacted all of the stainless steel.

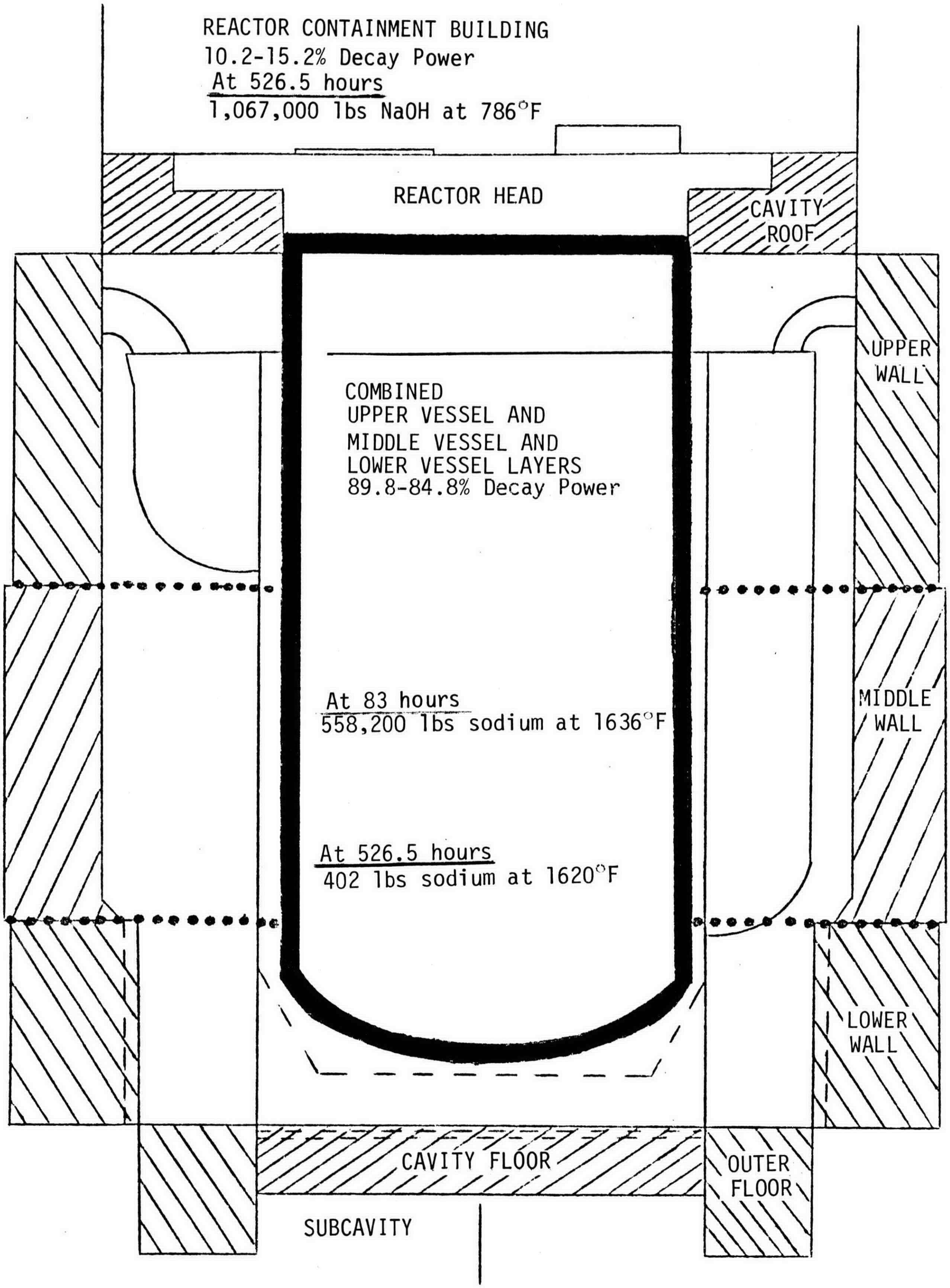

FIGURE 5-6. CACECO Case 654 - Sodium Inventories, 83 to 526.5 Hours.

The CACECO analyses of all cases stopped at the arbitrary time of 1,632 hours, which is 68 days after the HCDA. By this time all radioactive release had ceased. For Case 654, the hydrogen production and RCB air purge ceased at 1,056 hours. Thereafter, analysis showed the gradual attainment of a steam atmosphere in the RCB as core debris heating continued to drive moisture out of the cavity and subcavity concrete.

Following sodium boil-dry, penetration of the containment floors was calculated by the AYER code.[16] The AYER code was developed by Los Alamos Scientific Laboratory and modified by the Westinghouse Advanced Reactors Division. The code implicitly solves the general two-dimensional equation of transient heat conduction and includes in-plane anisotropic thermal conductivity and interface thermal contact resistance. It uses the finite element method. Core decay heat (input data) is distributed uniformly throughout the pool. Temperature distribution within the pool is determined by conduction and boundary conditions. When the average temperature of the nodes forming an element becomes greater than the melting point of the material in the element by an amount which accounts for heat of fusion, the element is included in the pool zone and the properties of the pool material are recalculated using appropriate mass or volume weighting. The code outputs the temperatures at the nodes, the average and maximum temperatures in each zone, volumes of the zones, and information on the heat balance of the zones.

The AYER analysis of Case 654 began at 527 hours with the core debris of 2,850 kg of molten fuel spilled over the 346 ft^2 area of the cavity floor under the reactor vessel. The core debris melted into the floor to form a basalt concrete-core debris molten pool. The analysis assumed that heat loss from the surface of this pool amounted to 75 percent of the decay power of the debris. This cavity floor was assumed to fail when the pool had melted through 33 inches of firebrick, insulation brick, and concrete to within 6 inches of the bottom surface. This failure occurred at about 880 hours. The AYER analysis was continued with the core debris and molten concrete of the cavity floor spilled onto the subcavity floor. The AYER analyses are described in Appendix C.

5.3.2 Ex-Vessel Case Analysis

Case 683 assumed the HCDA core debris to be released ex-vessel at 3 hours. Briefly, the sodium spilled onto the cavity floor, the liner failed and the sodium heated. The RCB was vented to begin an air purge to limit the hydrogen concentration. The cavity floor failed and spilled core debris and sodium into the subcavity. The reactions with bare concrete reacted and boiled away the sodium. When the subcavity was dry, the core debris melted into the subcavity floor. The CACECO analysis was stopped after hydrogen production had ceased.

The CACECO analysis of this ex-vessel case is outlined in Table 5-2. The containment scenario's successive steps using cell redefinition occur at 3 hours and 384 hours. At 3 hours the core debris melted through the vessel and tank bottoms and spilled the vessel sodium into the cavity. At 384 hours the cavity floor collapsed and the core debris and sodium spilled into the subcavity.

The analysis situation at the beginning of Case 683 is shown in Figure 5-7. The upper vessel layer began with 290,000 lbs of sodium at 1050°F and heated to 1276°F at 3 hours. The combined middle and lower layers began with 330,000 lbs of sodium at 980°F and heated to 1024°F.

In these ex-vessel cases, the assumption was made that the core debris melted through the bottoms of the reactor vessel and guard tank and, with the sodium, spilled into the reactor cavity at 3 hours. The melt-through, spill and time are nonmechanistic and arbitrary. The sodium spill flooded the cavity to a depth of 16.5 feet.

The analysis situation after the sodium spill is shown in Figure 5-8. The floor liner was assumed to fail and sodium flooded behind the liner. In Case 683, 1,402 ft^2 of wall and floor area were contacted by the sodium. The sodium-concrete reaction lasted 4 hours and extended 2 inches into the concrete. Water released from the concrete behind the flooded liner went into the sodium pool, reacted and produced hydrogen.

TABLE 5-2

CACECO Analysis of Case 683

		CACECO Code Cell Definition			
Time after HCDA	Scenario	Code Cell A	Code Cell B	Code Cell C	Code Cell D
0 to 3 hours	Upper vessel heats more than the lower vessel	Upper Reactor Cavity	Reactor Cavity	Reactor Containment Building	Lower Reactor Vessel
at 3 hr restart	Assume core debris melts through vessel bottom into cavity. Combine upper vessel, lower vessel and cavity. Introduce H&V cooler room and subcavity. Assume cavity floor liner fails.	--	--	--	--
3 to 384 hrs	Cavity heats. RCB ventdown to 0 psig at 55 hrs to begin air purge to limit hydrogen concentration. Accumulate water in H&V cooler room.	Reactor Vessel-Reactor Cavity	Subcavity under the Reactor Cavity	RCB	H&V Cooler equipment room
at 384 hr restart	Assume cavity floor collapses and spills core debris and sodium into the subcavity. Combine vessel, cavity and subcavity. Eliminate Code Cell B from analysis.	--	--	--	--
384 to 1632 hrs	Consume and boil away all of the sodium. Use 2600°F heat source to simulate core debris attack into subcavity floor. Water release from the floor consumes all of the steel associated with debris. Stop RCB air purge.	Reactor Vessel-Reactor Cavity-Subcavity	Not Used	RCB	H&V Cooler equipment room

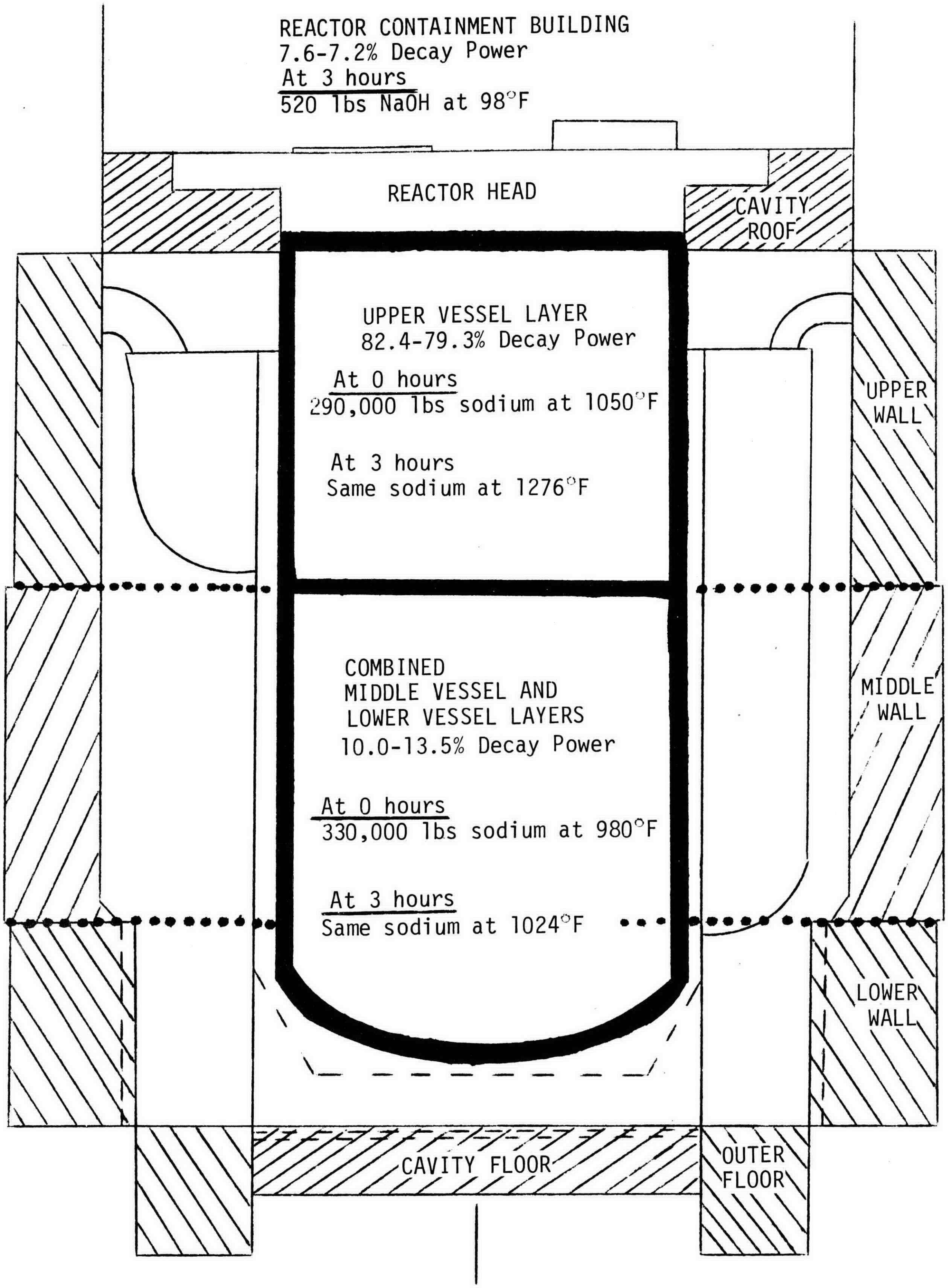

FIGURE 5-7. CACECO Case 683 - Sodium Inventories, 0 to 3 Hours.

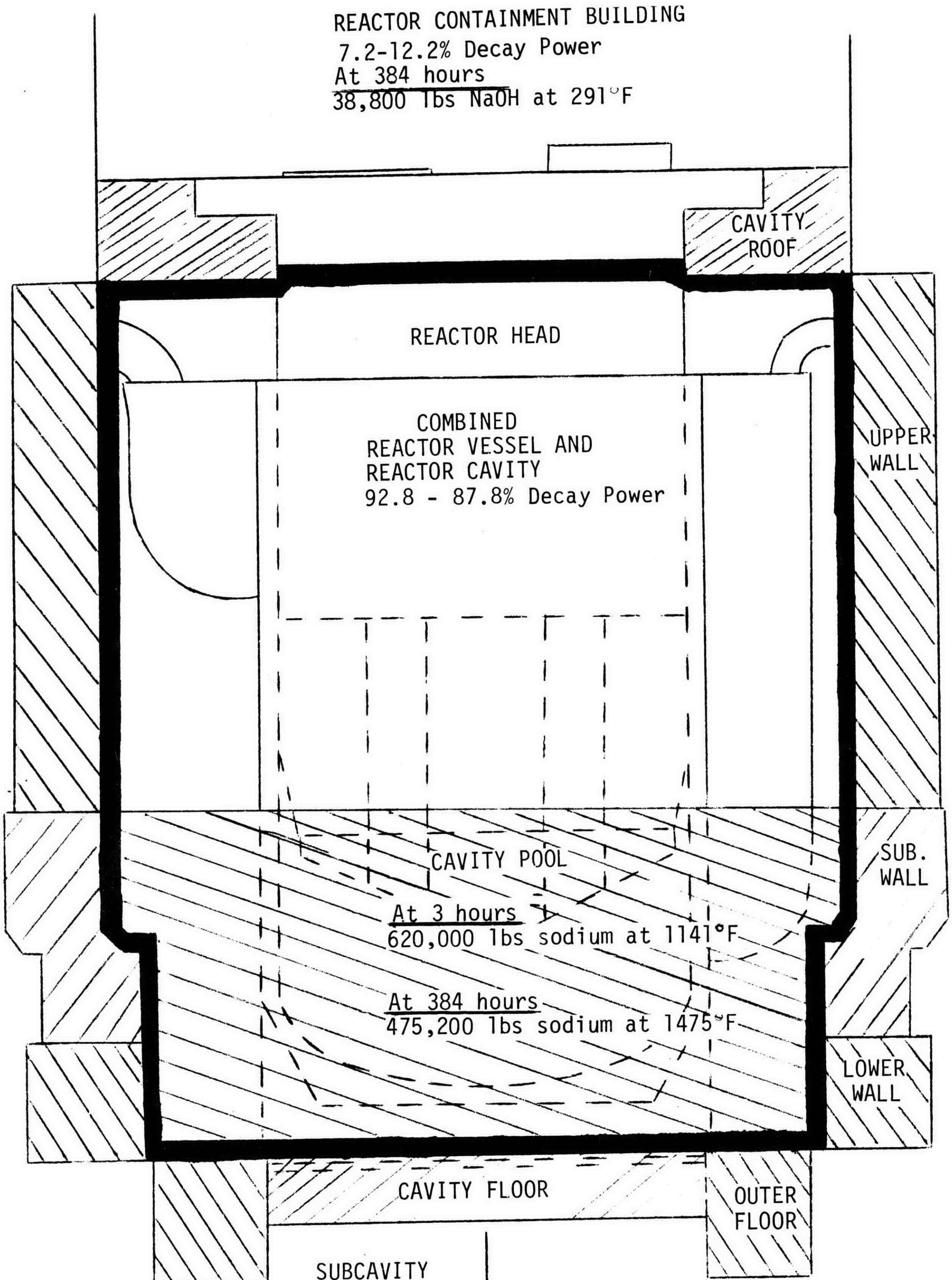

FIGURE 5-8. CACECO Case 683 - Sodium Inventories, 3 to 384 Hours.

The hydrogen flow from the cavity carried sodium vapor into the RCB atmosphere. The sodium and hydrogen reacted with the atmosphere, the sodium forming sodium oxide and the hydrogen "recombining" to form water vapor. The conditions for hydrogen recombination have been the subject of recent experimental investigations at HEDL.[12] These indicate that recombination stops when the oxygen concentration falls below 11.0 percent. At 40 hours, these sodium and hydrogen reactions reduced oxygen concentration in the RCB from 21 to 11.0 percent; hydrogen-oxygen reaction ceased and hydrogen began to accumulate.

The RCB was vented at 55.1 hours in order to start an air purge to limit hydrogen concentration. The ventdown started at 6.4 psig with hydrogen at 3.4 percent. The ventdown to near-atmosphere pressure was assumed to take 0.9 hours (to 56 hours) and then operation of the H&V ventilation blowers was simulated to begin the air purge.

At 384 hours, the sodium pool was at 1475°F and about 13.3 feet deep. Then the assumption was made (in this case) that the cavity floor collapsed and spilled core debris and sodium into the subcavity. The analysis situation after the floor collapse is shown in Figure 5-9. The flooding of the subcavity drained the cavity so that the new surface was only about 9 feet above the previous floor level. This collapse exposed the following new areas of bare concrete to sodium attack;

346 ft^2 of the under side of the cavity floor,
700 ft^2 of the walls of the subcavity and
346 ft^2 of the floor of the subcavity.

The sodium-concrete reactions and the attendant sodium-water reactions heated the sodium to boiling. By 428.7 hours the sodium had boiled dry; some 33 percent (203,900 lbs) had evaporated into the building, 26 percent (162,800 lbs) had reacted with the water release to form sodium oxide in the cavity and subcavity, and 41 percent (253,000 lbs) had reacted with the concrete.

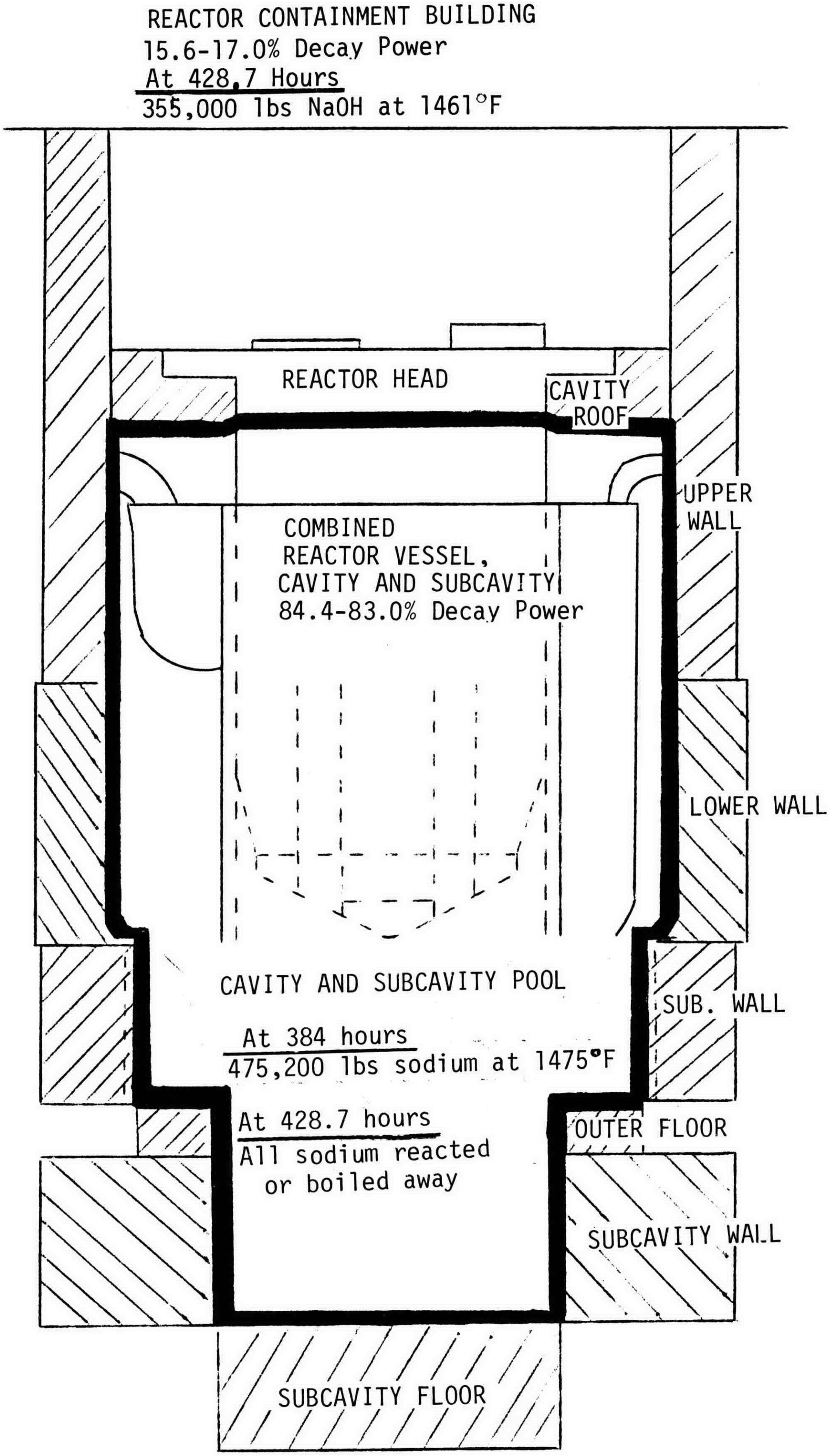

FIGURE 5-9. CACECO Case 683 - Sodium Inventories, 384 to 428.7 Hours.

The CACECO analysis was continued past the sodium boil-dry time in order to predict the RCB releases that would follow. That is, the RCB releases were calculated by the CACECO code, while the penetration of the subcavity floor by core debris was calculated by the AYER code.

The CACECO simulation of the post-boil-dry period introduced the stainless steel-water reaction to produce hydrogen which had to be controlled by the RCB air purge, and the 2600°F heat source in the subcavity to represent the heating caused by the molten pool of core debris and basalt concrete. The analysis of the concrete heating was the basis for the concrete water release which reacted with the stainless steel. By 770 hours, the water release from the subcavity walls and floor had reacted all of the stainless steel. For Case 683, the hydrogen production and RCB air purge ceased at 770 hours. Thereafter, the analysis showed the gradual attainment of a steam atmosphere in the RCB as core debris heating continued to drive water out of the cavity and subcavity concrete.

The AYER analysis of Case 683 began at 429 hours with the core debris of 2,850 kg of molten fuel spilled over the 346 ft^2 area of the subcavity floor. The debris was covered by 5.5 feet of sodium-concrete reaction products from the cavity floor and subcavity walls. The core debris melted into the concrete reaction products, above, and into the concrete, below, forming a basalt concrete-core debris molten pool. The analysis assumed that heat loss from the surface of the concrete reaction products was small until the pool broke through this surface. Thereafter, the heat loss from the pool surface amounted to 75 percent of the decay power of the debris. The AYER analysis continued until the molten pool reached maximum size and started receding. This analysis is described in Appendix C.

5.4 HAA Code Analysis

Aerosol behavior in the RCB and head compartment was calculated with the HAA-3B code. The initial aerosol input included fuel and sodium oxide from the reactor head HCDA release. The fuel included UO_2 and

PuO_2, and was assumed to be mixed homogeneously with the sodium oxide. The entire aerosol was assumed to mix homogeneously with the RCB air atmosphere. The initial aerosol input of sodium oxide was determined from the SPRAY code analysis, while the long-term sodium oxide source released from the reactor vessel and/or cavity was determined from the CACECO code analysis. RCB leak rate input to HAA was supplied by SOFIRE and CACECO. Fission product noble gases do not dissolve in or agglomerate with fuel and sodium oxide aerosol but will leak out of the RCB with the aerosol. The major aerosol mass will settle on the RCB floor, a small amount will plate out on RCB walls and a small amount will leak out over the long term.

Sodium vapor leaked from the reactor vessel or cavity into the RCB was assumed to react into sodium monoxide as rapidly as it was released when oxygen was present. Once oxygen was depleted the calculated fallout rate dropped to zero, while leakage from the RCB continued without benefit of aerosol fallout. This was a conservative assumption, because some fallout depletion is expected from product aerosols of the sodium-water reaction and/or condensation of sodium vapor. However, no experimental evidence has yet been identified to quantify this assumption. The aerosol fallout rate vs. time calculated by HAA was utilized as input to the COMRADEX code for the radiological evaluation.

5.5 COMRADEX Analysis

The COMRADEX[1] computer code was utilized to calculate the release of radioactive materials from the Reactor Containment Building (RCB) and the potential exposures at the site boundary (4-1/2 miles).

5.5.1 Radioactivity Release Model

The release of each isotope from containment is found by following it through one to four "chambers" in series, so that the first chamber leaks to the second, the second to the third, and so on; the last chamber leaks to the environs. For each isotope in each chamber at each time step, the following differential equation is solved:

$$\frac{dN_i^k}{dt} = \lambda_L^{(k-1)} N_i^{(k-1)} + \lambda_R^{(i-1)} N_{(i-1)}^k - \lambda_R^i N_i^k - \lambda_C^k N_i^k - \lambda_L^k N_i^k$$

where: i is the isotope index (i is this isotope; i-1 is the preceding member of this decay chain).

k is the chamber index (k is this chamber; k-1 is the previous chamber).

N is the number of atoms (N_i^k is the number of atoms of this isotope in this chamber).

λ_L is the leak rate from the chamber indicated.

λ_R is the radioactive decay constant for the isotope indicated.

λ_C is the cleanup rate (fallout rate in FFTF) for the chamber indicated. Fallout is not applied to noble gases. Due to the abundance of sodium in this scenario there are no free halogens; consequently, the sodium halides are treated as particulates with respect to fallout and filtration.

A necessary boundary condition is the initial inventory of each isotope in the first chamber. The core inventory library resides on a computer file (see 5.5.3) and a fraction of that inventory is assigned to the first chamber by input. The leak rates are input from files developed by SOFIRE and CACECO and interpolated by TRIMIT. The decay constant for each isotope is furnished by the library and the fallout rate is an input file developed by HAA, and interpolated by TRIMIT.

For convenience, the releases from the "boilup" phase were calculated first. They were then superimposed upon those from the initial HCDA release phase, and finally the potential doses were calculated.

The COMRADEX modeling of the boilup phase considered the reactor vessel/reactor cavity as the first chamber of a two-chamber calculation. At the outset, 99 percent of the volatiles and 620,307 lbs of sodium were assigned to that chamber. The volatile elements are those whose probable chemical form has a substantial vapor fraction at the boiling temperature of sodium; specifically As, Se, Br, Cd, Rb, I and Cs. These were than available to "leak" from Chamber 1 to Chamber 2, the containment building. The leak rate of Chamber 1 was the sodium boiloff rate determined by CACECO and interpolated by the TRIMIT program. TRIMIT performs a "least squares" fit to all CACECO data which are reasonably continuous, but where the data change very rapidly, as at the time of vent, TRIMIT integrates the area under the data curve for three time steps, subtracts the product of the previous ordinate and its time step and assigns the average of the remainder for the next two ordinates. In this manner all leakage is accounted for. Figure 5-10 is an example of the TRIMIT interpolation; a stepwise curve is plotted together with the input data. There is no fallout in the initial chamber; any refluxing had already been accounted for by CACECO.

The arsenic, selenium, and cadmium were assumed to boil off at the same rate as the sodium. For two special groups, rubidium-cesium and bromine-iodine, that leak rate was modified by the program TRIMIT to reflect the characteristics of fission product release from sodium as presented by Castleman.[19] Figure 5-11 shows Castleman's estimate of the fission product releases as a function of sodium vaporization. The rubidium was assumed to be similar to cesium and the constants for cesium were used to modify the Na vaporization source data; this provided a specific representation for cesium, the major contributor of the two, and a good representation for the rubidium. Although no data were presented for sodium bromide, it is expected that it would exhibit much the same characteristics

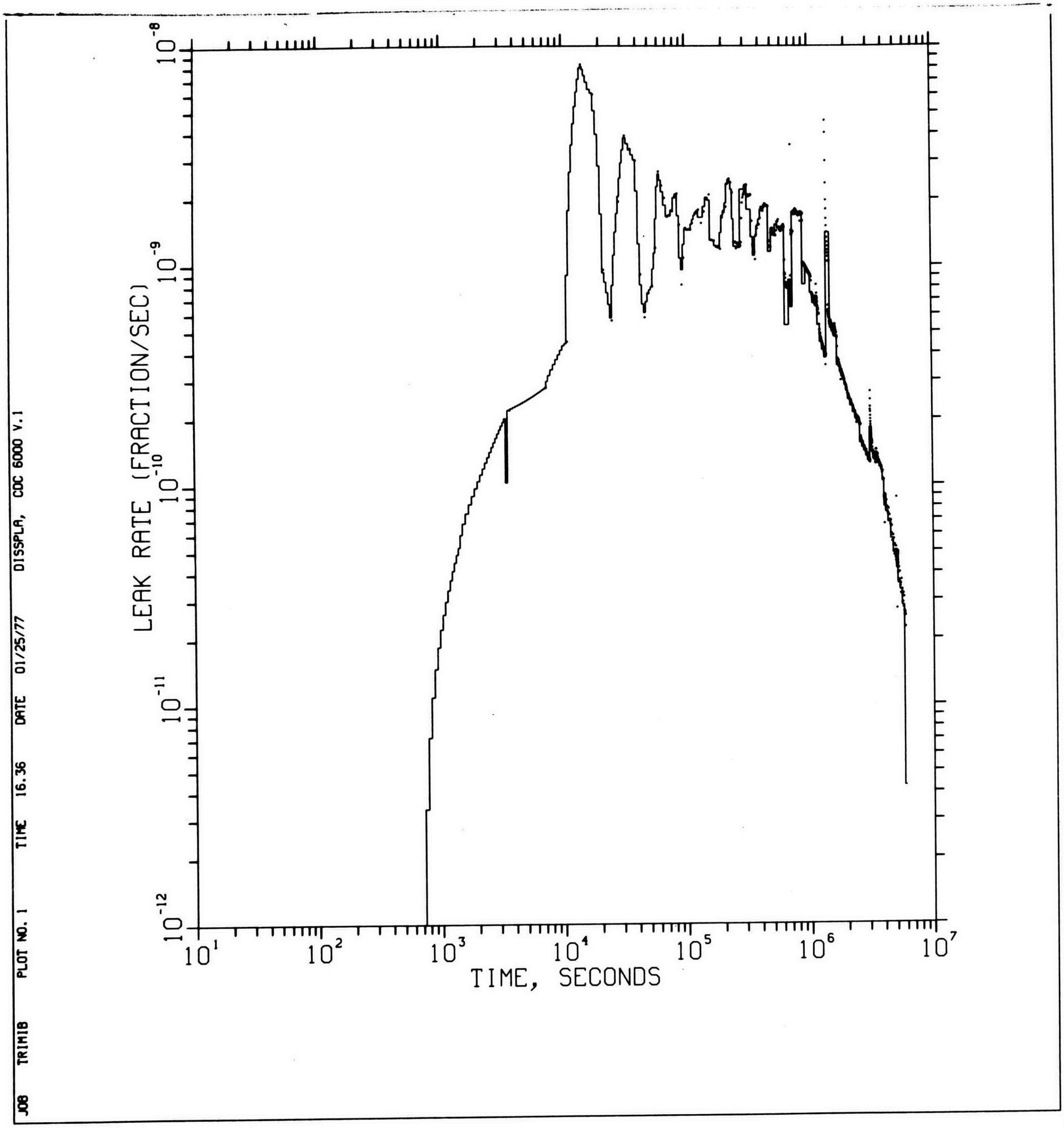

FIGURE 5-10. Case 681 - CACECO Leakrate Data for Reactor Cavity.

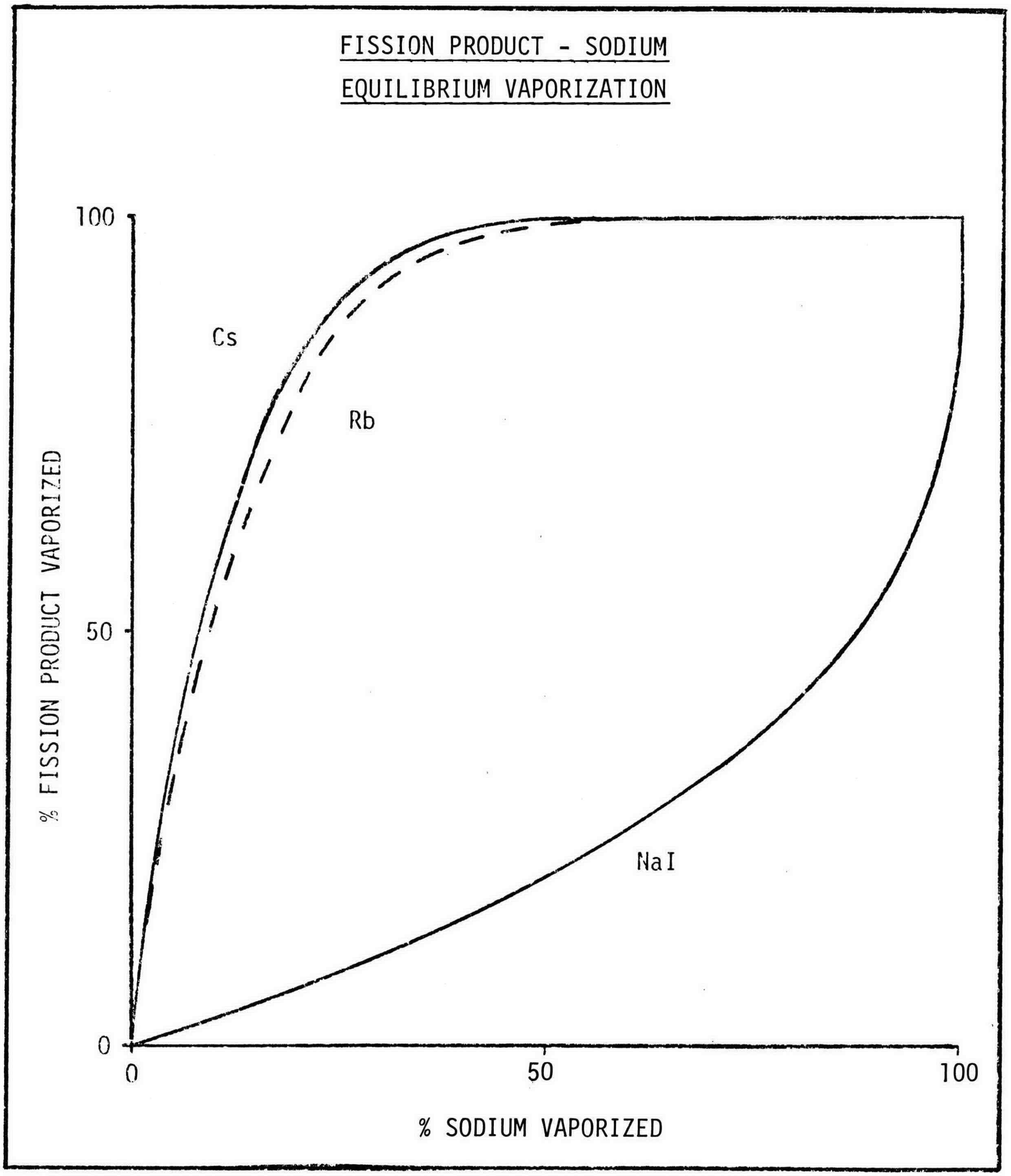

FIGURE 5-11. Fission Product - Sodium Equilibrium Vaporization.

as sodium iodide; therefore, the constants for NaI were used for both. The sodium pool temperature for these calculations was assumed to be a constant 1200°K (1700°F).

The initial pressure in containment was due to the HCDA release; therefore, the leak rate was determined by the SOFIRE calculation for the first several hours then by CACECO for the remainder of the run. The fallout within containment is predicted by HAA-3B. TRIMIT interpolates all these data for COMRADEX. Figures 5-12 and 5-13 illustrate the TRIMIT output of these data.

Utilizing the restart feature, the "CAN" portion of COMRADEX, which computes the release from the containment, was executed three times, once for the Na, As, Se and Cd, once for the Rb and Cs, and once for the halogens. All fission product chains were present in each run but with the initial inventories of the nonvolatile isotopes equal to zero. The release data were accumulated on a source tape. The halogens and noble gases produced within Chamber 1 due to radioactive decay of the volatiles were allowed to escape to Chamber 2 at the cavity leak rate but nonvolatile solids produced by such decay were assumed to precipitate.

The COMRADEX modeling of the initial HCDA phase was done as a single chamber run. The release contained 100 percent of the noble gases, 300 lbs of sodium, and 1 percent of the fuel and fission products as described in Section 5.5.3. The leak rate and fallout rate for the containment building were the same as were used in the boilup phase modeling. The releases from the initial HCDA phase were summed with those from the boilup phases utilizing the restart feature. The plot data for the individual isotopes for the four "CAN" executions were summed by the program ADDEM and building releases plotted by group using the program NUKARF.

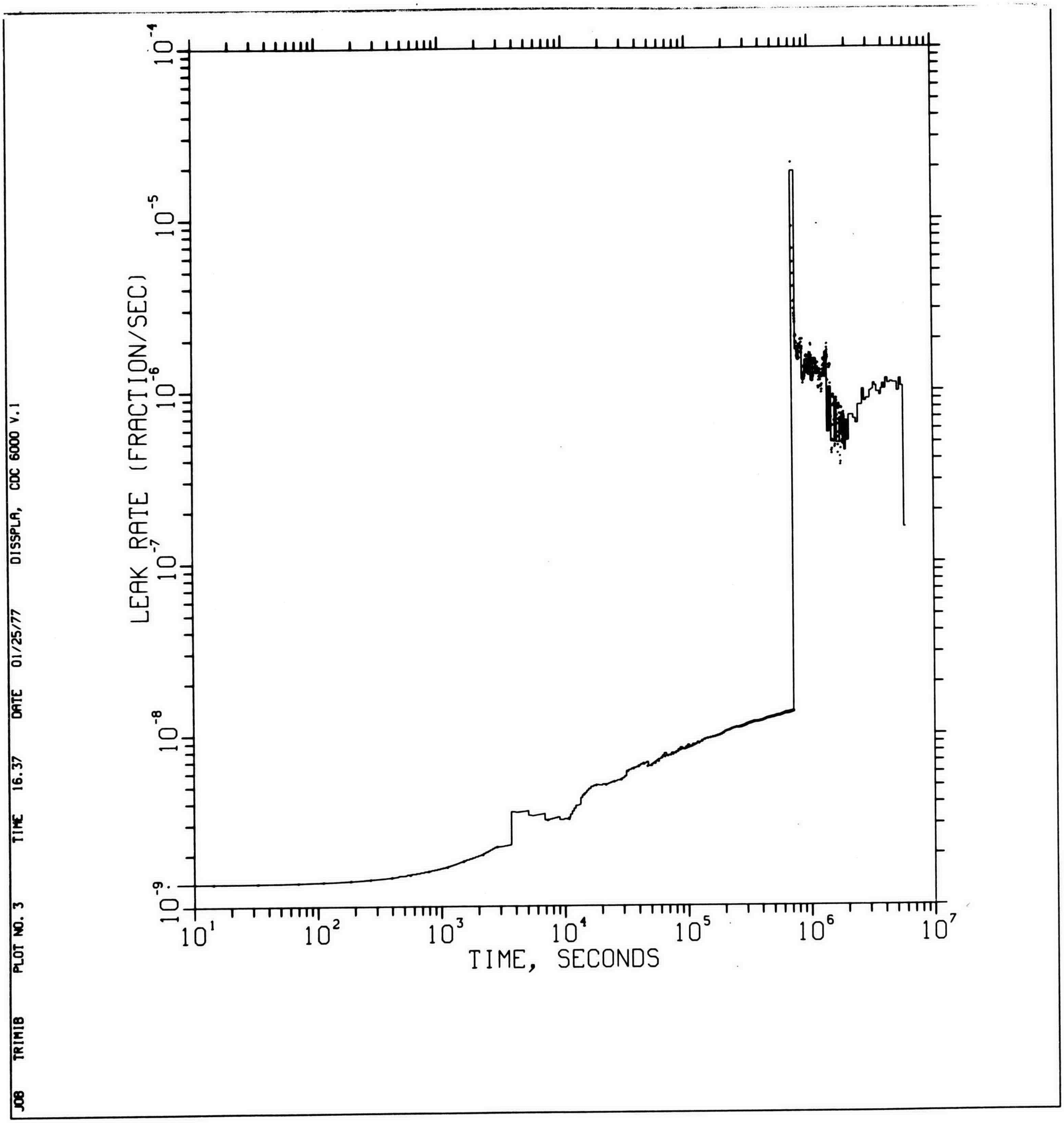

FIGURE 5-12. Case 681 - Leak Rate.

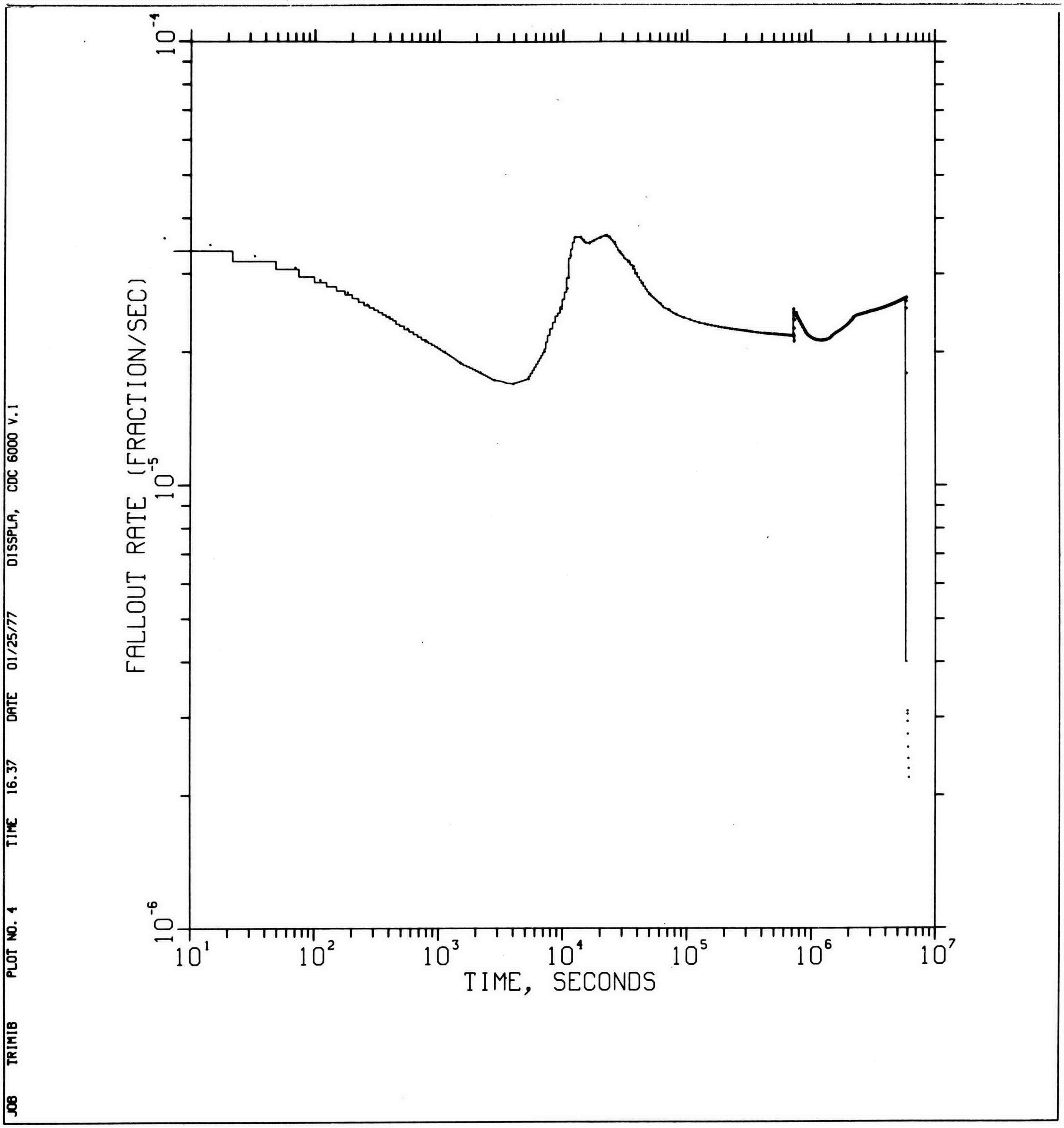

FIGURE 5-13. Case 681 - Fallout Rate.

5.5.2 Radiological Exposure Models

5.5.2.1 Direct Dose

The direct dose model assumed the Containment Building to be a spherical container with the radioactivity uniformly distributed therein. The location of the FTR and the shielding in the reactor head and structures effectively obviate consideration of "Chamber 1" as a source for direct dose. The direct dose was calculated, at each time requested, by summing the products of the airborne activity of each isotope and the gamma value (see Section 5.5.4) for that isotope. This sum was then used as a source in an equation which calculates the resultant dose at requested distances accounting for attenuation by air. The shielding provided by the Containment Building was modeled by a constant multiplier. This constant was calibrated by comparing direct doses from COMRADEX with those from ISOSHIELD.[20]

5.5.2.2 External Dose

The external or cloud dose was calculated from the released radioactivity. An array of downwind distances was generated; for each isotope the decay in transit was calculated and the product of the gamma value and the activity at each of these distances was found. When summed for all isotopes between each of the requested times this product array became the external dose source array.

The plume (cloud) properties were as reported in 5.5.5. The dose at each receptor location was calculated by dividing the plume into X, Y, & Z (downwind, crosswind, and vertical) elements, determining the source within the element, determining the attenuation in air over the distance between the center of the element and the receptor, and finally summing the contributions from all elements. This set of calculations utilized 30 elements in each direction, giving 27,000 elements. The doses at the first requested time (2 hr) were calculated, then the increase in doses between that time and the next requested time (8 hr) are calculated and added to the first. Since the dose increase between times was calculated separately, the meteorological conditions prevalent during that period were used in that calculation.

5.5.2.3 Internal Dose

The internal dose is the dose due to radionuclides accumulated within the body; the mechanism assumed is inhalation of the plume based upon continuous residence at a receptor location from the time of the accident until the time reported.

After the release of each isotope from the Reactor Containment Building had been calculated, the radioisotope decay or production in transit to the various receptor locations was used to modify that data. The quantity of each isotope passing each receptor position between the times of interest was multiplied by each of the F values (see Section 5.5.4) and accumulated in a table of times and potential doses to organs as a function of downwind distances. The dose for each organ at each time and each distance was then found by accumulation of the product of the values in this table and the fraction inhaled. The fraction inhaled was determined using the χ/Q values (see Section 5.5.5) and the breathing rates provided in Regulatory Guide 1.4[21] (i.e., $3.47 \times 10^{-4} m^3/sec$ for the first 8 hours, 1.75×10^{-4} for the remainder of the first 24 hours, and finally 2.32×10^{-4} thereafter).

5.5.2.4 Total Dose

COMRADEX adds the direct, the external, and the "whole body" component of the internal dose to arrive at a "total" dose.

5.5.3 Initial Source Term Model

Just prior to the HCDA the core was assumed to be at the end of equilibrium cycle, at which time it would contain the maximum inventory of radioactive fission products. The fission product inventory was calculated by the RIBD3 code[22] using the ENDF/B-IV[23] fission product file.

The sodium activity was based upon an estimated saturated specific activity of 0.74 μCi/cc for sodium 22 and, for sodium 24, FTR simulation testing in EBR-II: 9.68 mCi/cc[24].

The fuel inventory was also estimated for end-of-equilibrium cycle with the core assumed to have been fueled with LWR recycled plutonium. The fuel was assumed to have waited 7-1/2 years between separation and loading into the FTR, thus allowing decay of Pu 241 to Am 241. The curium and americium inventories were also estimated for the end-of-equilibrium cycle. The core inventory is the composite of all of these and is displayed in Appendix B-1.

5.5.4 Biological Dose Model

After computation of the activity of each isotope which passes each receptor position, the potential doses were calculated using "F" values and gamma values listed in Appendix B-1. The gamma values are used to convert the activity of an isotope to potential direct dose from that isotope. The gamma values are based on the gamma energy released per disintegration[25] and have units of (roentgen-ft^2)/(curie-hour).

"F" values are used to predict internal dose, given the activity of individual isotopes inhaled. The internal dose is due to radionuclides accumulated within the body. The dose is based on a 50-year life expectancy. The "F" values for bone, thyroid, and total body (internal component only) were calculated using the ICRP-II model[26] and were taken from a fission product library tape supplied by Atomics International.[25] All the lung "F" values and the plutonium bone "F" values were calculated at HEDL using the ICRP Task Group Lung Dynamics Model.[27] The bone, thyroid, and total body "F" values for americium and curium are based on the ICRP-II model and were taken from HERMES.[28] "F" values have units of Rem/curie inhaled.

5.5.5 Meteorological Model

The meteorological parameters used were intended to duplicate those of Regulatory Guide 1.4.[21] The standard Pasquill classes were used and the windspeed adjusted so that the χ/Q values would approximate those of the Guide. Table 5-3 compares the Reg. Guide and COMRADEX parameters and Figure 5-14 compares the χ/Q values. Wind meandering is included, based upon the following equation from Reg. Guide 1.4,

$$\frac{\chi}{Q} = \frac{2.032}{\sigma_z u x}$$

Where σ_z = the vertical standard deviation of the plume (meters),
u = windspeed (meters/sec), and
x = distance from point of release to the receptor (meters).

The actual COMRADEX calculations for this study used a windspeed of 1.7 m/sec rather than 3.0 m/sec to compute doses later than four days. This significantly affects the in-vessel cases and ex-vessel Case 683 in which substantial thyroid doses were accumulated after four days. The effect is an overestimation of the 30-day and 68-day thyroid doses by 20-40 percent. This does not alter the conclusions reached in this report.

TABLE 5-3

COMPARISON OF METEOROLOGICAL CONSTANTS

Time Range	REGULATORY GUIDE 1.4 %	Pasquill Class	Wind Speed	Meandering	COMRADEX CALCULATION %	Pasquill Class	Wind Speed	Meandering
0-8 Hr	100	F	1 m/sec	no	100	F	1 m/sec	no
8-24 Hr	100	F	1 m/sec	yes	100	F	1 m/sec	yes
1-4 Days	40	D	3 m/sec	yes	100	E	1.5 m/sec	yes
	60	F	2 m/sec	yes				
4-30 Days or Longer	33.3	C	3 m/sec	yes*	100	D	3 m/sec**	yes*
	33.3	D	3 m/sec	yes*				
	33.3	F	2 m/sec	yes*				

* The Regulatory Guide assumes that the wind is only in a given sector 33% of the time, whereas COMRADEX assumes it remains in that sector and simply meanders.

** 1.7 m/sec actually used - see text.

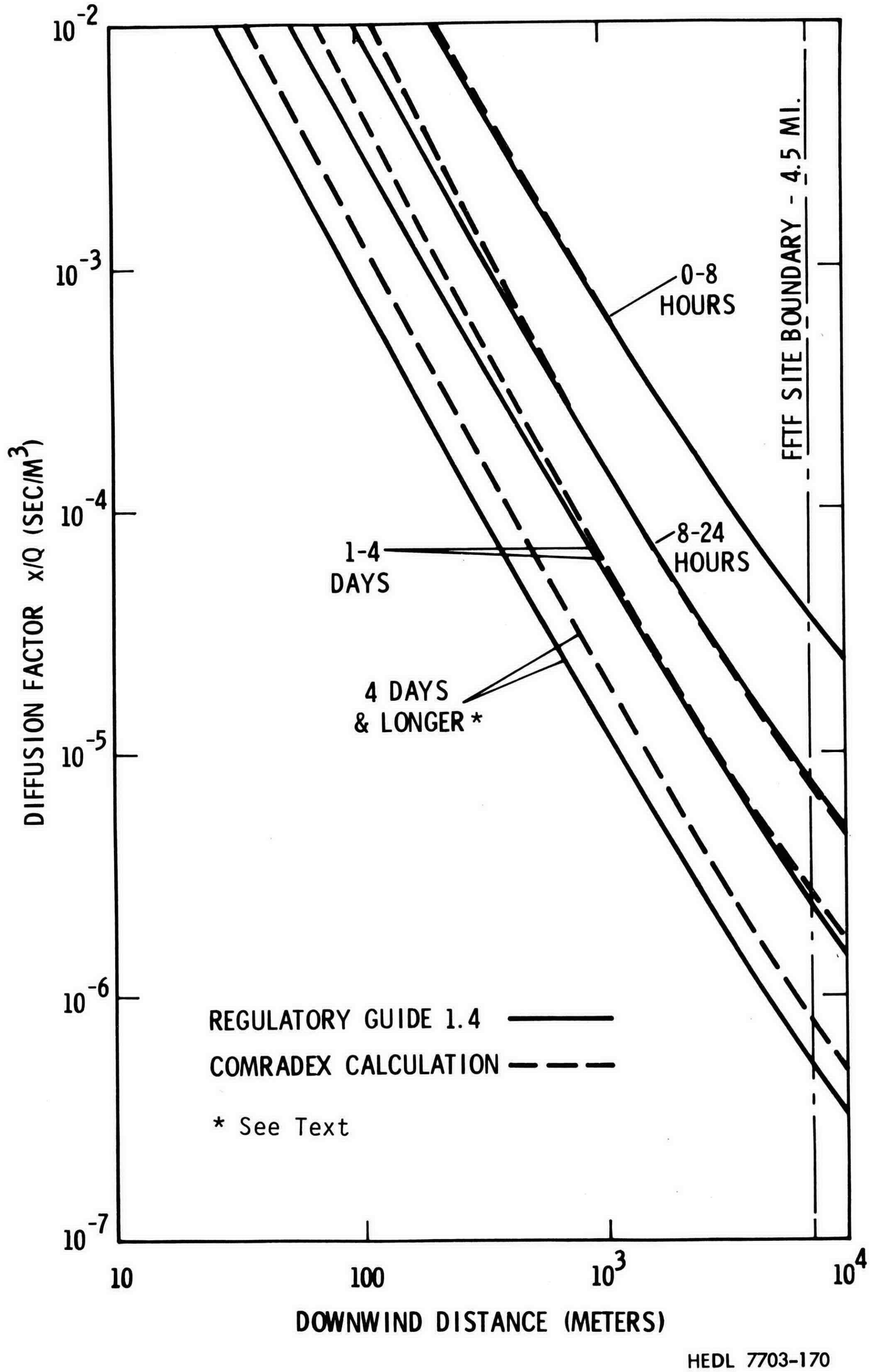

FIGURE 5-14. Comparison of Diffusion Models.

6.0 RESULTS OF ANALYSES

This section presents the results of analyses of cases investigated in this study of containment alternatives. Two cases are discussed in detail, one representative of the in-vessel cases and the other representative of the ex-vessel cases. The remaining cases are discussed at a reduced level of detail aimed at explaining differences relative to the representative cases. The discussions support the information given in the summary section of this report. Additional detailed results are given in appendices to this report.

6.1 Case 654

6.1.1 Containment Transients

This discussion is the first in the series of descriptions of in-vessel cases wherein the core debris remained in the reactor vessel during all (or most) of the sodium boiloff phase of the scenario. The sodium boiled off into the RCB atmosphere, and sodium reactions with oxygen and water vapor heated the atmosphere and generated hydrogen, both of which pressurized the RCB.

Case 654 is a representative in-vessel case, with ventdown and air purge to control the pressure and hydrogen concentration in the RCB. In this case, the natural hydrogen recombination was effective and RCB H&V space coolers were inoperative.

Following the initial HCDA release, the case proceeded with the sodium in the vessel upper layer at 1050°F and heated by nearly 9/10 of the core debris decay power, and with the sodium in the combined middle and lower layers at 980°F and heated by 1/10 of the core decay power. The upper layer heated to the boiling point, 1620°F, in 20 hours and the combined layers heated to the boiling point in 75 hours.

The sodium boiloff heated and pressurized the RCB atmosphere. At 82 hours, as shown in Figure 6-1, the RCB was heated to 633°F and pressurized to 10.0 psig. The sodium-oxygen reaction had reduced the oxygen concentration to 5.8 percent. No free hydrogen had been produced and its concentration was zero. The RCB was vented at 82 hours to relieve the pressure. The ventdown (also called blowdown) to atmosphere pressure was assumed to take one hour (to 83 hours). This ventdown vaporized 10,600 lbs of sodium from the vessel into the RCB, and the sodium consumed all of the remaining oxygen and water vapor, resulting in an inerted hot atmosphere in the RCB. The ventdown effects are shown in Figure 6-1: in the top curve by the sharp rise in temperature from 633°F to 1005°F; in the middle curve by the sharp fall in

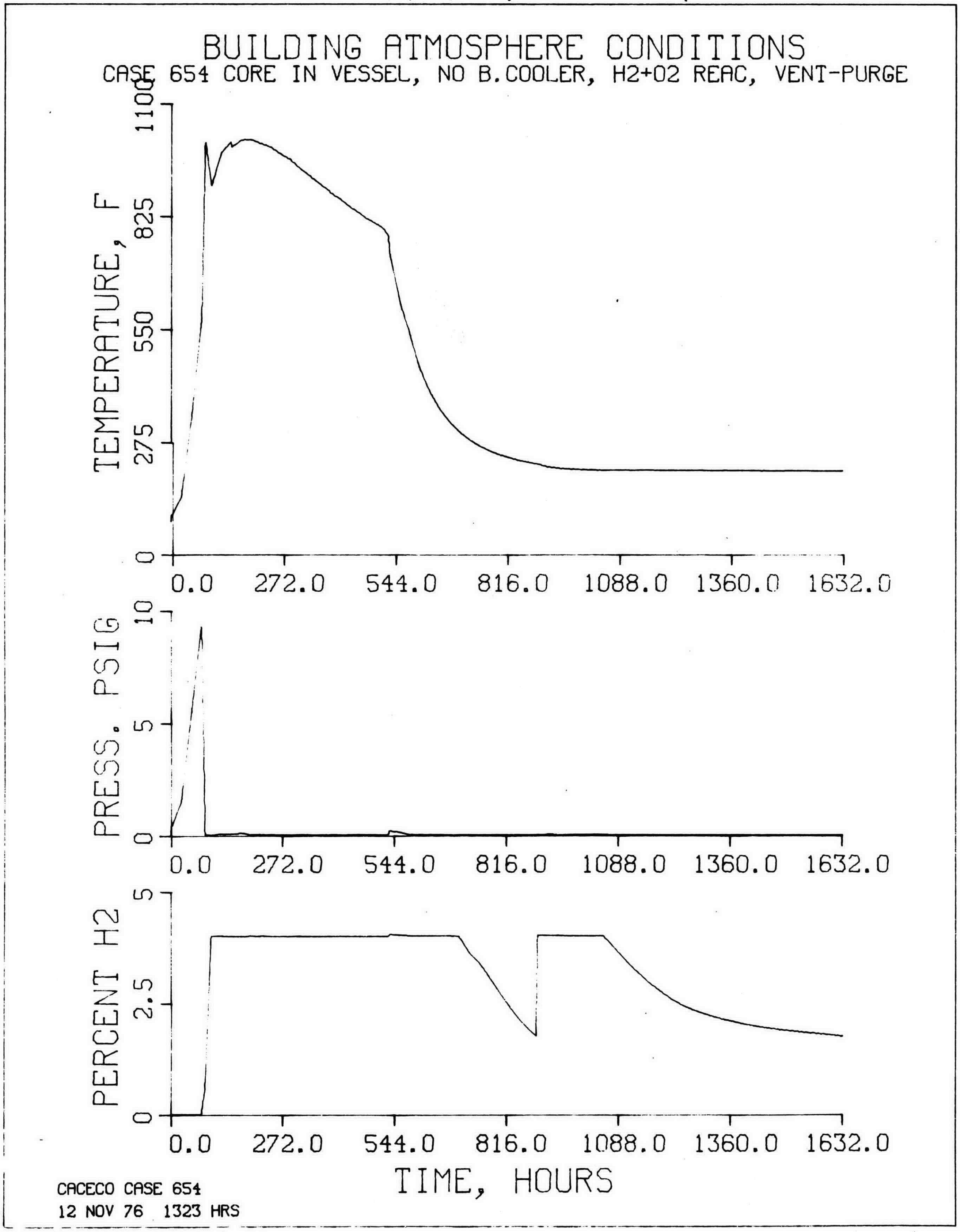

FIGURE 6-1. Case 654 - Building Atmosphere Conditions

pressure from 10 psig to zero; and in the bottom curve by the sharp rise in hydrogen concentration. The ventdown released 52 percent of the RCB atmosphere to the outside at an average vent rate of 28,100 ft^3/min, as shown in Figure 6-2.

The hot RCB atmosphere heated the concrete floor which released water vapor which, in turn, reacted with the sodium oxide deposit and with the sodium vapor from the boiloff. The sodium-water reaction generated more hydrogen. The RCB air purge to control the hydrogen concentration to 4 percent began at 83-84 hours. The fact that the air purge was operative is reflected in the bottom curve of Figure 6-1 by the constant 4.0 percent hydrogen. The RCB vent or exhaust rate, which includes the air purge effect, is shown in Figure 6-2. The RCB vent rate was about 5,000 ft^3/min at 84-91 hours and thereafter decreased to 430 ft^3/min at the end of the sodium boiloff, at 526.5 hours.

The air purge of the RCB, beginning at 83-84 hours, cooled the atmosphere to 782°F as shown in the curve at the top of Figure 6-1. The sodium boiloff reactions with purge air heated the RCB again to the maximum value of 1015°F at 185-189 hours. During this time of maximum temperature, the RCB roof steel reached its maximum value of 820°F. Thereafter, as the decay power decreased, the sodium boiloff rate decreased and the RCB temperature decreased to 786°F at the end of the sodium boiloff (526.5 hours).

A feature of the air purge during the sodium boiloff to 526.5 hours was an apparent "lock step" of oxygen and water vapor concentrations. These concentrations rose to a maximum of 12 percent at 110 hours, decreased to zero at 360 hours and then rose again. The oxygen and water vapor have separate sources: the oxygen from the air purge and the water vapor from heating the concrete floor. That is, the hot atmosphere heated the concrete floor, driving water vapor out, through the sodium oxide-sodium hydroxide deposit, into the atmosphere. The water vapor reaction with sodium vapor was the source of hydrogen. The air purge that introduced oxygen was regulated to limit hydrogen to 4 percent concentration. The analysis used the

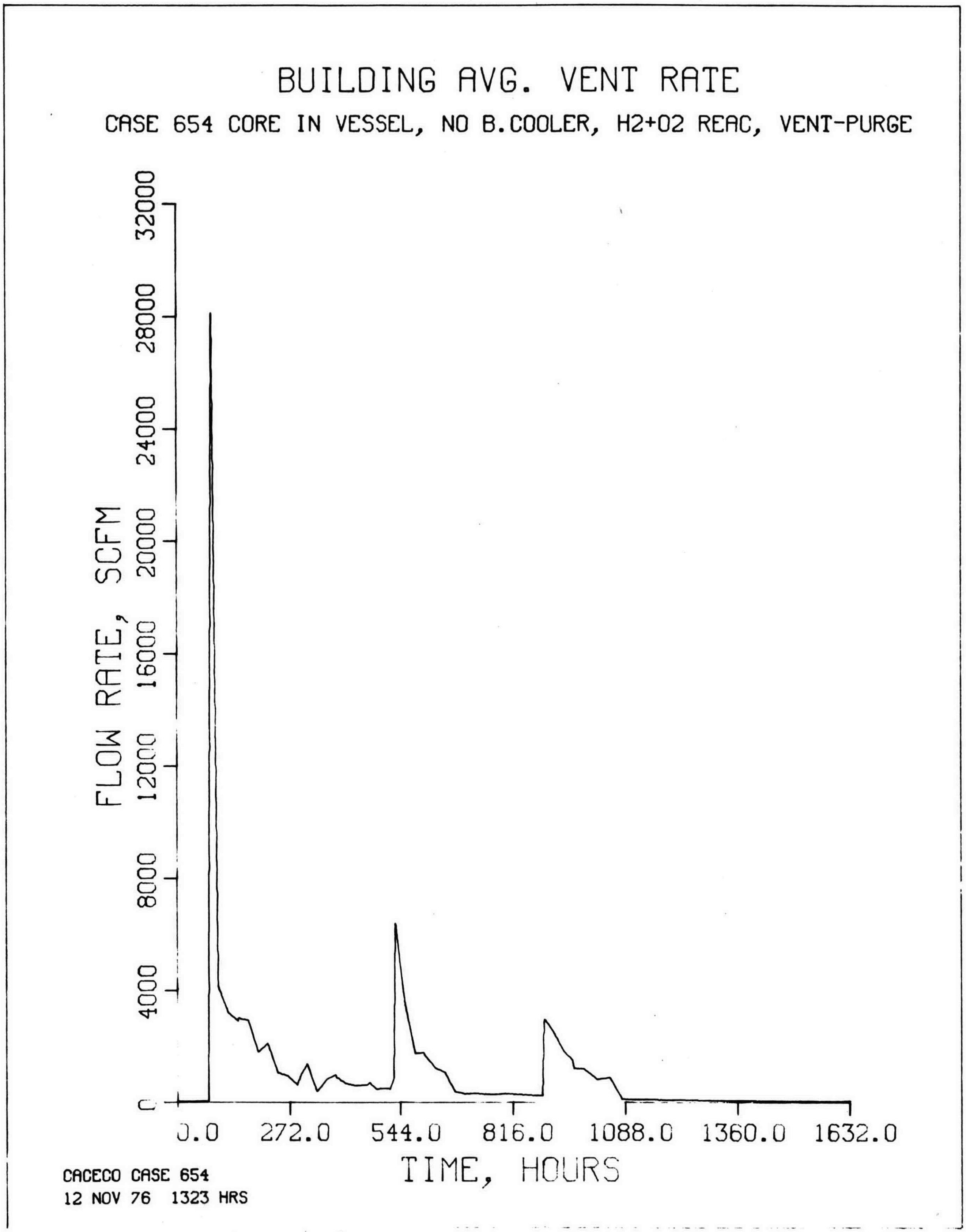

FIGURE 6-2. Case 654 - Building Average Vent Rate.

experimental observation from the HEDL hydrogen recombination tests[12] that the sodium does not react with water vapor unless the water concentration is greater than the oxygen concentration. This experimental observation was the restriction that regulated the water vapor concentration (the source of hydrogen) to the same value (and a bit more) as the oxygen concentration (the purge of hydrogen) during this boiloff phase of all in-vessel cases.

The in-vessel case assumed, following the boil-dry time, that the core debris would melt through the bottoms of the reactor and guard vessels onto the floor of the reactor cavity. The transient temperatures and disposition of the core debris were the subject of AYER code analysis which is discussed later. The CACECO code analysis was continued past the boil-dry time in order to predict the ensuing RCB conditions. This CACECO analysis assumed a pool of molten stainless steel at 2600°F on the floor of the cavity. This pool radiated heat energy to the floor and surrounding cavity walls. The stainless steel reacted with water vapor released from the floor concrete. The hydrogen which was produced from this reaction was limited by the RCB air purge.

In Case 654, from 536.5 hours to 888 hours, the 2600°F source simulated the core debris attack into the cavity floor. This source heated the concrete floor, driving off water vapor which reacted with the 114,000 lbs of stainless steel associated with the debris. At first, the water release rate and hydrogen production rate were rapid and the required air purge was reflected in Figure 6-2 by the sharp jump in vent rate to more than 6,400 ft^3/min at 537-543 hours. The cessation of the sodium boiloff permitted the RCB to cool off as shown in the top curve of Figure 6-1 by the temperature decrease following 526.5 hours. Again, the fact that the air purge was operative is shown in the bottom curve of Figure 6-1 by the constant 4.0 percent hydrogen. The water release from the cavity floor decreased with time, and the associated hydrogen production, air purge, and vent decreased, also. At 700 hours, the air purge ceased because hydrogen was limited sufficiently by water vapor from the RCB floor and

H&V cooler room. By 888 hours, as shown in the top curve of Figure 6-1, the RCB temperature was 220°F, in the bottom curve of Figure 6-1, the hydrogen concentration was 1.8 percent, and the oxygen and water vapor concentrations were 1.3 and 92 percent, respectively. On Figure 6-2, the vent rate was 200 ft^3/min. The water release from the cavity floor had consumed 52 percent of the stainless steel associated with core debris.

Based on an AYER calculation, discussed later, the core debris would melt into the cavity floor and cause it to collapse after about 360 hours (888 hours from HCDA). The collapse spilled the core and concrete debris from the floor into the subcavity. The CACECO code analysis was continued past this floor collapse time, still using the 2600°F source to simulate the heating caused by the fuel and floor debris, and continued to react stainless steel and water vapor to produce hydrogen.

In Case 654 following 888 hours, the 2600°F source was used to compute the heating of the subcavity walls and floor, and the water release rate. Again, at first the water release rate and hydrogen production rate were rapid, as shown in the bottom curve of Figure 6-1 by the sharp jump in hydrogen concentration at 888 hours. The hydrogen concentration control at 4 percent denotes air purge operation which is reflected by the jump in vent rate on Figure 6-2 to more than 3,000 ft^3/min at 888 hours. The water release from the subcavity walls and floor decreased with time, as did the associated hydrogen production, air purge, and vent. At 1,056 hours, the stainless steel was consumed and the associated hydrogen production, air purge, and vent ceased. Thereafter, as shown in the bottom curve of Figure 6-1, the hydrogen concentration was lowered by the accumulation of water vapor released from the RCB floor, the H&V cooler room, cavity and subcavity walls, and the subcavity floor.

Since temperatures, pressure, and other significant factors were decreasing or stable, the CACECO analyses of all cases stopped at the arbitrary time of 1,632 hours, which is 68 days after the HCDA. At 1,632 hours for Case 654, the RCB temperature was 203°F, as shown in the top curve of Figure

6-1, the pressure was atmospheric, as shown in the middle curve of Figure 6-1, and the hydrogen concentration was 1.7 percent, as shown in the bottom curve of Figure 6-1. This RCB atmosphere had 7.7 percent oxygen and 61.6 percent water vapor. Its vent rate was 12-16 ft^3/min as water vapor continued to be driven out of the concrete of the cavity and subcavity.

The AYER code analysis of Case 654 started at 527 hours with the core debris spilled onto the 346 ft^2 cavity floor under the reactor vessel. The initial conditions for the AYER analysis were arbitrarily set with the fuel debris at its melting point (5160°F). A more realistic temperature would have been that of molten steel (2600°F). Even with the conservative assumption of molten fuel, the core debris, when spilled onto the 260°F cavity floor, chilled quickly to about 1500°F, shown as the initial point in Figure 6-3 at 527 hours. This debris subsequently heated and melted into the firebrick, insulating brick, and basalt concrete of the cavity floor, forming a molten concrete-pool. The pool size increased by melting sideways and downward into the basalt concrete (melting point taken at 2100°F) until, at 890 hours, the fuel-concrete pool had melted through 33 inches of the 39-inch-thick floor. The average pool temperature increased during this phase to 2620°F, as shown in Figure 6-3. At 890 hours, the cavity floor was assumed to collapse, spilling the fuel-concrete pool into the subcavity.

The AYER analysis was restarted at 890 hours with the concrete-fuel pool on the floor of the subcavity. The pool at 2620°F, spilled onto the 123°F subcavity floor, chilled quickly to about 2580°F, as shown in Figure 6-3 at 890 hours. The AYER analysis indicated a pool surface temperature of 2100°F (nominal melting point of basalt concrete) after the stainless steel had been consumed by the steel-water reaction. The average pool temperature increased to a maximum of 3000°F at 2,000 hours (83 days) and then decreased as the pool continued to grow. At 6,850 hours (285 days), the average pool temperature had decreased to 2320°F, as shown in Figure 6-3, when the pool volume attained its maximum size of 1,500 ft^3. Also at this time the pool reached its maximum penetration of about 7 feet below

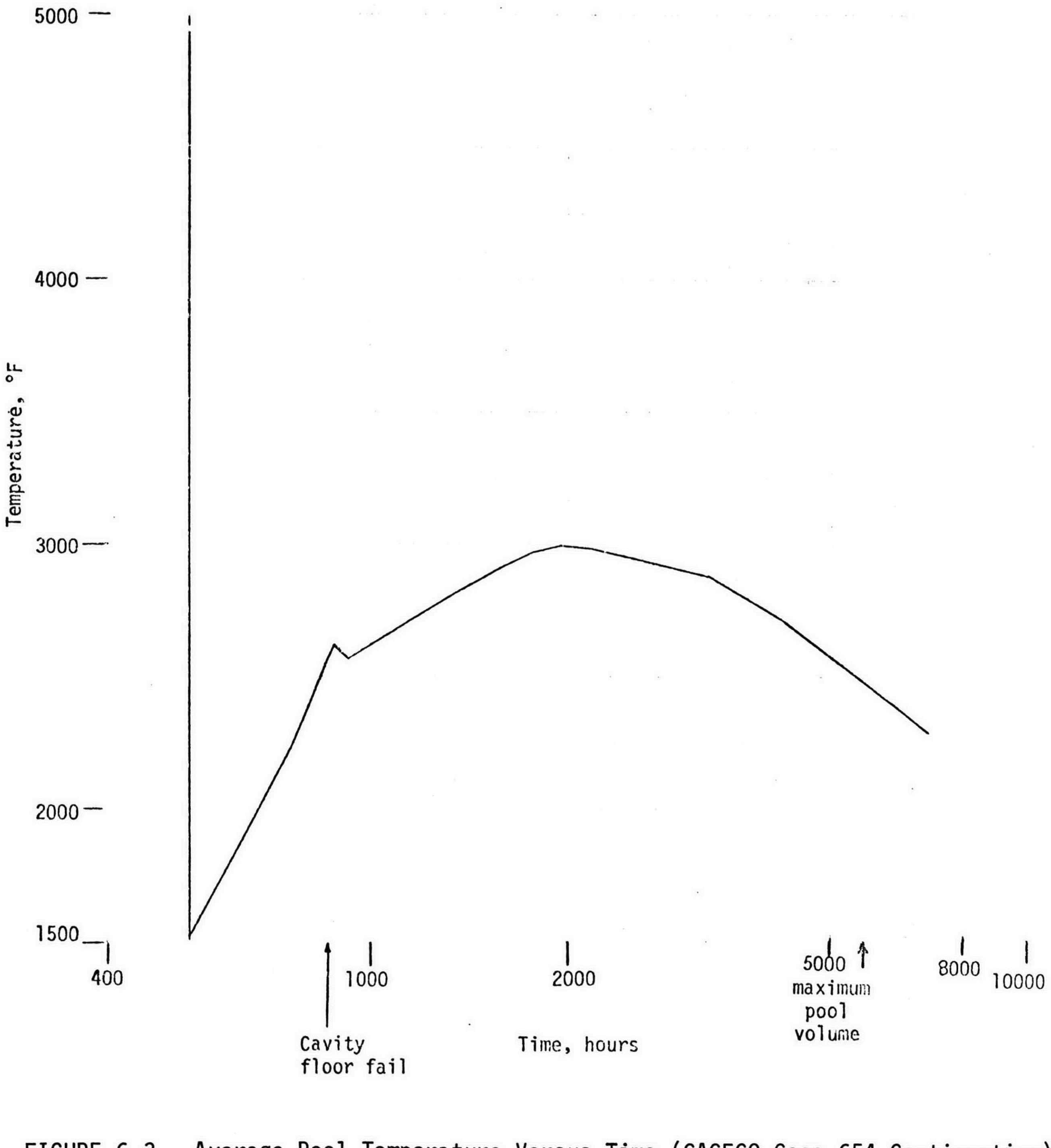

FIGURE 6-3. Average Pool Temperature Versus Time (CACECO Case 654 Continuation).

the former surface of the subcavity floor. This penetration distance would place the fuel-concrete debris at the bottom of the concrete base under the containment vessel of the RCB, at elevation 467 feet.

6.1.2 Radiological Evaluation

The radiological evaluation is based on the rate of sodium oxide aerosol formation and the RCB leak rate as determined in the foregoing CACECO calculations. In addition to considering the noble gas release, the radiological evaluation was based on the physical processes (suspension, deposition, and release) which affect radioactive aerosols. Aerosol depletion was computed with the HAA-3B code as described in Section 5. Figure 6-4 shows the RCB aerosol concentration vs. time due to the HCDA and the reactor vessel sodium boilup. The initial concentration of ~2 μg/cc was due to the HCDA sodium spray into the head compartment as discussed in Section 5. Further out in time, as the aerosol concentration increased, the suspended fuel concentration decreased, since sodium oxide was the only important input to the RCB atmosphere. The aerosol concentration curve followed that for the initial release for several hours, then increased to ~20 μg/cc as sodium boilup from the vessel became significant. At 82 hours the RCB vented and the aerosol concentration surged to 60 μg/cc due to sodium flashing. The aerosol concentration returned to ~30 μg/cc, and subsequently decreased gradually to 15 μg/cc at 526.5 hours, when the reactor vessel boiled dry of sodium. The aerosol concentration then dropped rapidly and was down to .042 μg/cc at 550 hours.

COMRADEX calculated the release of radioactivity from containment and then the potential doses resulting from the release. The integrated releases are presented by group curves in Figure 6-5. The slope of the noble gas curve increases at 25 hours as the increasing pressure causes an increased RCB leak rate, then increases sharply at the 82 hours vent time; all noble gases are exhausted from containment shortly thereafter. "All

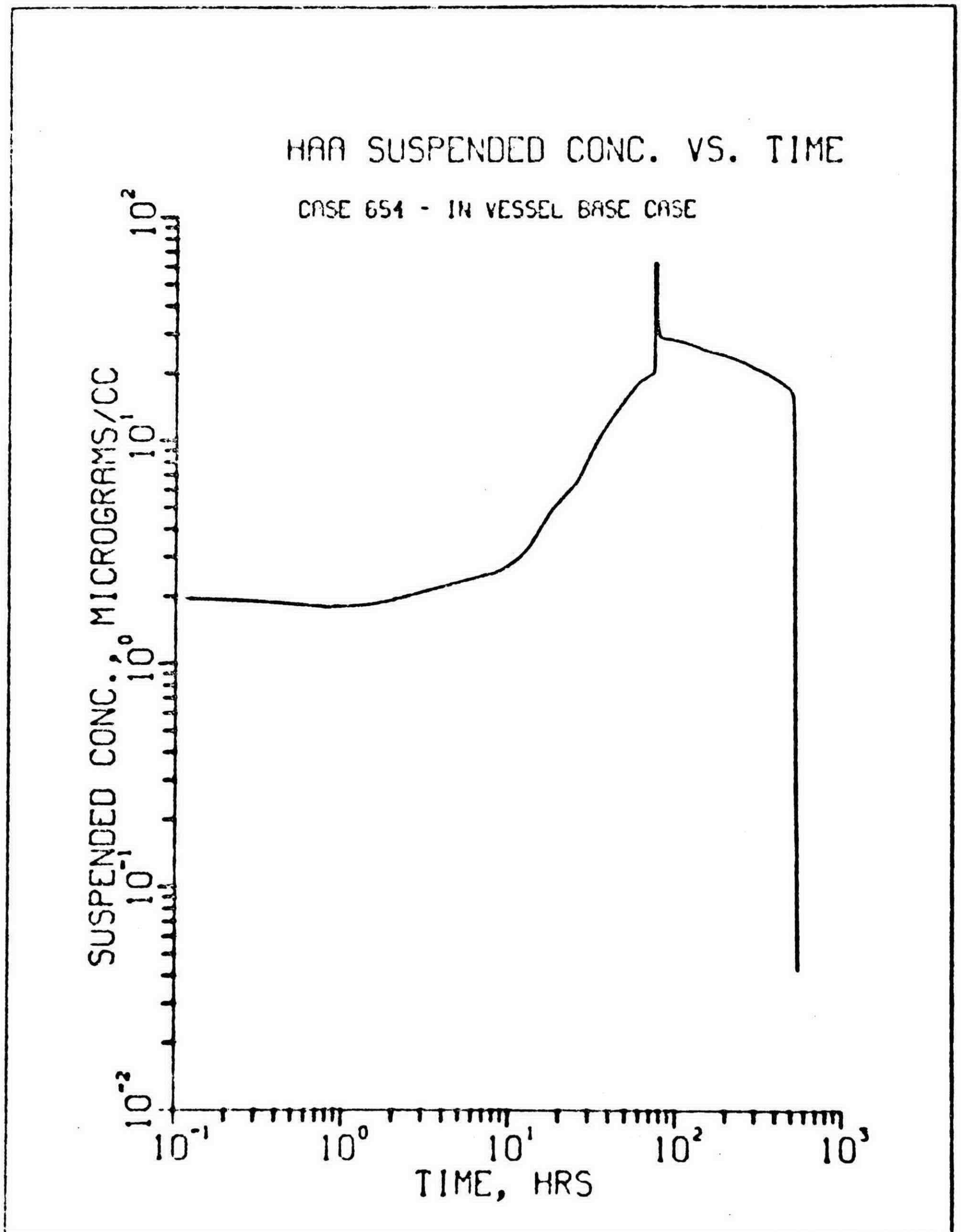

FIGURE 6-4. Case 654 - HAA Suspended Conc. Vs. Time.

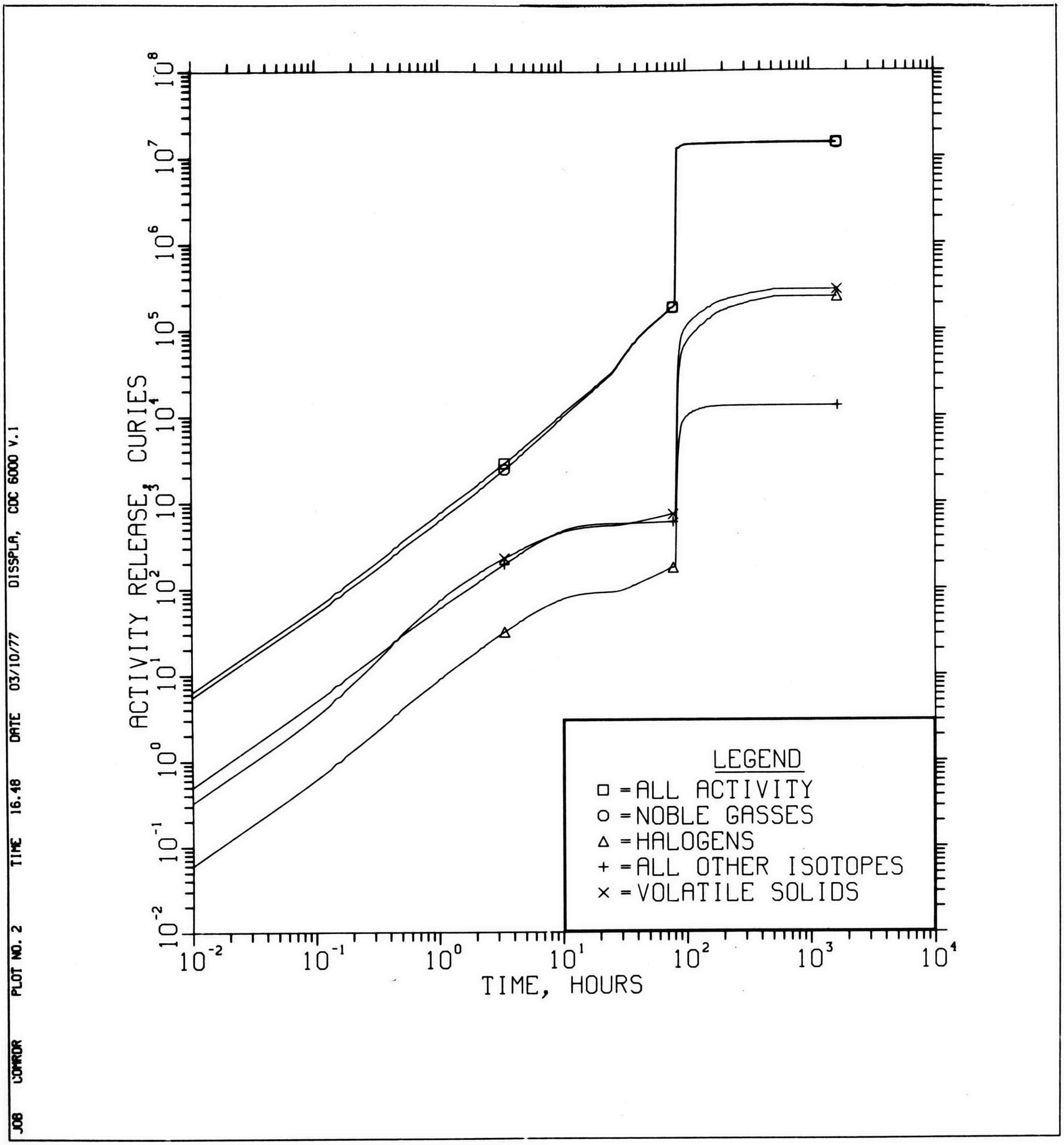

FIGURE 6-5. Case 654 - Activity Release Curves.

other isotopes" are chiefly solids, volatiles, and halogens; this curve exhibits much the same characteristics as the noble gas curve, except it begins to level out at about 15 hours due to deposition and decay of the solid material released in the initial HCDA puff phase. The continued rise in the release of "all other isotopes" after the vent is due to release of solids formed as daughters of the volatiles. Noble gases are also formed by decay of volatiles but the effect is not apparent since the noble gas release curve is approximately three orders of magnitude higher. The release of halogens is similar until after the vent, when it continues to rise as halogens are released from the reactor until shortly after the reactor boils dry. The volatile solids include the halogens. The volatile solids curve is essentially parallel to the halogen curve except that between 0.2 and 6 hours the effect of the early release of cesium and rubidium, predicted by Castleman, may be seen as an increase in the volatile solid curve relative to the halogen curve.

Figure 6-6 shows the 30-day dose for various organs as a function of distance from the containment vessel. The 30-day doses are almost identical to the 68-day doses for this case. The site boundary is at 4-1/2 miles (7,242 m); it is significant that the whole-body, bone, and lung doses are very low. The most significant dose is to the thyroid, and this dose is less than half the guideline value of 10 CFR 100. Doses at other distances of interest may be determined from this curve, e.g., the edge of the nearest population center, Richland, is about 8 miles distant (13,000 m), where the thyroid dose would be approximately 50 Rem. The shape of the whole-body curve is explained by Figure 6-7; close to the vessel the direct dose is the major component; at about 1/2 mile (803 m) the internal component gains predominance. The external or cloud dose is never of significance in this case.

Potential radioactivity release following the sodium boil-dry time was considered, as discussed in Appenidx D. It was concluded that releases in the post-boiloff period would not dominate hypothetical accident consequences.

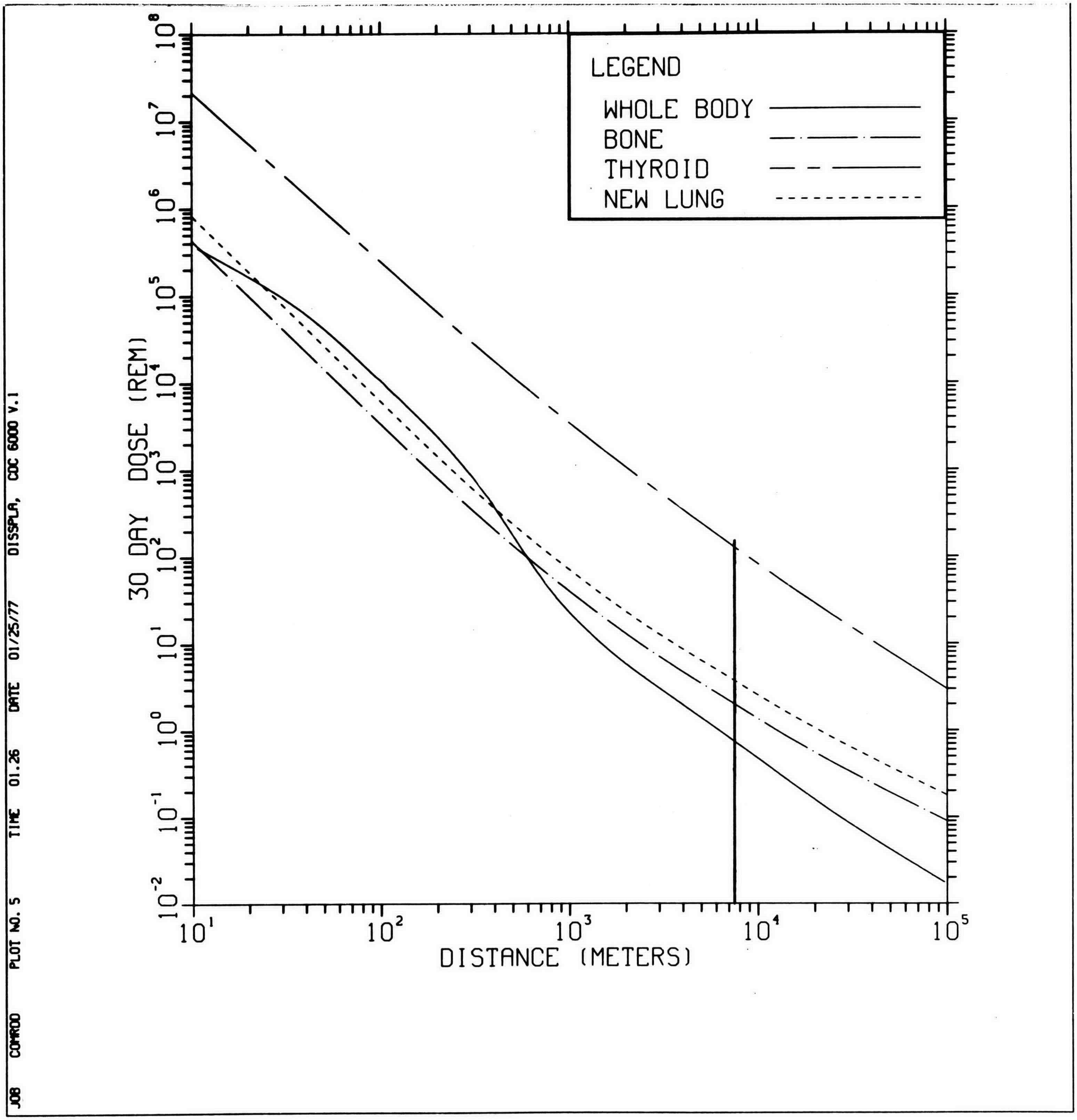

FIGURE 6-6. Case 654 - Dose vs. Distance Curves.

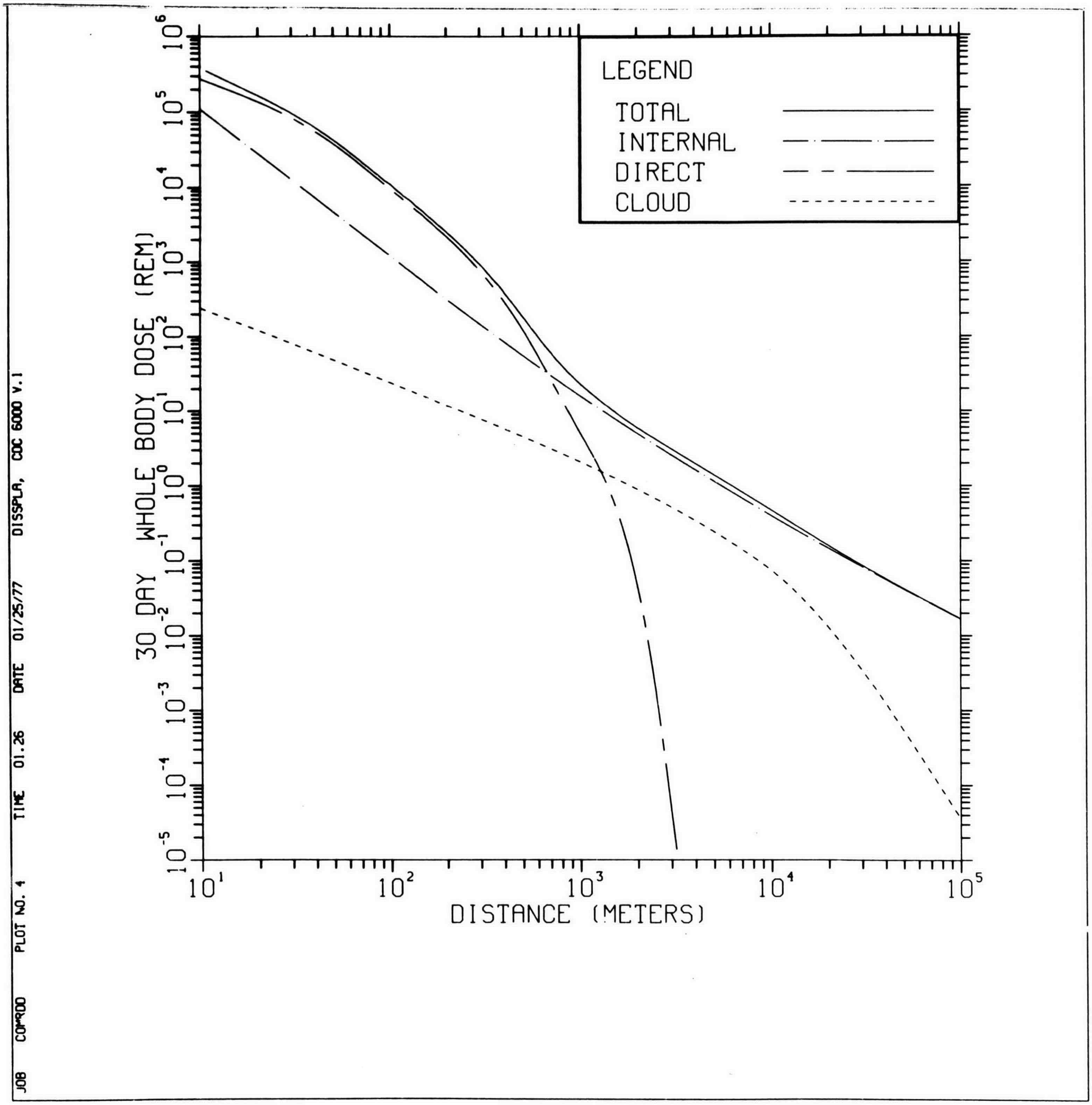

FIGURE 6-7. Case 654 - Dose vs. Distance Curves.

6.2 Case 655

6.2.1 Containment Transients

The RCB conditions for Case 655 are shown in Figures 6-8 and 6-9. Up to 384 hours, the interpretation of these Case 655 figures is identical to that of Case 654 (Figures 6-1 and 6-2). During this time, the source rate input from sodium oxide and fission products (and the resulting suspended concentration of sodium oxide and fission products) were also similar to those of Case 654. The curves which present these results are shown in Appendix B.

At 384 hours, Case 655 departed from Case 654 in that the reactor vessel support arms fail. This support arm failure dropped the reactor vessel into the guard vessel and the reactor cavity floor, and was assumed to cause failure of the vessels, so that 126,000 lbs of boiling sodium spilled into the reactor cavity. The spill of sodium and associated core debris was assumed to fail the floor liner under the reactor vessel, and the floor liner failure permitted a reaction between the sodium-concrete over 1,190 ft^2 of floor and wall area. The sodium-concrete reaction stopped in four hours but the associated sodium-water reaction continued and produced hydrogen which was controlled by the RCB air purge.

At the time of the sodium spill (384 hrs) the source rate input decreased, as a result of the termination of sodium boiloff. This occurred because of increased heat transfer to the structural materials. The suspended concentration of sodium oxide and fission products was also reduced.

A characteristic of the Case 655 air purge following the vessel failure at 384 hours was the cycle of hydrogen concentrations: rapid recombination to zero percent, accumulation, air purge at the 4 percent limit, and rapid recombination to zero again, repeatedly. These cycles were caused by the code requirement for 11 percent oxygen concentration to initiate the hydrogen-oxygen

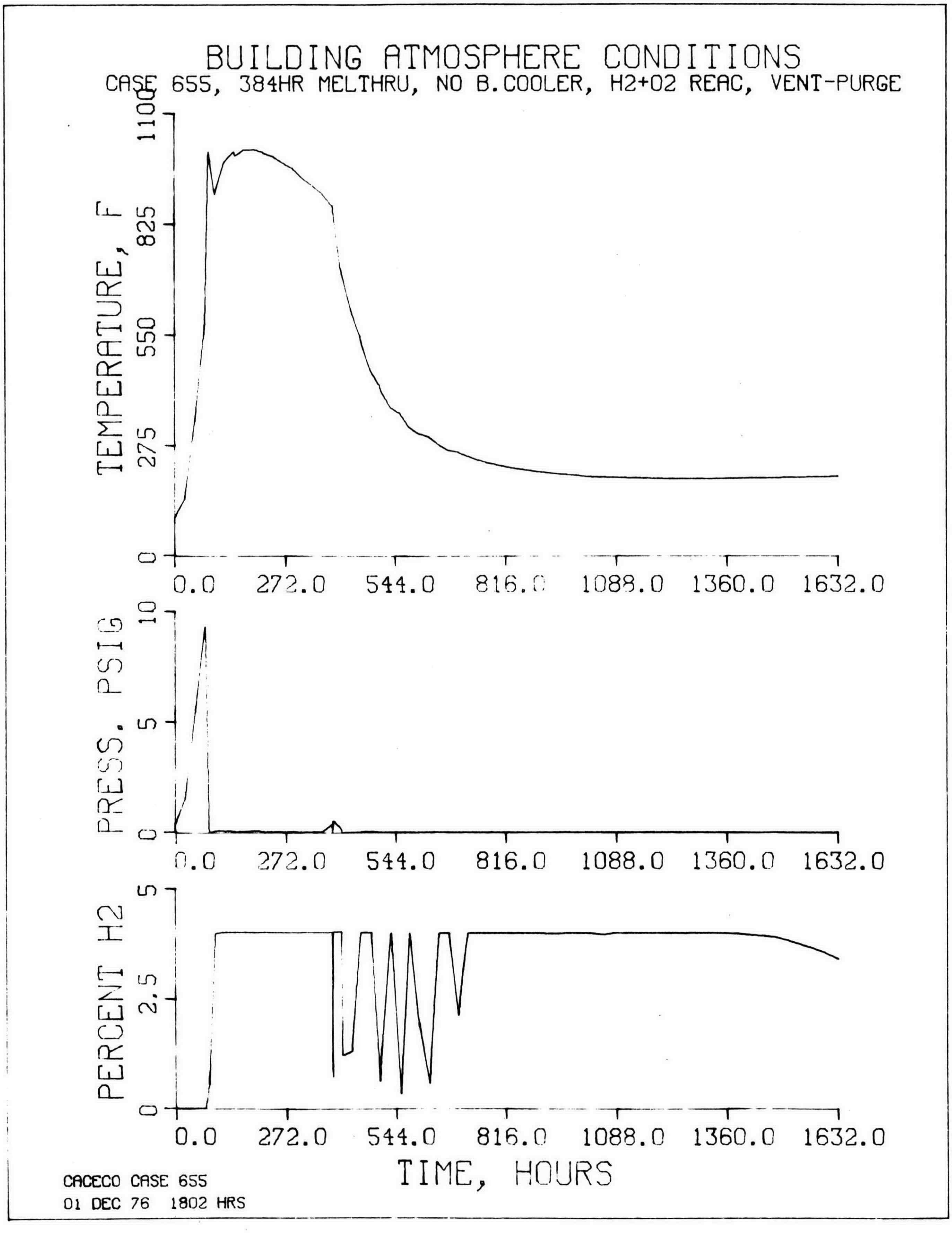

FIGURE 6-8. Case 655 - Building Atmosphere Conditions.

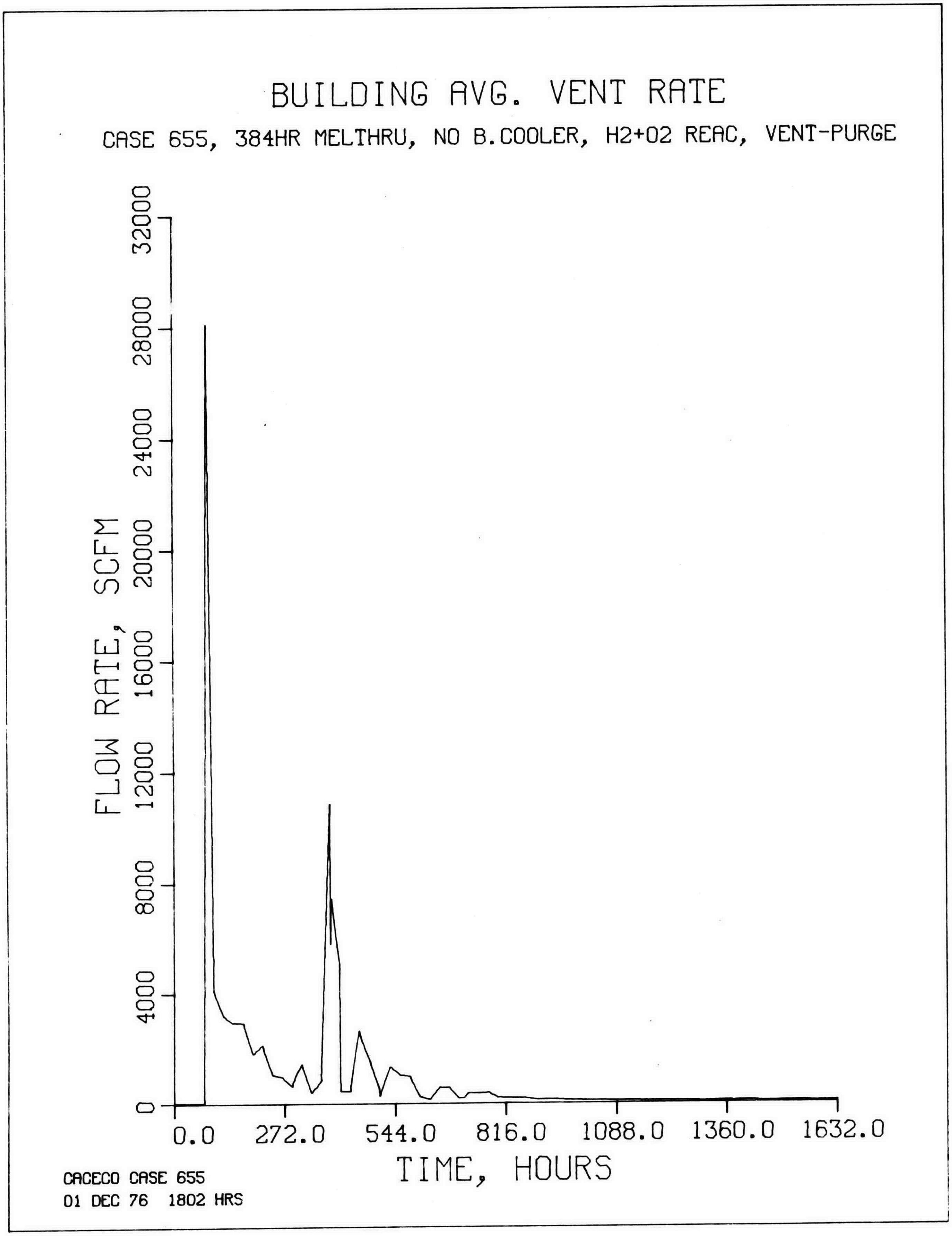

FIGURE 6-9. Case 655 - Building Avg. Vent Rate.

(recombination) reaction.[12] These hydrogen recombination cycles caused the irregular pattern of hydrogen concentrations shown in the bottom curve of Figure 6-8, beginning at 384 hours, and the irregular vent rates shown on Figure 6-9.

Hydrogen accumulated until 388 hours, when the air purge was renewed, which increased the oxygen concentration so that the hydrogen recombined again at 388-389 hours. Between 384 and 700 hours the hydrogen recombined 17 times, beginning with 3-hour cycles and ending with 44-hour cycles.

Heat losses into the walls and floor of the reactor cavity cooled the boiling (1620°F) sodium spill to 1490°F. The sodium-concrete reaction reheated the sodium pool to 1549°F at 388 hours. Then the pool cooled to its minimum of 1170°F at 419 hours before reheating to 1289°F at the end of the case at 1,632 hours. Sodium boiloff ceased effectively at 388 hours and the RCB temperature dropped as shown in the top curve of Figure 6-8.

Between 700 and 1,200 hours, steam release from the cavity walls contributed to the air purge in limiting the hydrogen concentration to 4 percent. The air purge ceased at about 1,200 hours and the steam release diluted the hydrogen concentration to 3.4 percent at 1,632 hours as shown at the bottom of Figure 6-8.

6.2.2 Radiological Evaluation

Figures 6-10 and 6-11 present the "Release of Activity" and the "Dose as a Function of Distance" curves for Case 655. The shape of these curves is similar to those of Case 654 and the previous explanation for the behavior of the Case 654 is appropriate for Case 655 as well. The failure of the reactor and guard vessels and the failure of the cavity liners added to the resultant doses only slightly.

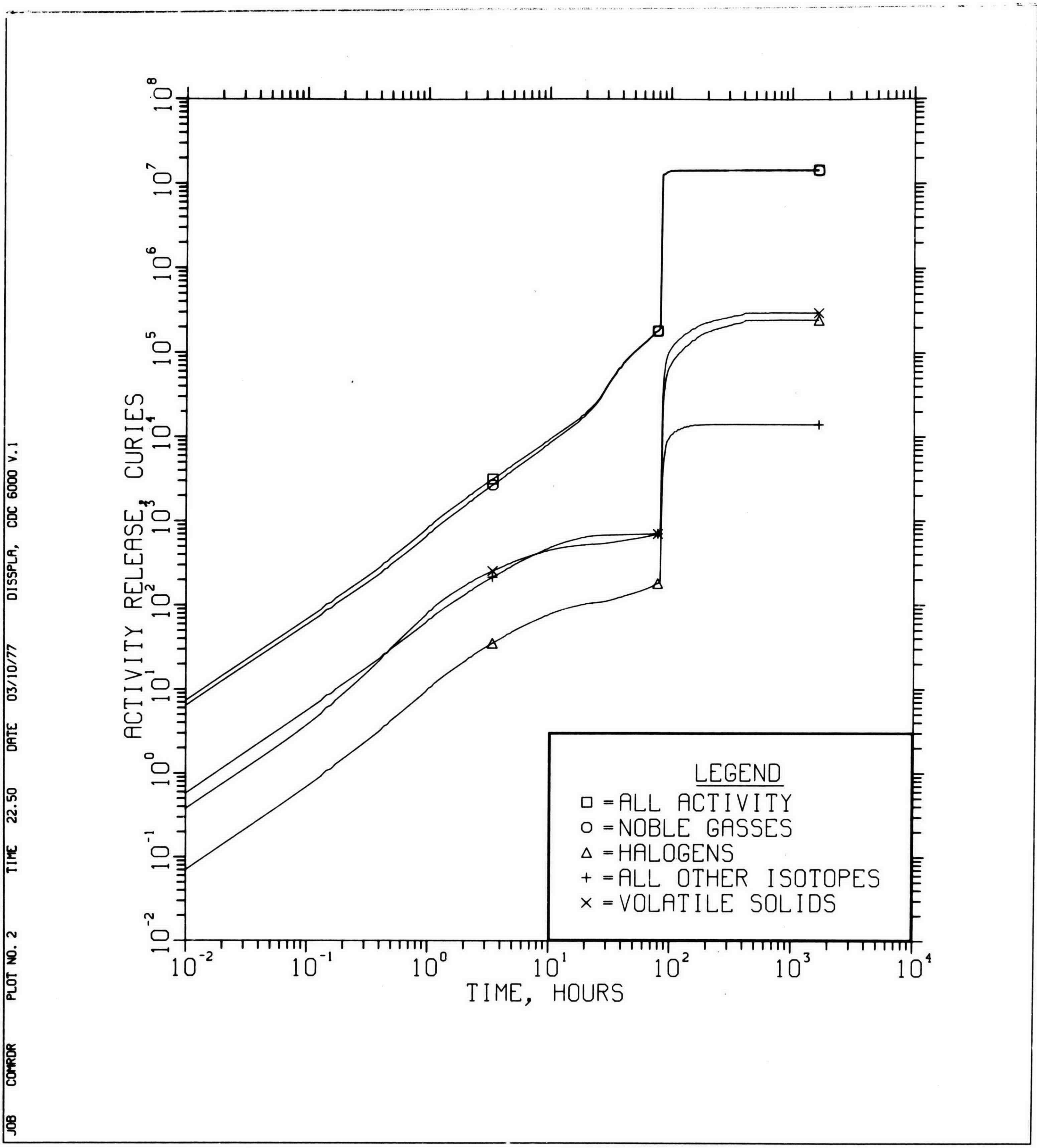

FIGURE 6-10. Case 655 - Activity Release Curves.

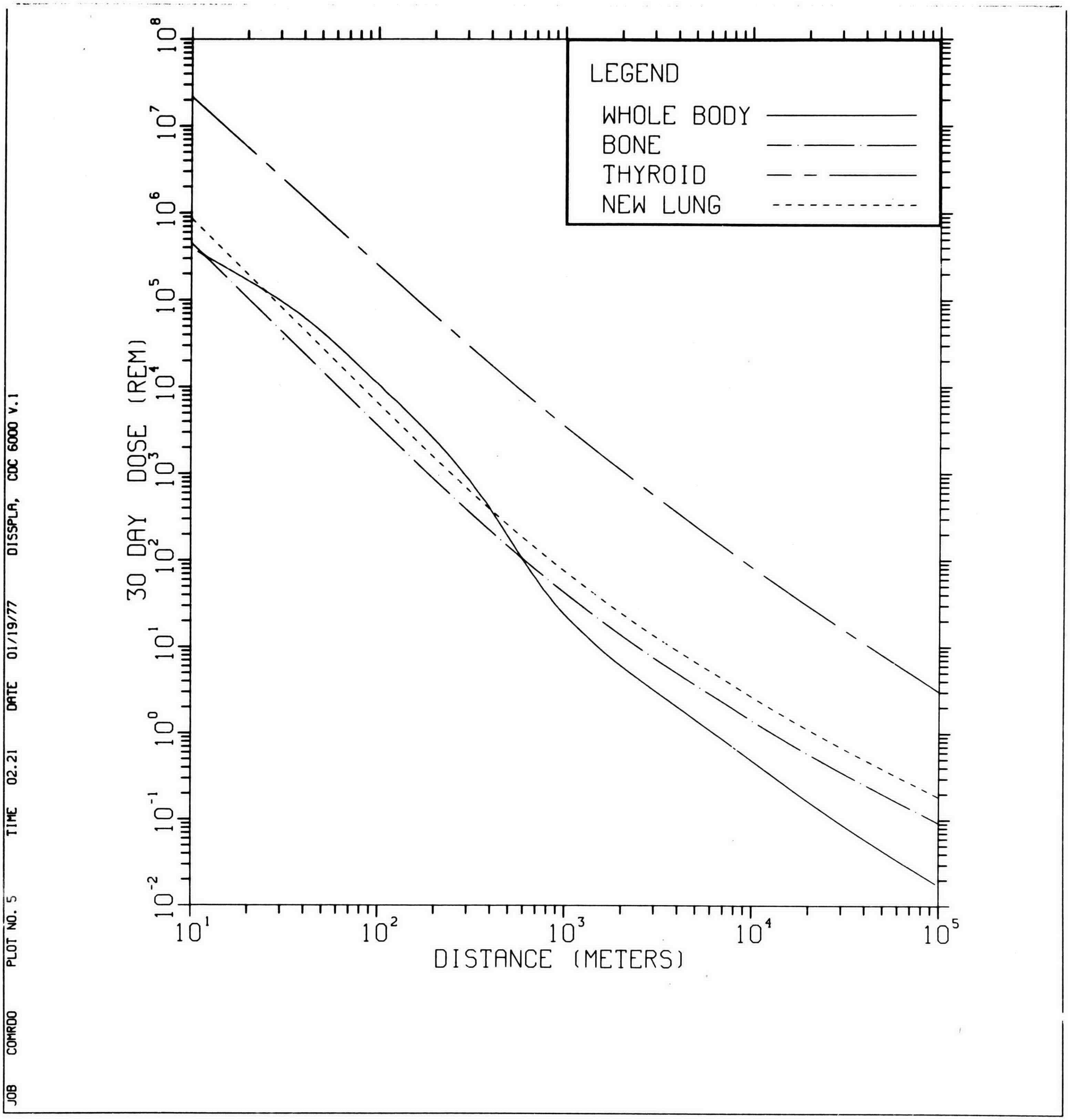

FIGURE 6-11. Case 655 - Dose vs. Distance Curves.

6.3 Case 656

6.3.1 Containment Transients

Case 656 is similar to Case 654, but without natural hydrogen recombination. The RCB conditions for Case 656 are shown in Figure 6-12 and 6-13. The interpretation of these figures is the same as for the corresponding figures of Case 654. The main effect of omitting hydrogen recombination is a small increase in purge rate which is best seen by inspection of the run summary tables given in Appendix A. Similarly, the suspended concentration curves for the two cases are similar. These curves are presented in Appendix B.

6.3.2 Radiological Evaluation

The radioactivity releases and site boundary doses for Case 656 are shown in Figure 6-14 and 6-15. These curves are also similar to those of Case 654. Without hydrogen recombination, however, the radioactivity release and consequent site boundary doses are somewhat higher during the boiloff phase. Nevertheless, this case shows that the site boundary dose would not exceed the 10 CFR 100 guidelines even if hydrogen recombination did not occur.

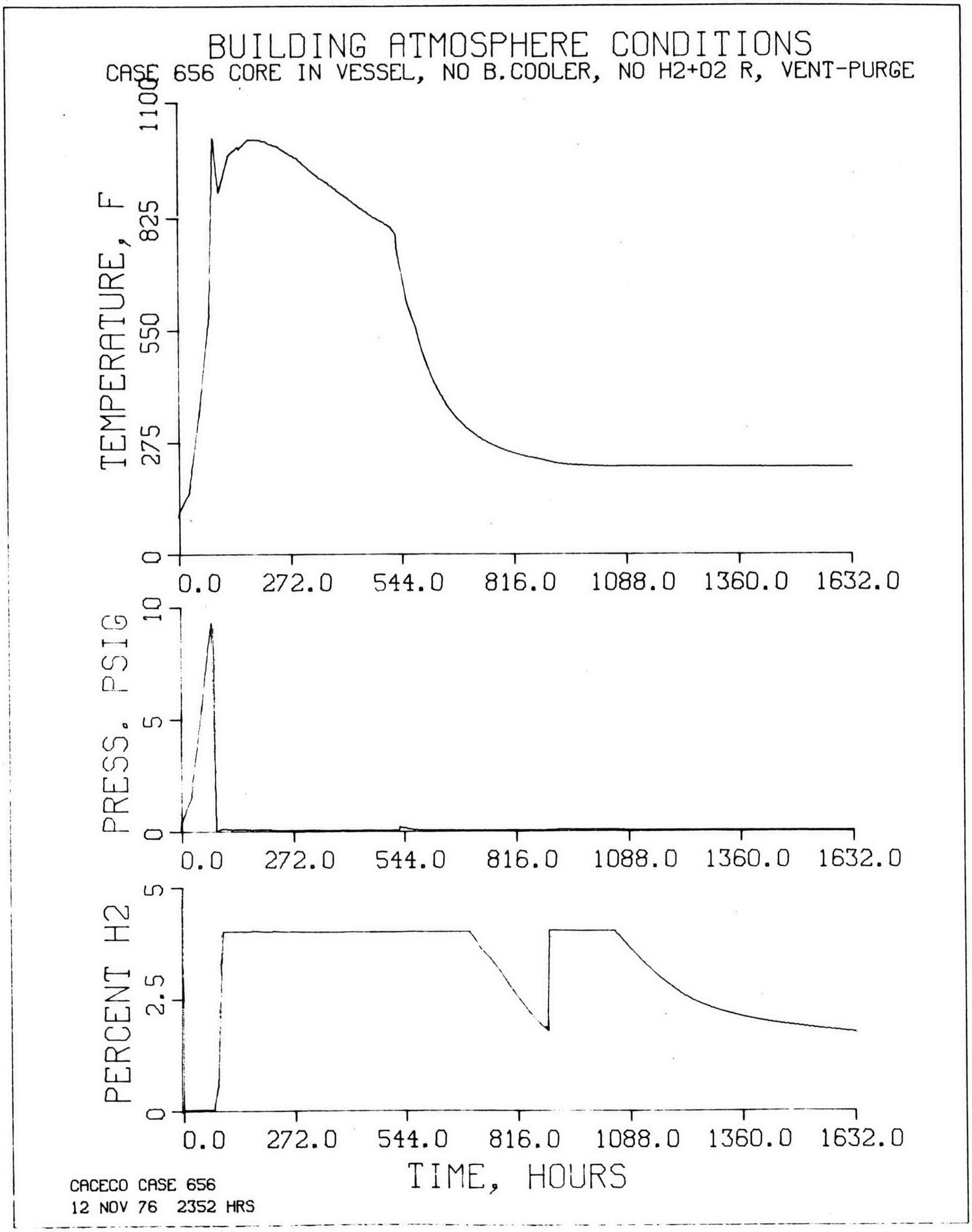

FIGURE 6-12. Case 656 - Building Atmosphere Conditions.

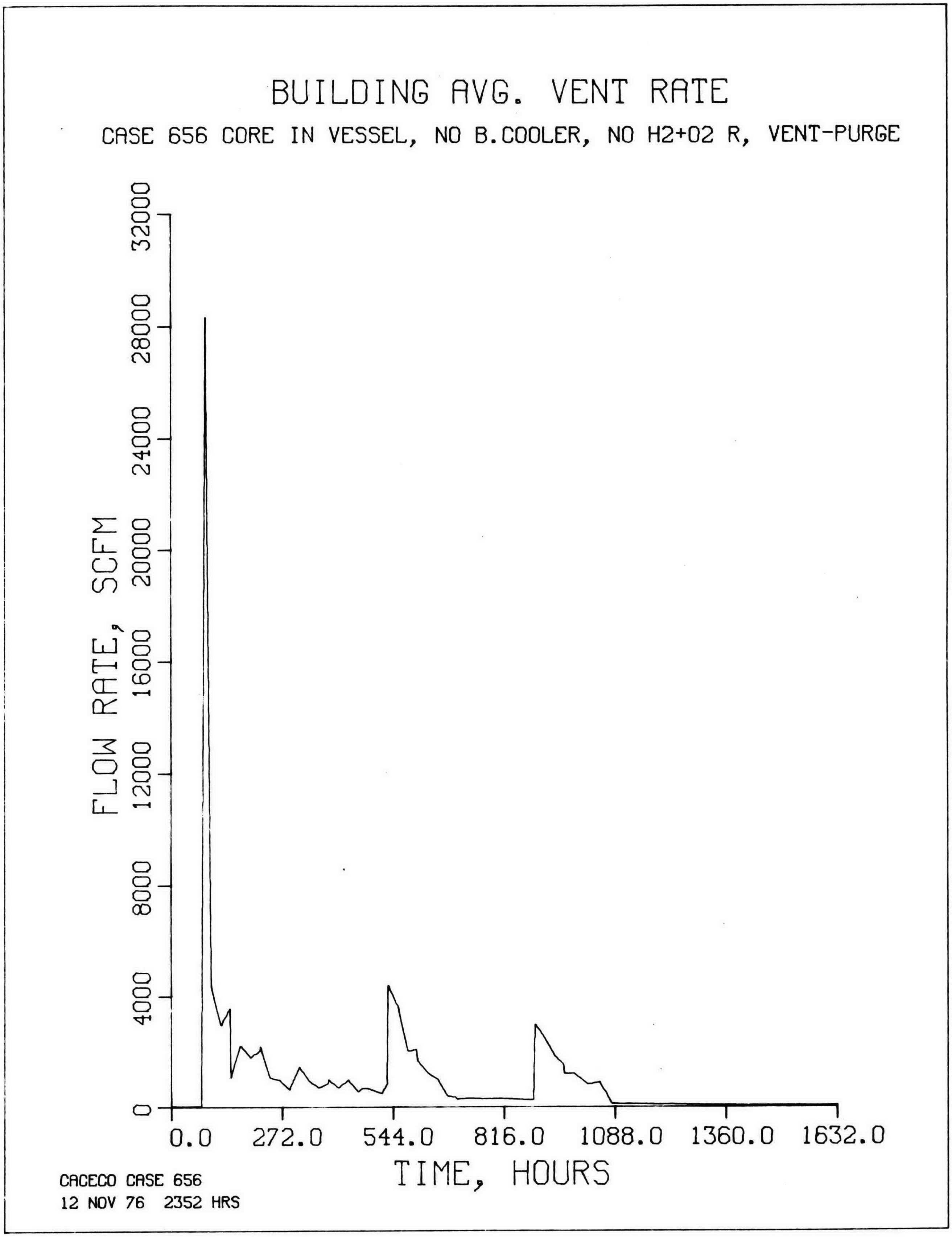

FIGURE 6-13. Case 656 - Building Avg. Vent Rate.

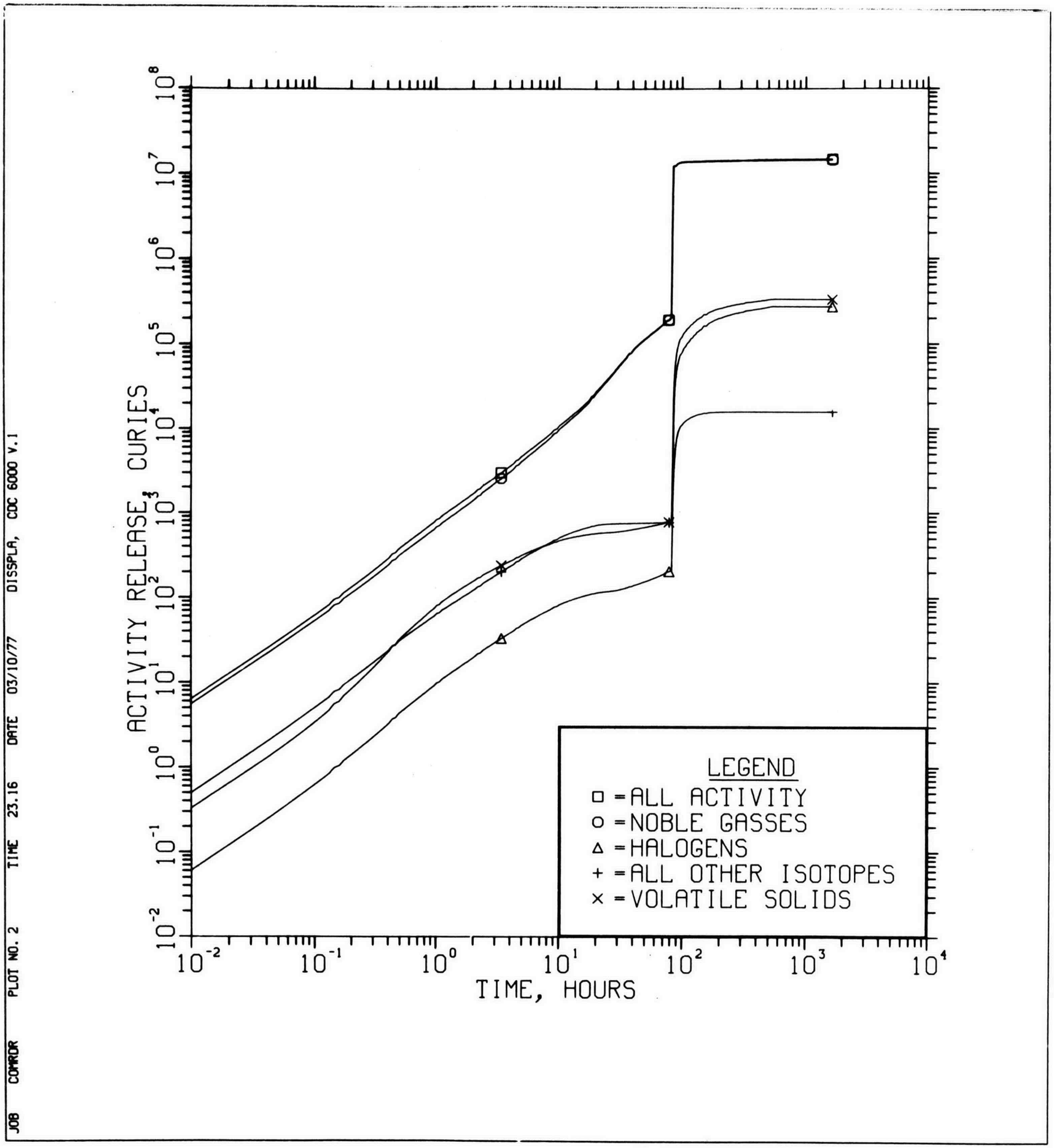

FIGURE 6-14. Case 656 - Activity Release Curves.

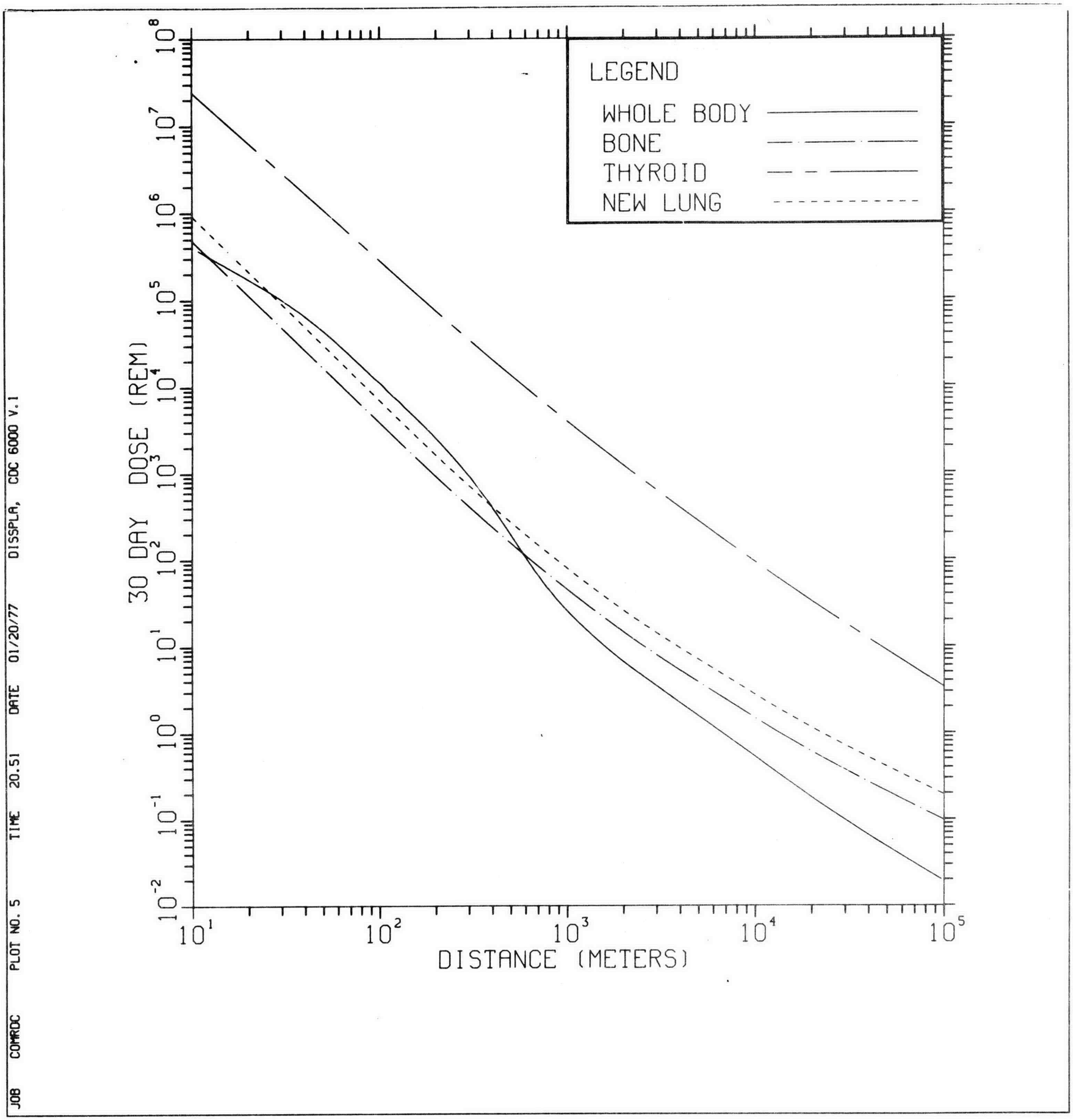

FIGURE 6-15. Case 656 - Dose vs. Distance Curves.

6.4 Case 657

6.4.1 Containment Transients

Case 657 is similar to Case 654 except the RCB is assumed to be continuously cooled by space coolers rated at 1.8×10^6 Btu/hr. The RCB conditions for Case 657 are shown in Figure 6-16 and 6-17. The interpretation of these figures is essentially the same as for the Case 654 figures. However, note that Case 657 was vented at 91 hours from 7.9 psig to avoid exceeding 4.0 percent hydrogen concentration at the end of the ventdown. This hydrogen concentration occurred because all of the oxygen had been burned out of the RCB atmosphere leaving none to compete with the water vapor in the sodium reaction at ventdown.

The continuous RCB space cooling condensed the water vapor that escaped through the sodium oxide-sodium hydroxide deposit on the RCB floor. This condensation and removal by the cooler kept water vapor at low concentrations throughout the sodium boiloff phase. The low water vapor concentration reduced the hydrogen production and need for air purge. As a result, at the end of the sodium boiloff, Case 657 had vented 574,000 lbs of gas from the RCB, only 60 percent of the 956,000 lbs of gas vented in Case 654. The initial inventory of the RCB is about 102,000 lbs of air. Suspended aerosol concentration data are given in Appendix B. Results are similar to Case 654.

6.4.2 Radiological Evaluation

The release and dose curves of Case 657 as shown in Figure 6-18 and 6-19, respectively, are basically similar to those of Case 654. The oscillation shown on the volatile, halogen, and other curves immediately following the RCB vent is due to the Simpson rule integration used by COMRADEX to integrate the releases. This type of oscillation, often seen following a vent, will be noticed in other cases also. Oscillations are damped at the

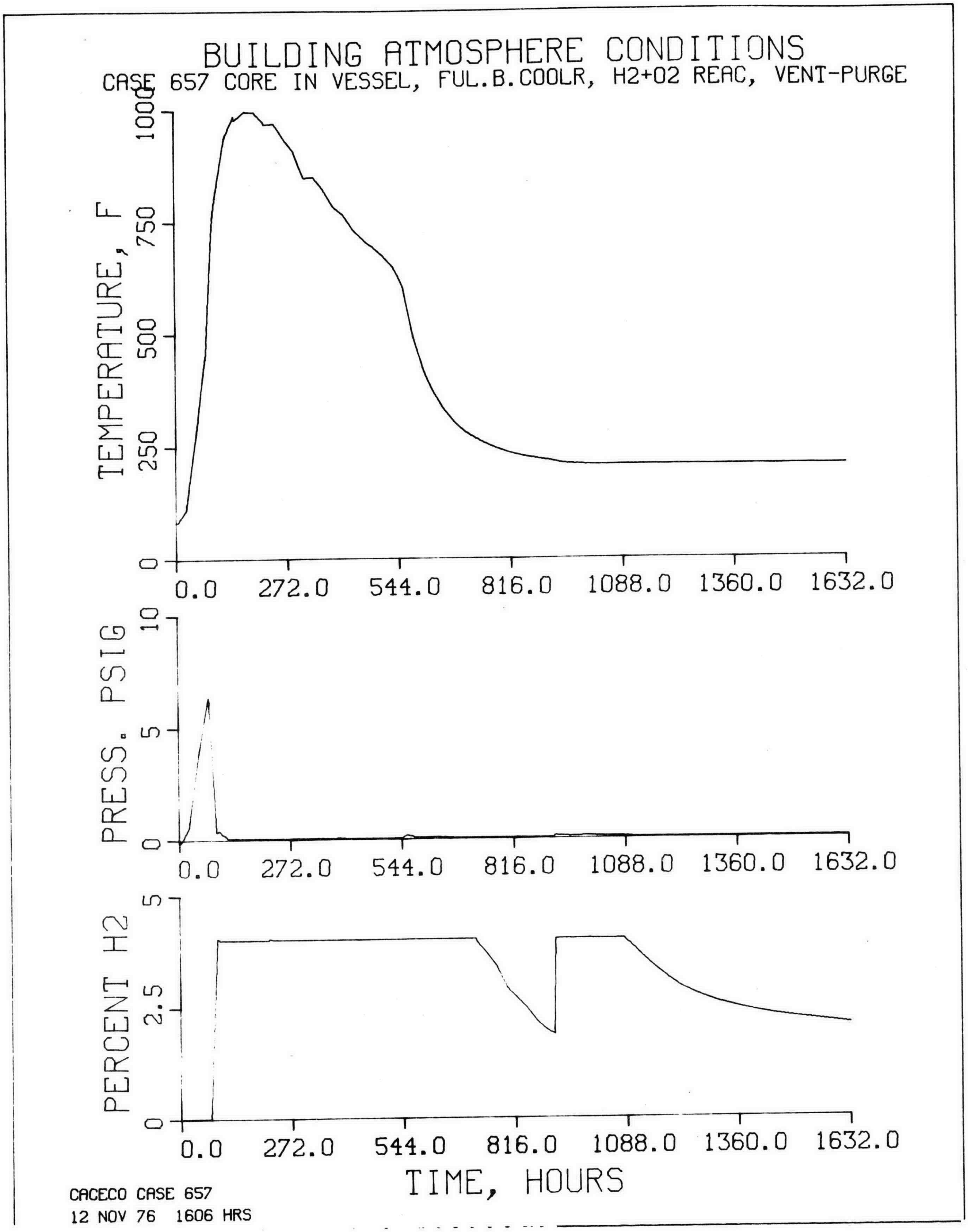

FIGURE 6-16. Case 657 - Building Atmosphere Conditions.

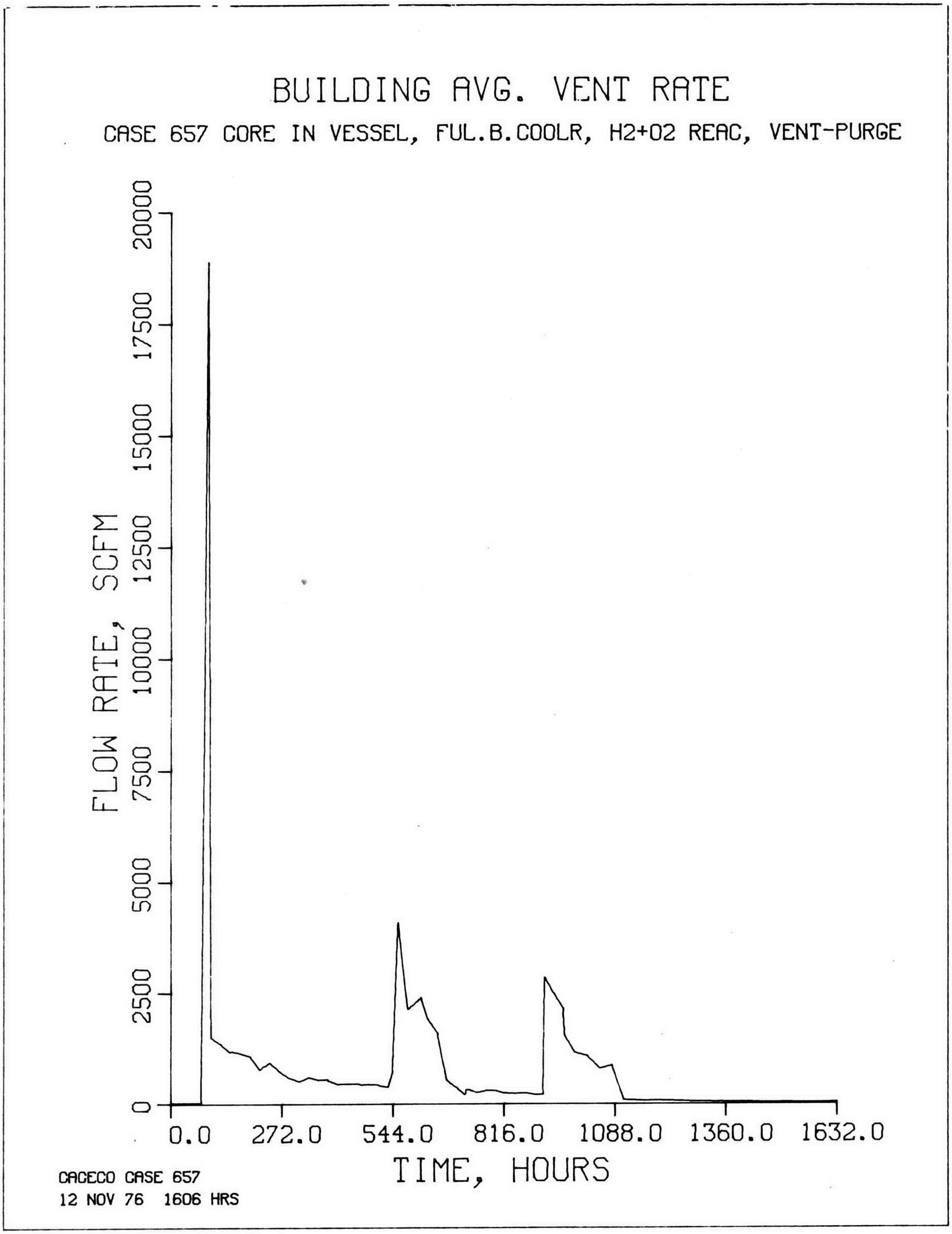

FIGURE 6-17. Case 657 - Building Avg. Vent Rate.

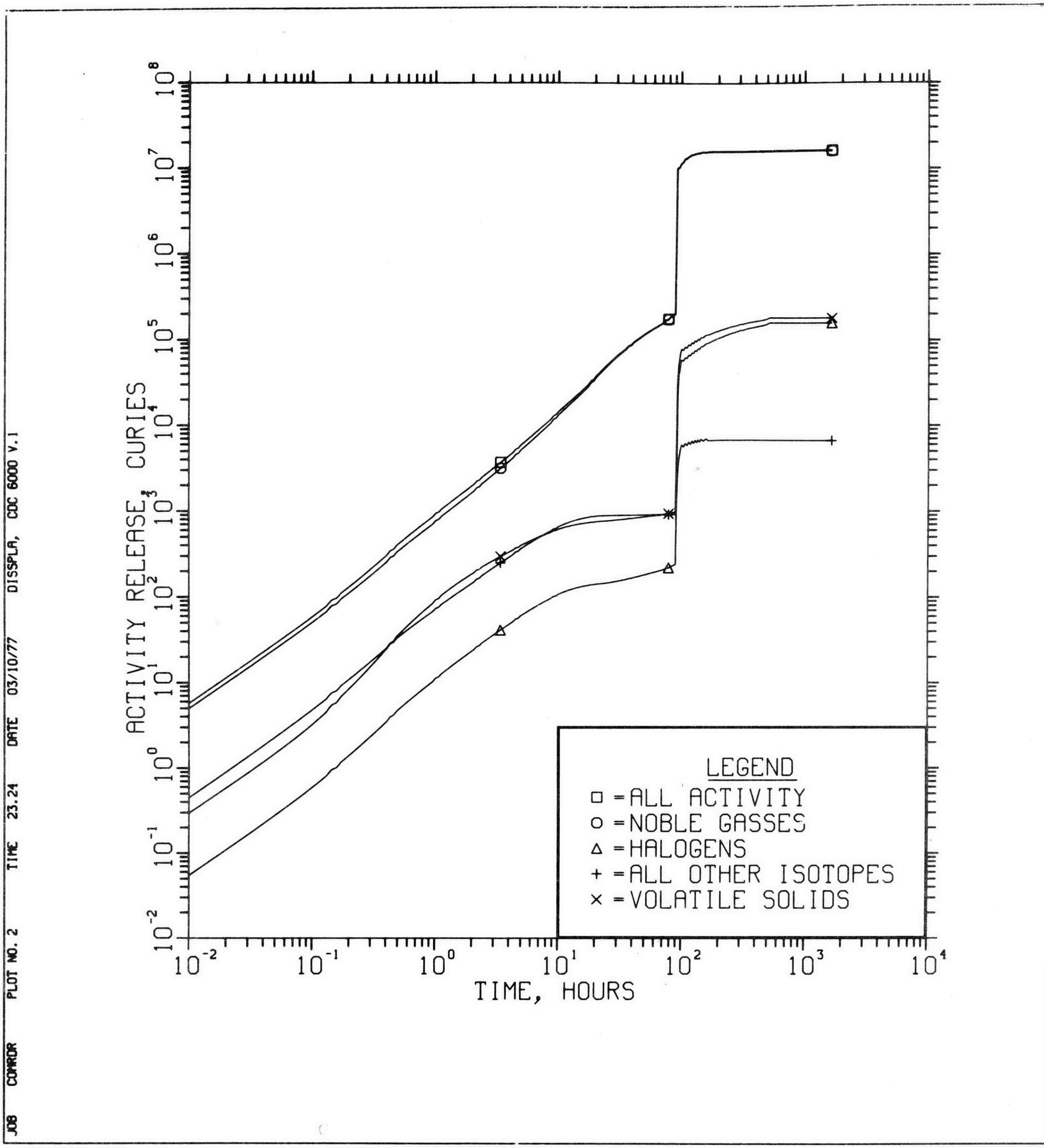

FIGURE 6-18. Case 657 - Activity Release Curves.

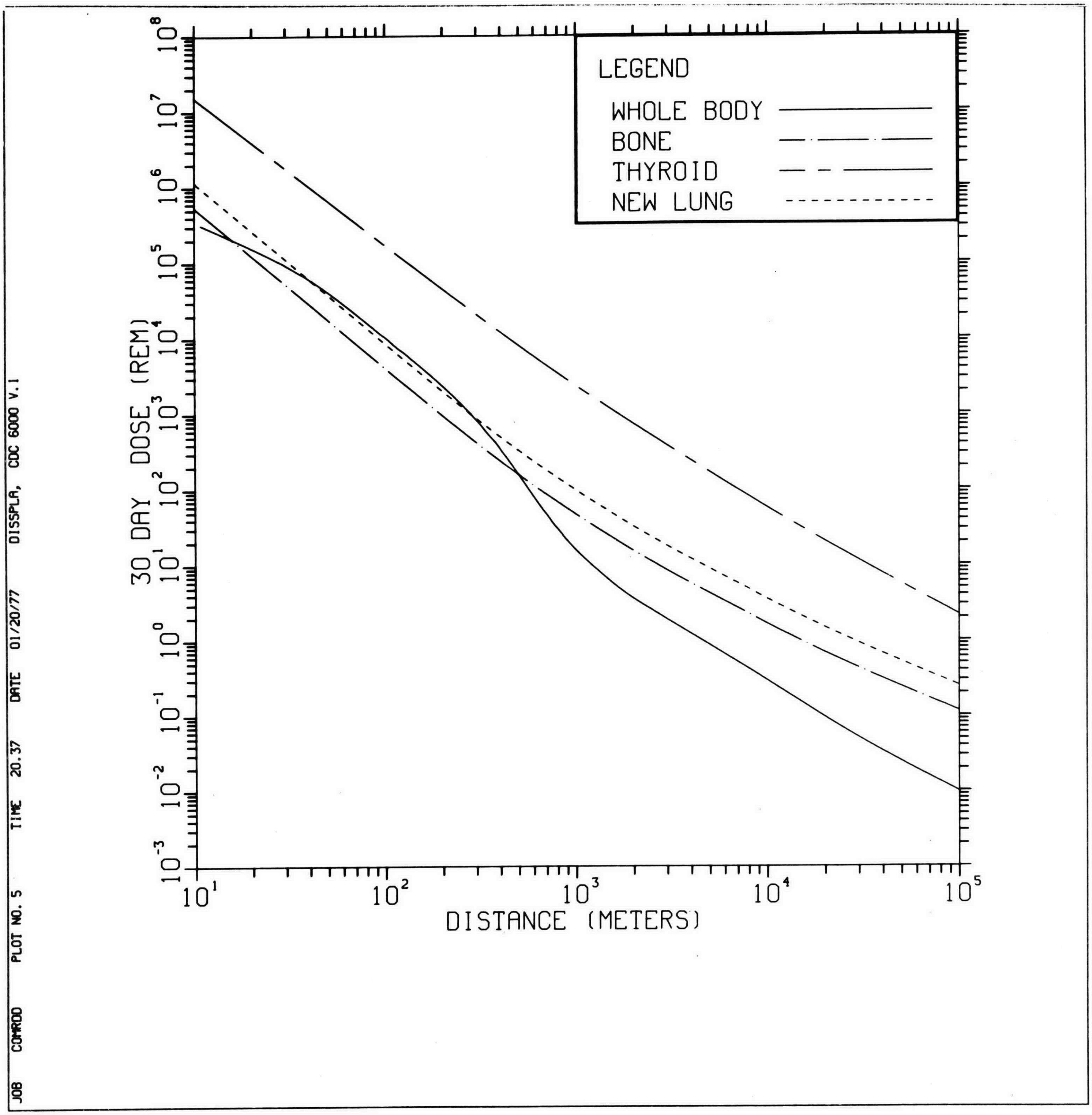

FIGURE 6-19. Case 657 - Dose vs. Distance Curves.

fifth step of each time step bunch. Otherwise, results are similar to Case 654. As a result of the building coolers, there is a substantial reduction in the dose from the volatiles. The apparent increase in bone and lung dose, as shown in Table 2-2, is considered to be unrealistic, owing to a discrepancy in data fitting which occurred in this run only. Since the doses were already low it was not considered worthwhile to repeat the run.

6.5 Case 658

6.5.1 Containment Transients

Case 658 arbitrarily assumed the RCB to fail at a pressure of 20 psig (twice the design pressure). The analysis assumed natural hydrogen recombination and no operation of RCB H&V space coolers. There was no air purge to limit hydrogen concentration in the RCB.

RCB conditions are shown in Figures 6-20 and 6-21. Sodium boiloff into the RCB atmosphere began at about 20 hours. By 83 hours, sodium boiloff had depleted the oxygen concentration below its flammable limit of 5 percent (for hydrogen combustion). Later on, by 96 hours, hydrogen had accumulated from the sodium-water vapor reaction, to its flammable limit of 4 percent (for combustion in air). The sodium boiloff heated and pressurized the RCB atmosphere. At 123 hours, as shown in Figure 6-20, the RCB was heated to 691°F, pressurized to 20 psig, and hydrogen concentration was 17 percent. (The pressure spike to 20 psi was missed by the computer plotting routine; summary tables in Appendix A show the pressure). Oxygen concentration was only 0.7 percent and water vapor concentration was 14 percent.

The RCB was vented at 123 hours to simulate overpressure failure. Ventdown to atmosphere pressure was assumed to take one hour (to 124 hours). This ventdown flashed 29,700 lbs of sodium out of the vessel into the RCB, which consumed all oxygen and water vapor, and heated the atmosphere. The ventdown is shown in Figure 6-20 by the sharp rise in temperature from 691°F to 1140°F, and by the sharp fall in pressure. The ventdown released 66 percent of the RCB atmosphere to the outside at an average vent rate, off the scale of Figure 6-21 at 123-124 hours, of 53,000 ft^3/min. This ventdown resulted in an inert RCB atmosphere.

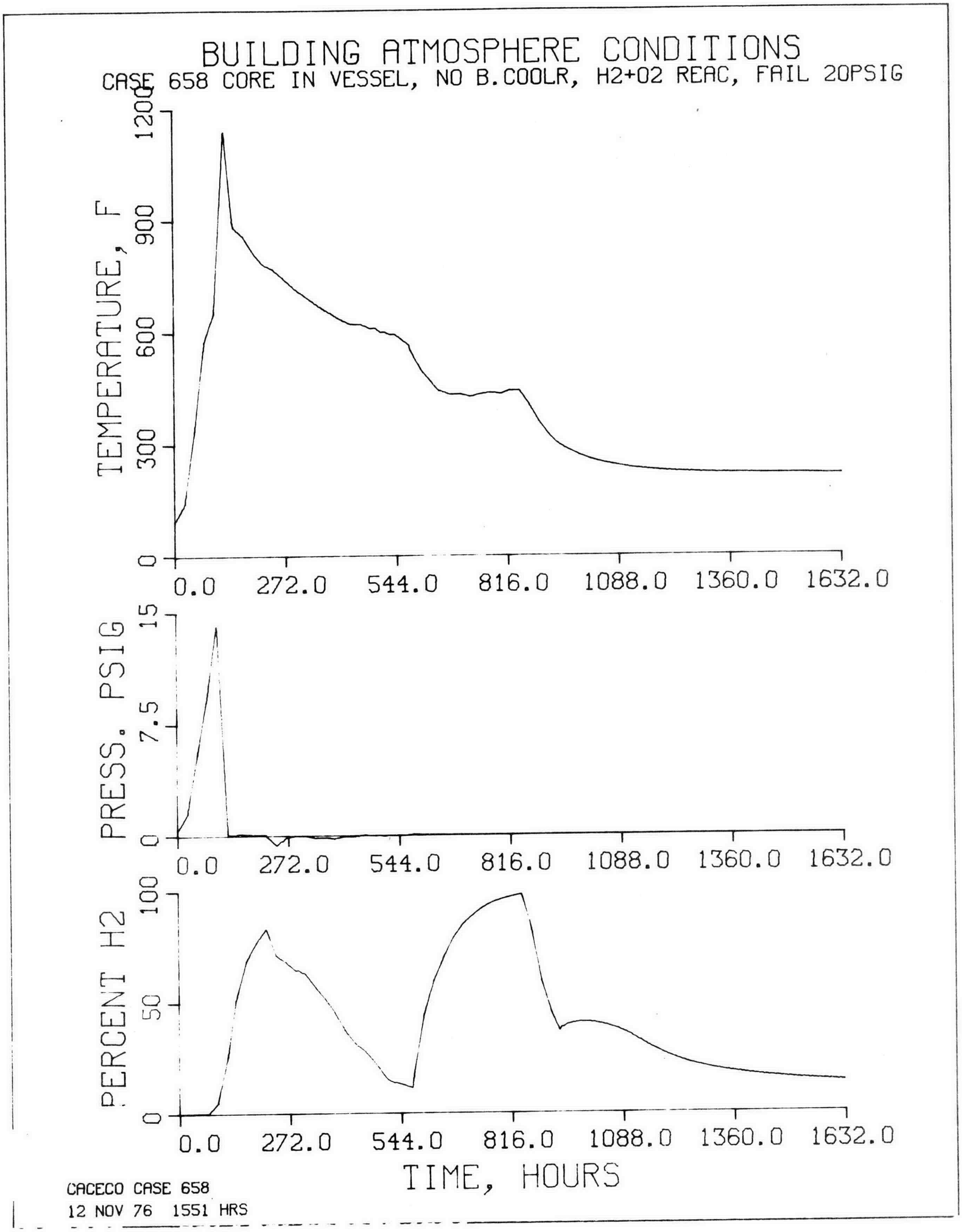

FIGURE 6-20. Case 658 - Building Atmosphere Conditions.

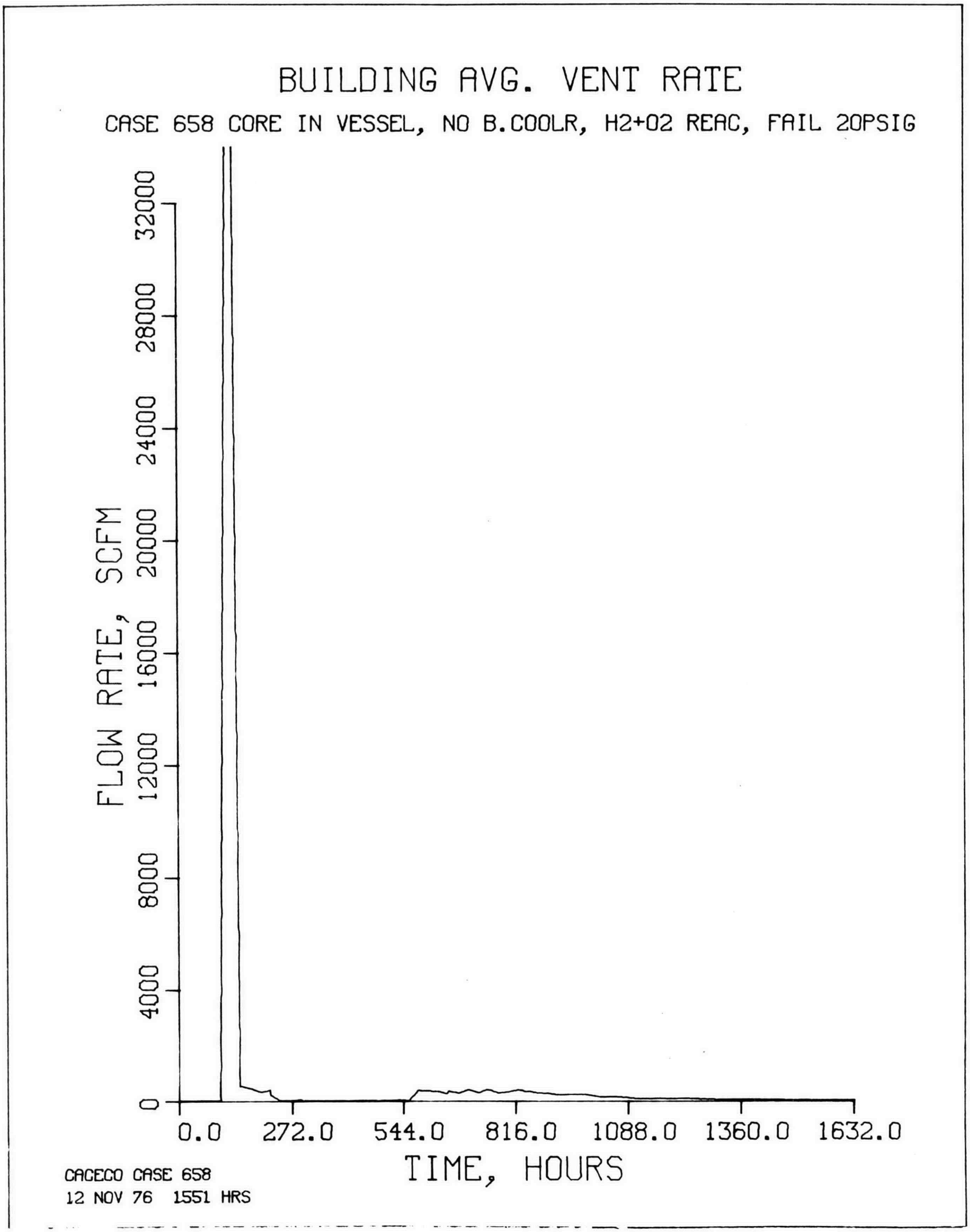

FIGURE 6-21. Case 658 - Building Avg. Vent Rate.

The RCB cooled after its ventdown of 123-124 hours. There was no air purge. Hydrogen accumulated to a peak of 83 percent at 220 hours from the reaction between sodium boiloff and water release from the RCB floor. Thereafter, hydrogen decreased as RCB cooling drew in outside air. The sodium boiloff kept the RCB inert (essentially no oxygen or water vapor present) until the reactor vessel boiled dry at 572.0 hours. At this time, as shown on Figure 6-20, the RCB temperature was cooled to 568°F and hydrogen concentration reduced to 10 percent.

After sodium boil-dry, core debris is assumed to melt out of the vessels. In Case 658 from 572.9 hours to 936 hours, core debris was simulated by setting the floor temperature at 2600°F, the melting point of steel. This source heated the concrete floor, driving off water vapor which reacted with the 114,000 lbs of stainless steel associated with the debris. At first, water release and hydrogen production were very rapid, changing RCB hydrogen concentration from 10 percent at 573 hours to 98 percent at 840 hours. After 840 hours, steam release from the RCB floor and from the H&V cooler room diluted the RCB hydrogen. At 936 hours, the RCB had cooled to 299°F and hydrogen concentration was reduced to 36 percent.

The reactor cavity floor was assumed to collapse at 936 hours and unreacted molten steel was transferred to the subcavity floor. The effect of this new source of water is shown as the third peak on the Figure 6-20 hydrogen curve, where concentration peaks to 41 percent at 992 hours before dilution by continuing steam release. The steel was consumed by about 1,080 hours, which terminated hydrogen production. At case end, 1,632 hours, the RCB atmosphere was cooled to 212°F and the hydrogen concentration reduced to 13 percent.

6.5.2 Radiological Evaluation

Figures 6-22 and 6-23 show the radioactivity releases and doses for Case 658. Although basically similar to Case 654, other phenomena can be noticed by a study of the activity release curves. The spike on the noble gas curve immediately following the building failure is the start of an oscillation in one of the Xe133 chains, but since the inventory is exhausted during the following time step, the Simpson integrator never compares with the previous step. The release of noble gases affects only the external (cloud) dose which is insignificant for this case and would not become significant even if the spike were a real phenomenon and were added to the integrated noble gas release. The increase in leak rate, following vessel melt-through (573 hrs), is apparent when considering the volatile and halogen release curves. This case exhibits the highest thyroid dose of any case run; in general, the reason for this is that the oxygen was depleted by blowdown upon building failure (and not replenished by an air purge), the sodium vapor leaving the reactor/reactor cavity was not oxidized and therefore was not assumed to precipitate. The fallout calculated by HAA utilizes a sodium oxide source rate which was cut off with oxygen depletion; the suspended concentration diminished and the fallout rate with it. Actually, if a large quantity of sodium vapor is released to an atmosphere which is cool enough to condense it -- in all probability it would rain sodium (a fallout mechanism which HAA did not evaluate). The sodium iodide which caused the thyroid dose would have been scavenged from the atmosphere rather than having been released at 573 hours. Therefore, the thyroid dose at the site boundary is substantially overestimated.

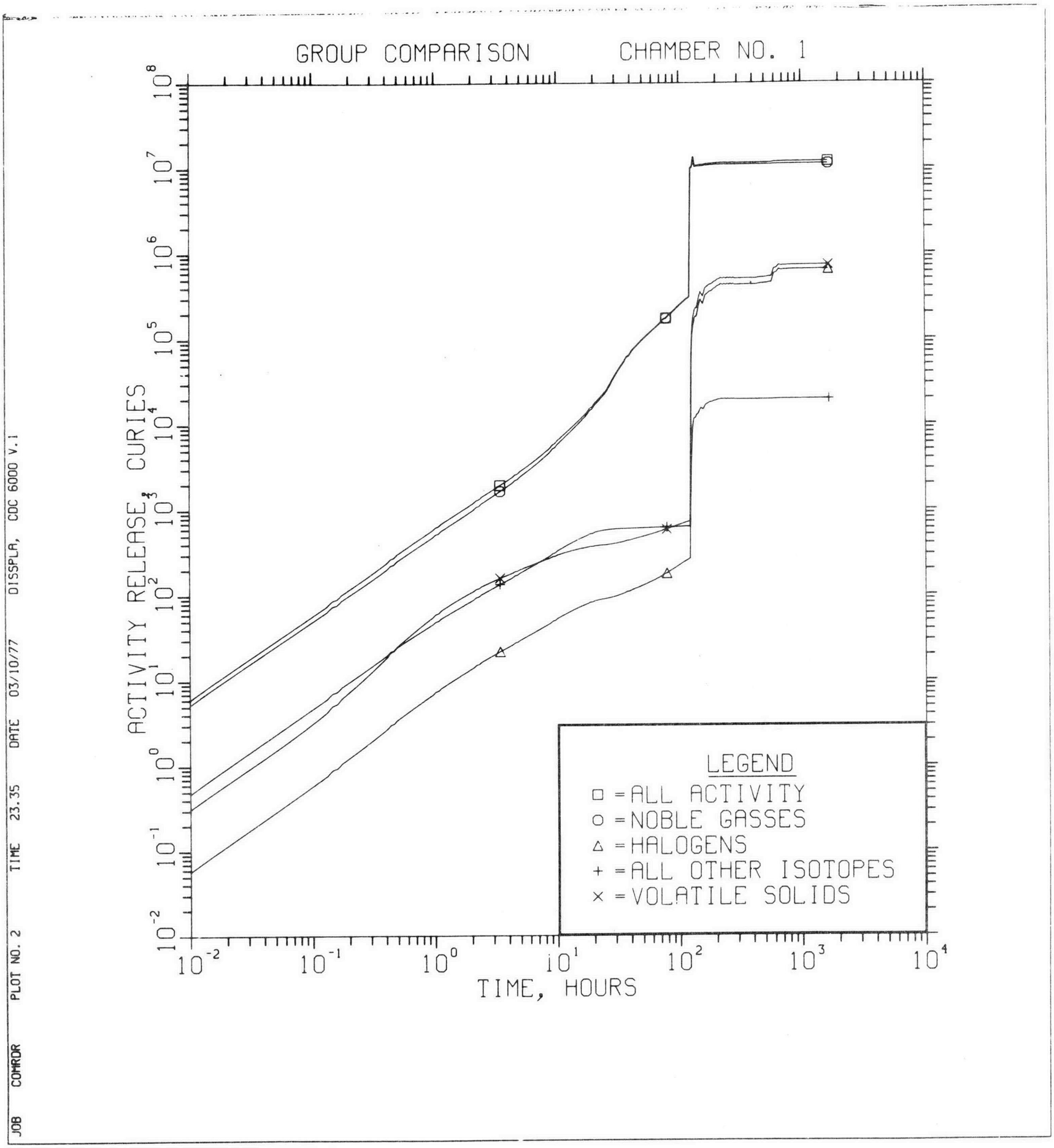

FIGURE 6-22. Case 658 - Activity Release Curves.

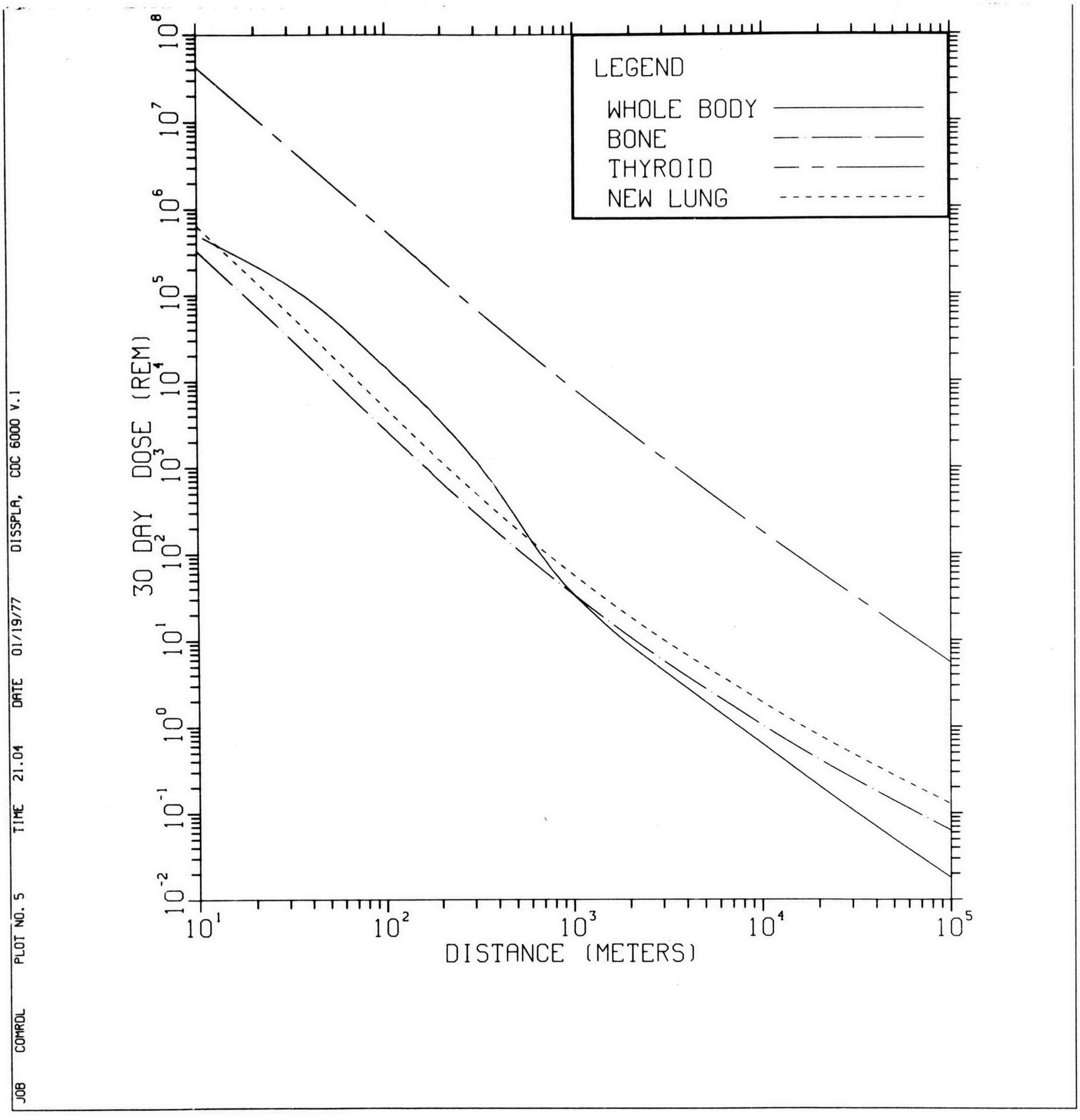

FIGURE 6-23. Case 658 - Dose vs. Distance Curves.

6.6 Case 659

6.6.1 Containment Transients

Case 659 is an in-vessel case that used a 10 psig pressure relief valve to prevent overpressurizing the RCB. This case was similar to Case 654 until RCB pressure reached 10 psig. The RCB transients are shown in Figure 6-24. The RCB pressure relief valve operated between 74 hours and 208 hours to limit the RCB pressure to 10 psig. The required vent rates are shown in Figure 6-25; none were larger than 300 ft^3/min. At 120 hours, the RCB temperature peaked at 819°F. At 208 hours, the RCB temperature had decreased to 799°F but the hydrogen concentration peaked at 69 percent. Thereafter, RCB temperature and pressure generally decreased during the sodium boiloff. At 314 hours, the hydrogen concentration started decreasing as the sodium boiloff reacted to form sodium hydride. At 544 hours, the RCB had cooled and depressurized. The reactor vessel boiled dry at 590.2 hours.

Case 659 had the 10 psig pressure relief valve which held in most of the RCB atmosphere during the critical period of the sodium boiloff. As a result, at the end of the sodium boiloff, Case 659 had vented 62,200 lbs of gas from the RCB, only 6.5 percent of the 956,000 lbs of gas vented in Case 654. The initial inventory of the RCB is about 102,000 lbs of air.

In Case 659 from 590.2 hours to 948 hours, the 2600°F source simulated the molten core debris on the cavity floor. As in the previous cases, water was driven off the concrete floor, reacting with the steel associated with the core debris. The hydrogen production repressurized the RCB so that the relief valve opened at 640 hours, and remained open thereafter to limit the RCB pressure to 10 psig. The hydrogen production also changed the RCB atmosphere from 48 percent hydrogen at 590 hours to 98 percent hydrogen at 929 hours, as shown on Figure 6-24. Thereafter, the hydrogen was replaced by steam. The reactor cavity floor was assumed to collapse at 948 hours and the remaining molten steel transferred to the subcavity floor.

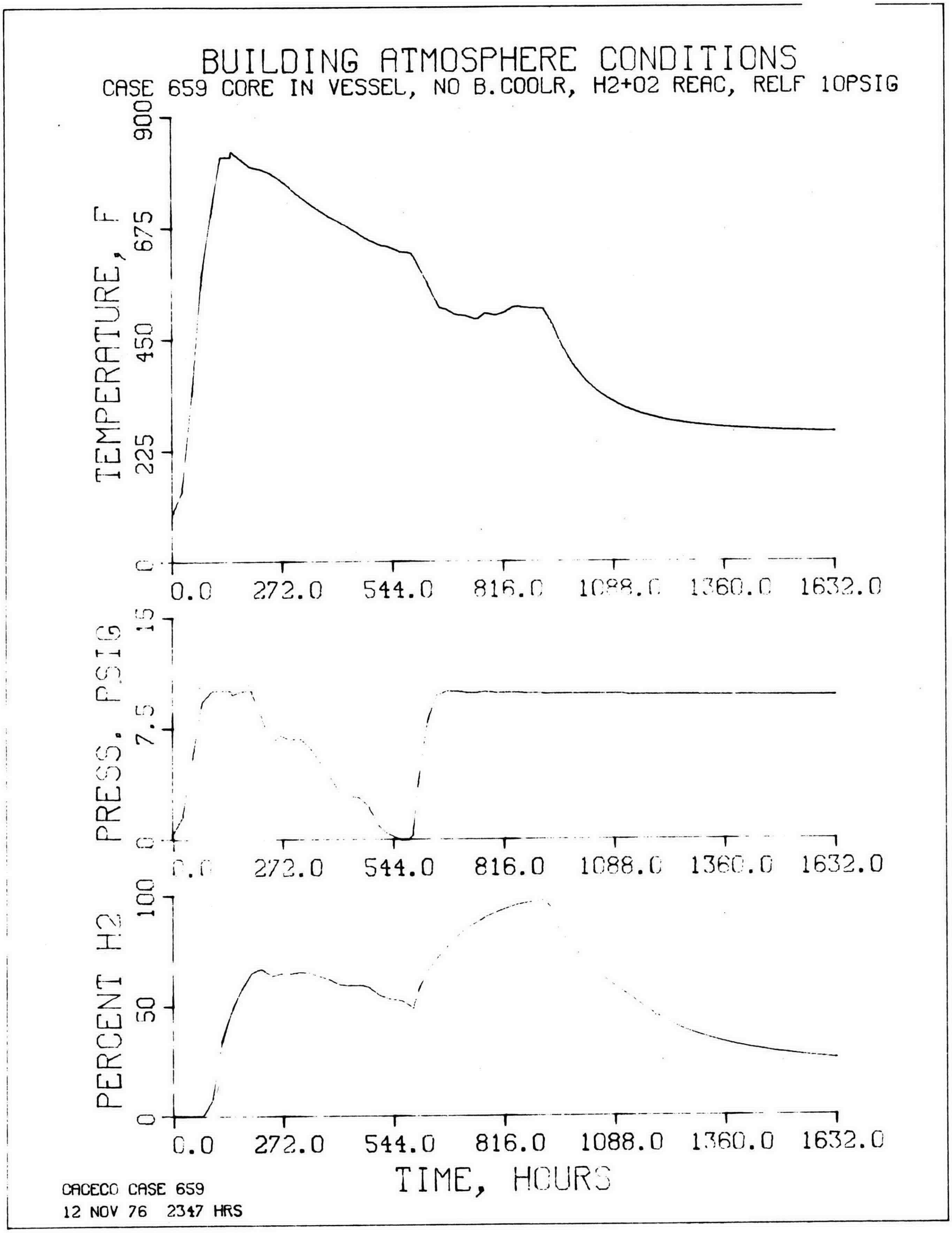

FIGURE 6-24. Case 659 - Building Atmosphere Conditions.

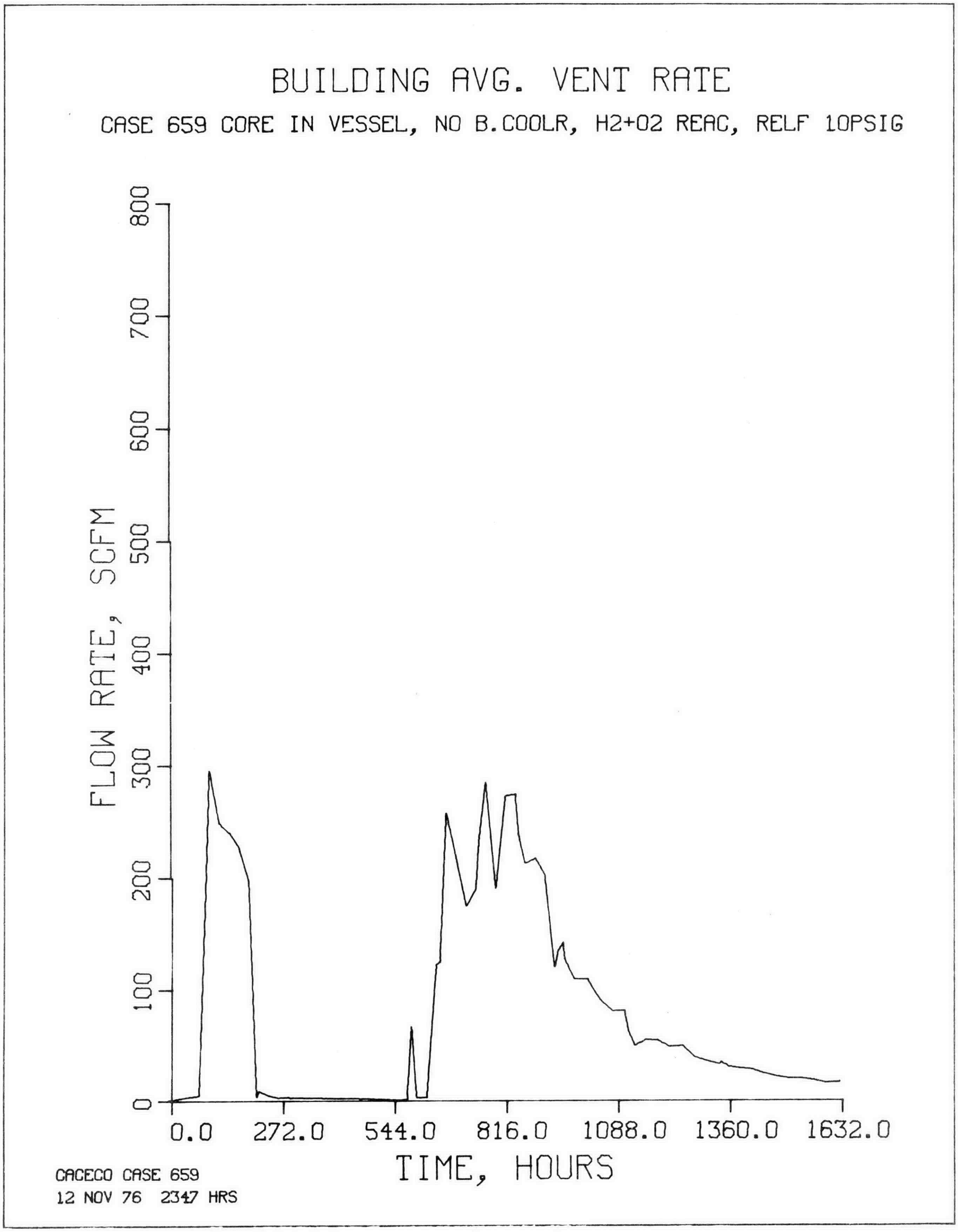

FIGURE 6-25. Case 659 - Building Avg. Vent Rate.

The steel was consumed by about 1,120 hours, which terminated the hydrogen production. At case end, 1,632 hours, the RCB atmosphere was cooled to 259°F, the pressure was 9.6 psig, and the hydrogen concentration was reduced to 25 percent.

6.6.2 Radiological Evaluation

Figures 6-26 and 6-27 present the activity releases and site boundary doses for Case 659. Up to the time of the first vent this case is similar to Case 654; however, here the venting was accomplished using a relief valve which extended the vent over a period of time. The relief valve vented only pressures above 10 psig. Maintaining a positive pressure within the containment increased the building leak rate but the overall discharge was substantially reduced. The hydrogen was allowed to accumulate as the oxygen had been depleted. The fallout is diminished as in Case 658, but in Case 659 the lower leak rate is predominant and the doses due to the volatiles are substantially reduced. Again, as in Case 658, the fallout rate dropped sharply at about 125 hours, when the oxygen was exhausted, and releases thereafter resulted in an overestimate of the thyroid dose.

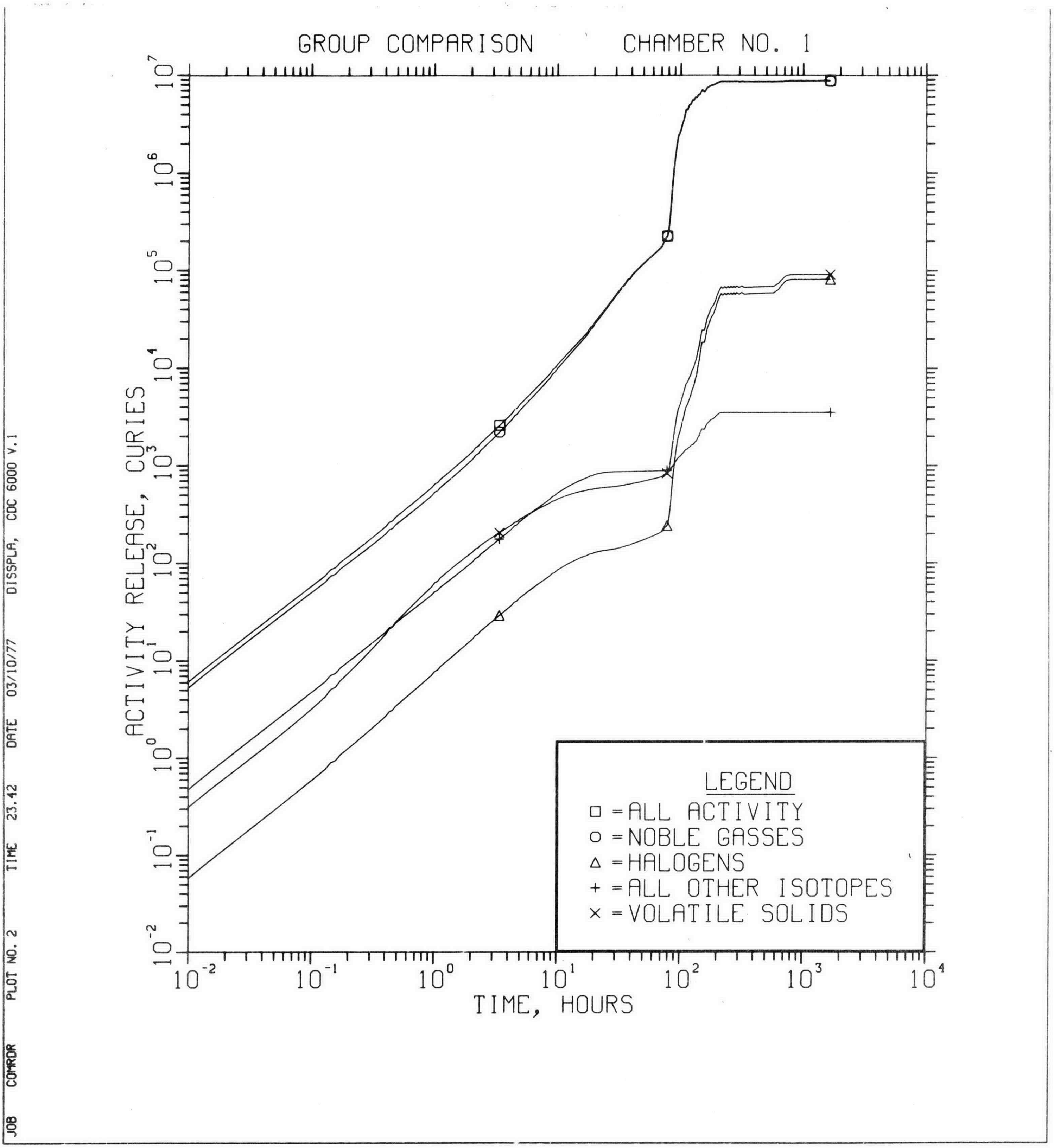

FIGURE 6-26. Case 659 - Activity Release Curves.

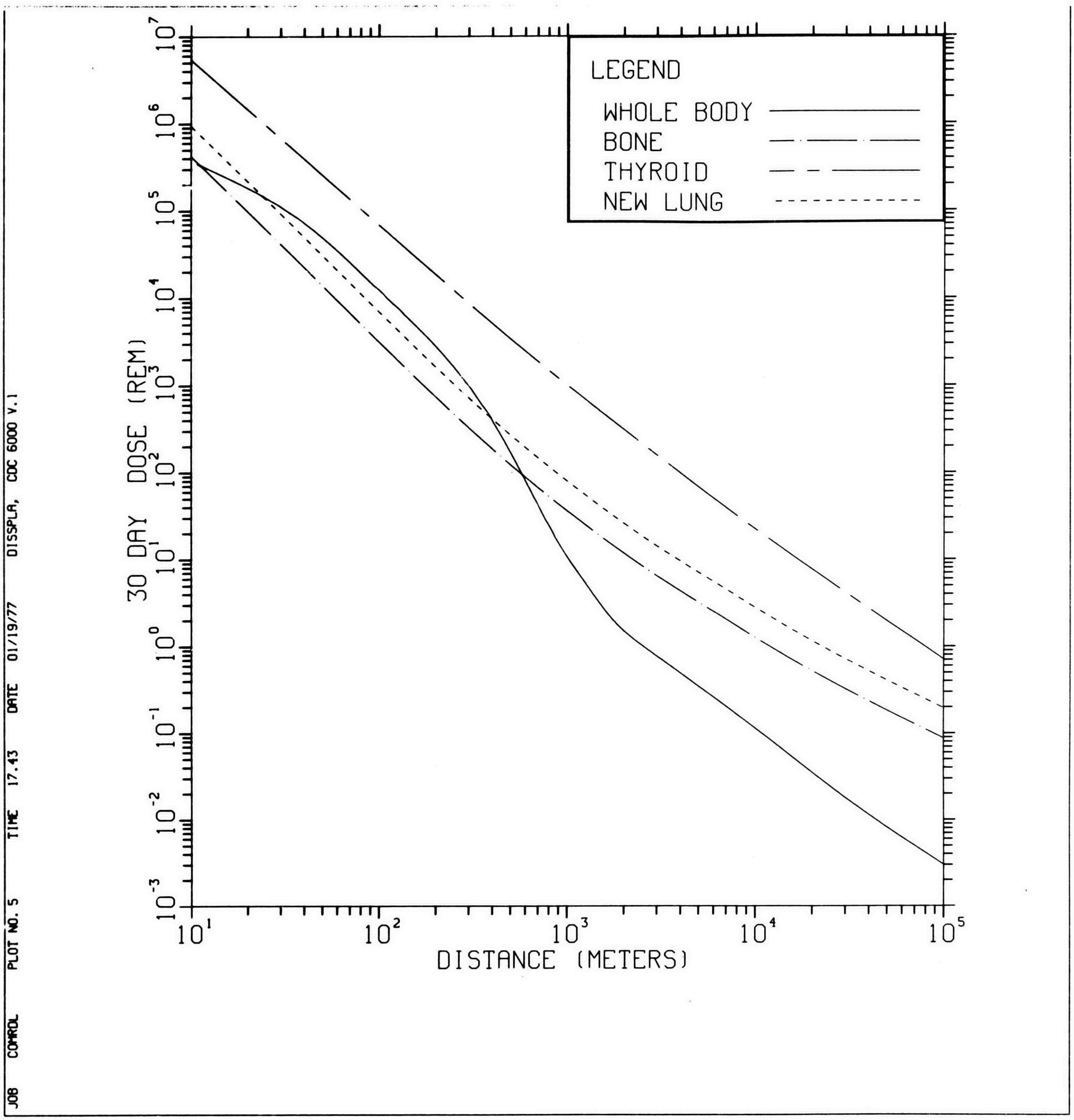

FIGURE 6-27. Case 659 - Dose vs. Distance Curves.

6.7 Case 675

6.7.1 Containment Transients

This case begins the series of descriptions of ex-vessel cases, wherein the core debris of the HCDA melts through the bottoms of the reactor vessel and guard vessel and, at 3 hours, spills onto the reactor cavity floor. The sodium accompanies the core debris and forms a pool in the cavity about 16-1/2 feet deep. Reactor cavity floor failure was predicted to occur at about 1,000 hours(13) for ex-vessel cases. Effects of cavity structural failures are included in Cases 683 and 688. The remaining ex-vessel cases presented in this report, Cases 675, 677, 678, 681, and 682, did not consider floor failure. Therefore, those cases are valid for the first 1,000 hours of the analyses presented herein. These cases have been included to provide a parametric assessment of a number of engineered operating features.

Case 675 is an ex-vessel case without failure of the floor liner. The RCB parameters for this Case 675 are shown in Figures 6-28 and 6-29. The RCB was heated and pressurized by steam driven out of the cavity concrete structures through the liner venting system. At 229 hours, as shown in Figure 6-28, the RCB was heated to 178°F, pressurized to 10.0 psig, and the hydrogen concentration was zero. The RCB was vented at this time to prevent further pressurization. After the RCB ventdown, the steam released from the cavity structures replaced the air atmosphere of the RCB. At the end of the case, at 1,632 hours, the RCB atmosphere was 99 percent steam at 211°F. Essentially no hydrogen was formed.

The sodium pool in the reactor cavity never boiled. The mixed spill temperature was about 1142°F at 3 hours. Heat losses cooled the pool to its minimum temperature of 1082°F at 8 hours. Thereafter it heated slowly to its maximum of 1472°F at 1,370 hours and then cooled to 1469°F at the end of the case at 1,632 hours.

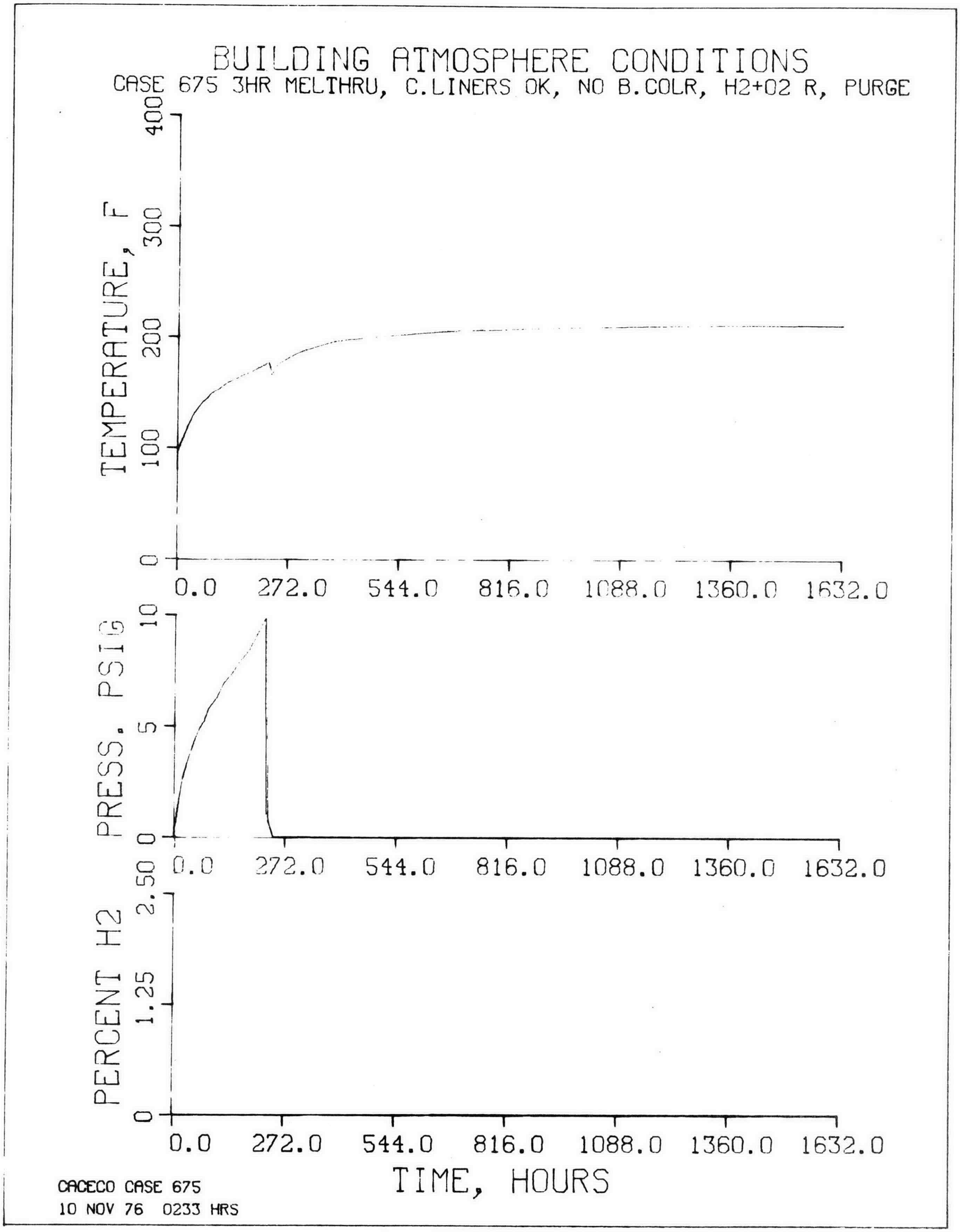

FIGURE 6-28. Case 675 - Building Atmosphere Conditions.

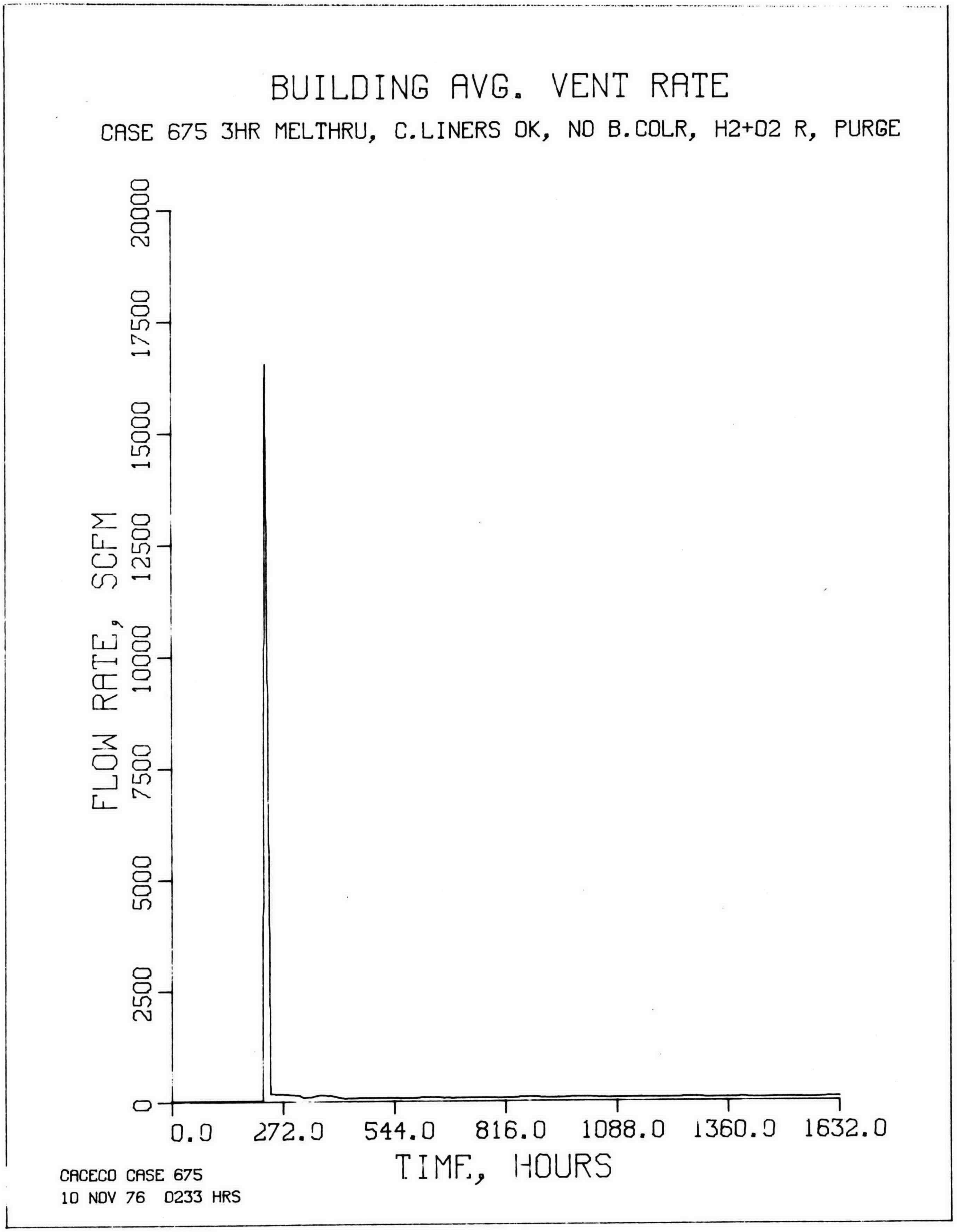

FIGURE 6-29. Case 675 - Building Avg. Vent Rate.

This ex-vessel case with no cavity liner failure is a situation that was analyzed before in HEDL-TC-76028, June 1976, as CACECO Case 536 with different results. The pertinent features of Case 675 are compared to those of Case 536 in Table 6-1 below.

TABLE 6-1

Case 675 vs. Case 536

Item	Case 675	Case 536
Thermal conductivity of concrete from 200°F to 1600°F, Btu/hr-ft-°F	0.87 to 0.46	0.35
Sodium temperature at 312 hours, °F	1356	1620
Sodium losses from cavity by 1632 hours, lbs	605	265,634

Between Cases 536 (June 1976) and 675 (November 1976) the concrete properties required for the CACECO analyses were the subject of library and experimental studies that resulted in the values used in the present study. These new values are discussed in Appendix A. As noted in Table 6-1, the values for concrete thermal conductivity are higher than before. The higher thermal conductivity increased the heat losses into the concrete cavity walls and floor. The higher conductivity increased the heat losses enough so that the sodium pool did not heat to boiling in the present study.

6.7.2 Radiological Evaluation

Figure 6-30 shows the radioactivity release curves for Case 675. Most of the sodium and the volatiles remained within the reactor cavity in Case 675. Thus, when venting and purging was necessary at 229 hours, only the noble gas fraction was airborne in the containment building. Only minor flashing of the sodium occurred when the RCB was vented. Released radioactivity and consequently the doses shown in Figure 6-31 were thus very small.

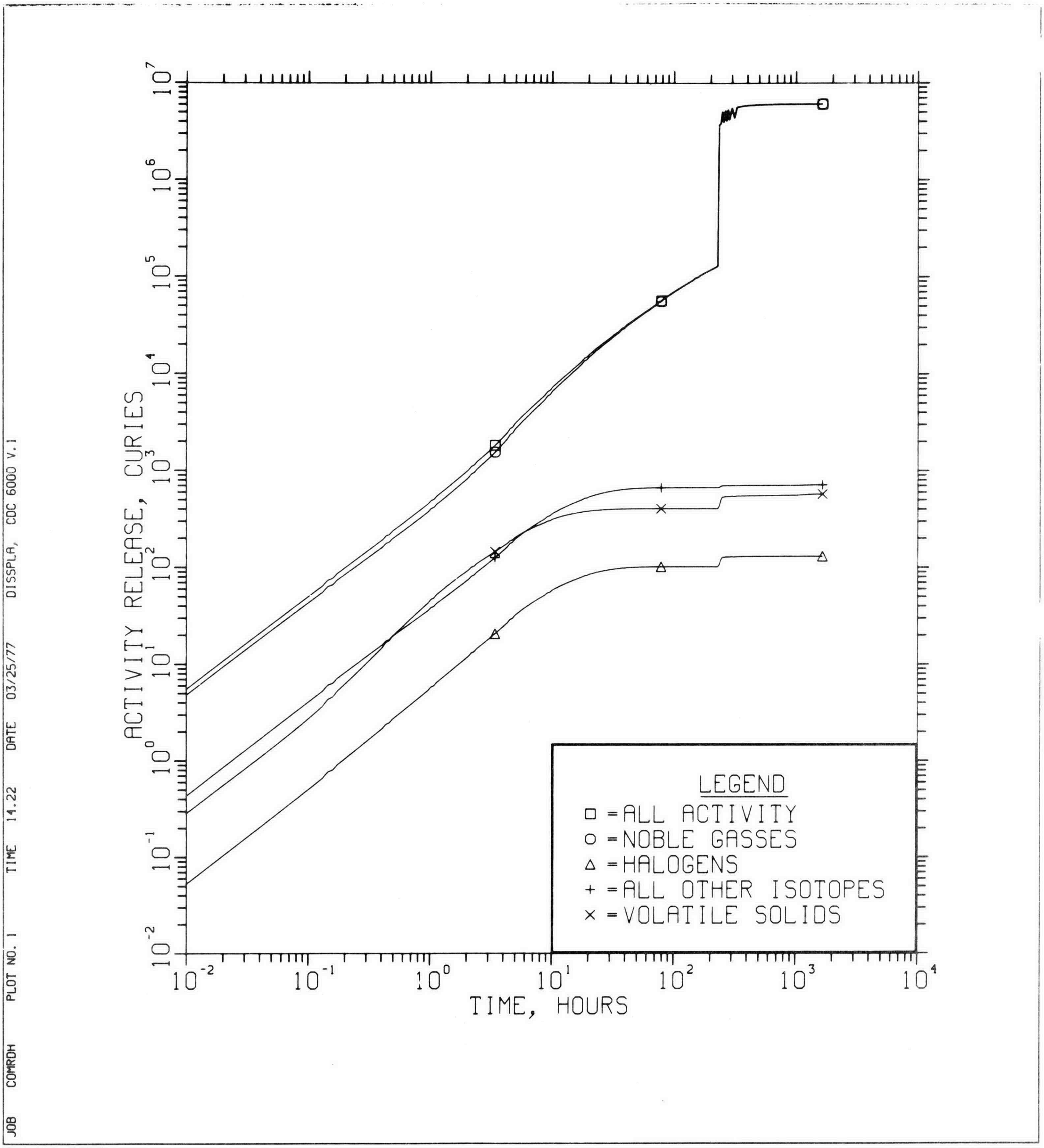

FIGURE 6-30. Case 675 - Activity Release Curves.

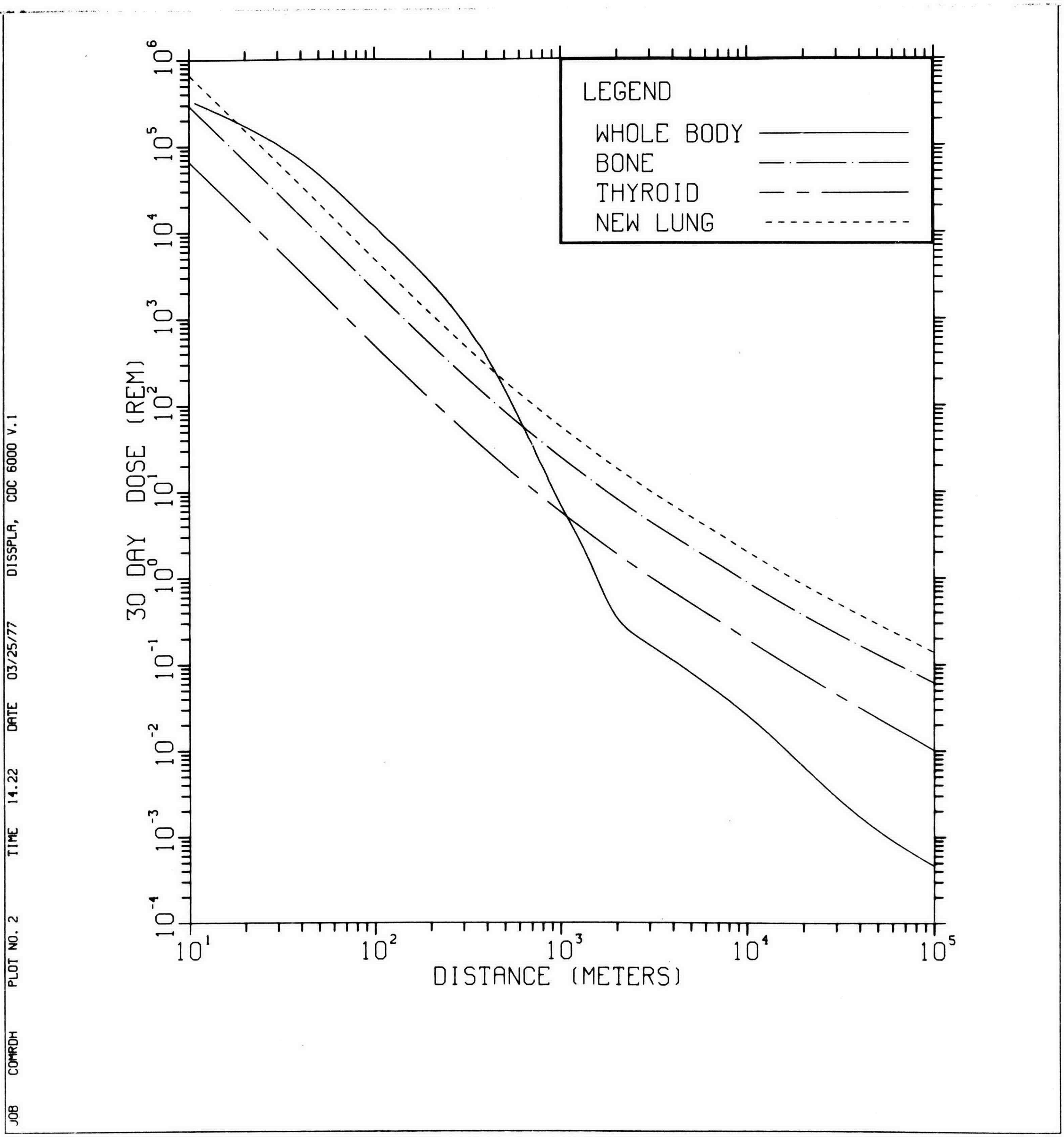

FIGURE 6-31. Case 675 - Dose Vs. Distance Curves.

6.8 Case 681

6.8.1 Containment Transients

Case 681 was set up to use ventdown and air purge to control the hydrogen concentration in the RCB. A cavity floor liner failure was assumed which allowed the sodium-concrete reaction across 346 ft^2 of floor area. The hydrogen source was the failed liner on the floor of the reactor cavity that allowed the water, released by the concrete floor heating, to react with the sodium pool. In this case, natural hydrogen recombination was effective and the RCB H&V space coolers were inoperative. The sodium-concrete reaction lasted 4 hours (from 3 to 7 hours) but the associated sodium-water reaction continued. This latter reaction produced hydrogen which vented, along with sodium vapor, into the RCB atmosphere. The sodium-hydrogen jet reacted with the atmosphere to make sodium oxide and water (hydrogen recombined with oxygen), until the oxygen was diluted. At 174 hours, the oxygen concentration had been reduced to 11 percent and the hydrogen recombination ceased. At 200 hours, as shown in Figure 6-32, the RCB was heated to 179°F, pressurized to 9.4 psig and the hydrogen concentration was 0.4 percent.

The RCB was vented at 200 hours to prevent further pressurization. This ventdown is shown in Figure 6-32 in the top curve by the small dip in temperature from 179°F to 166°F; in the middle curve by the sharp fall in pressure from 9.4 psig to zero; and in the bottom curve by the initial rise in hydrogen concentration, from 0.4 percent to 0.9 percent. This ventdown released 40 percent of the RCB atmosphere to the outside at an average vent rate, shown in Figure 6-33 at 200-201 hours, of 15,900 ft^3/min.

After the RCB ventdown at 200 hours, the steam release from the cavity structures replaced the air atmosphere of the RCB. At the end of the case, at 1,632 hours, the RCB atmosphere was 99.5 percent steam at 212°F.

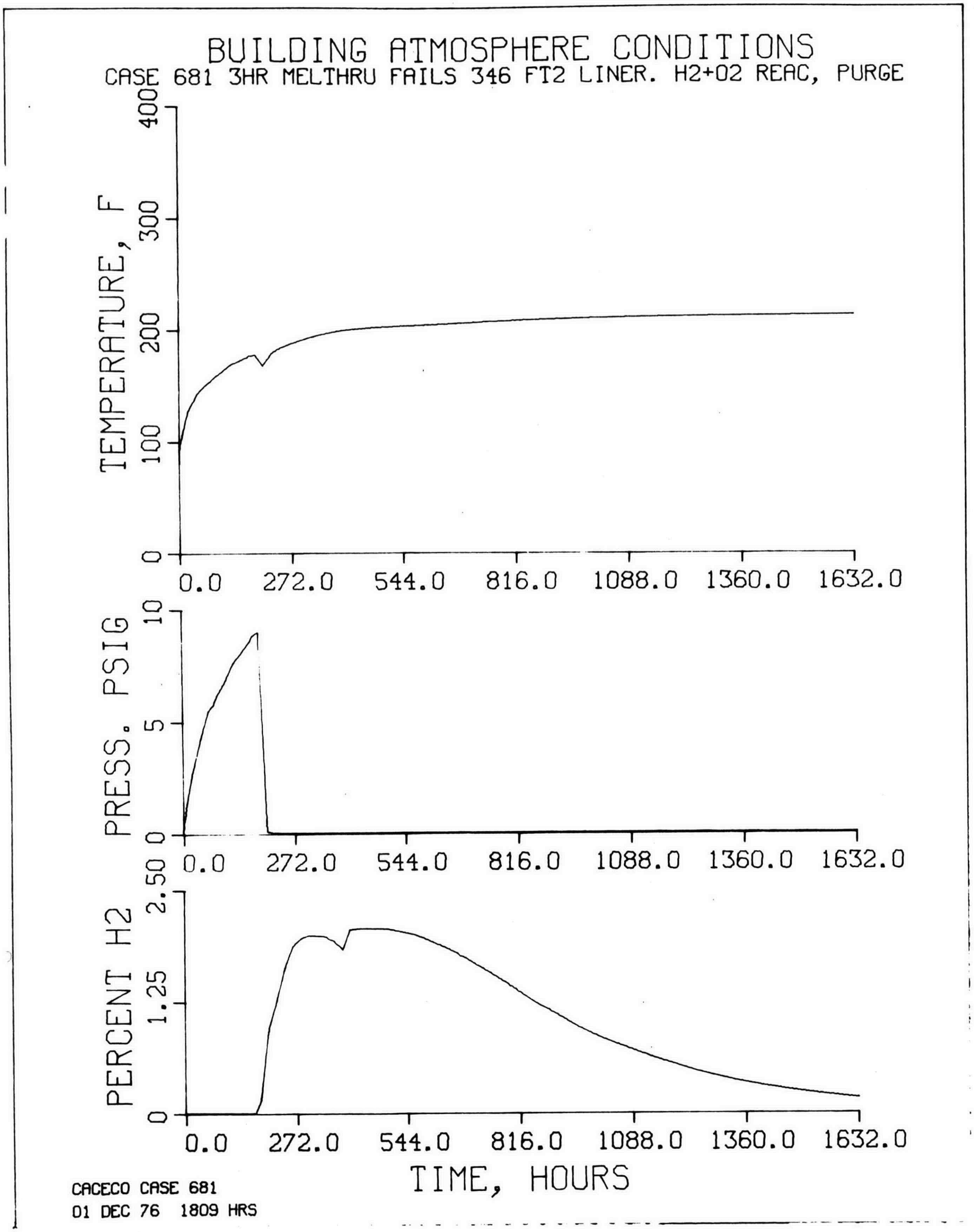

FIGURE 6-32. Case 681 - Building Atmosphere Conditions.

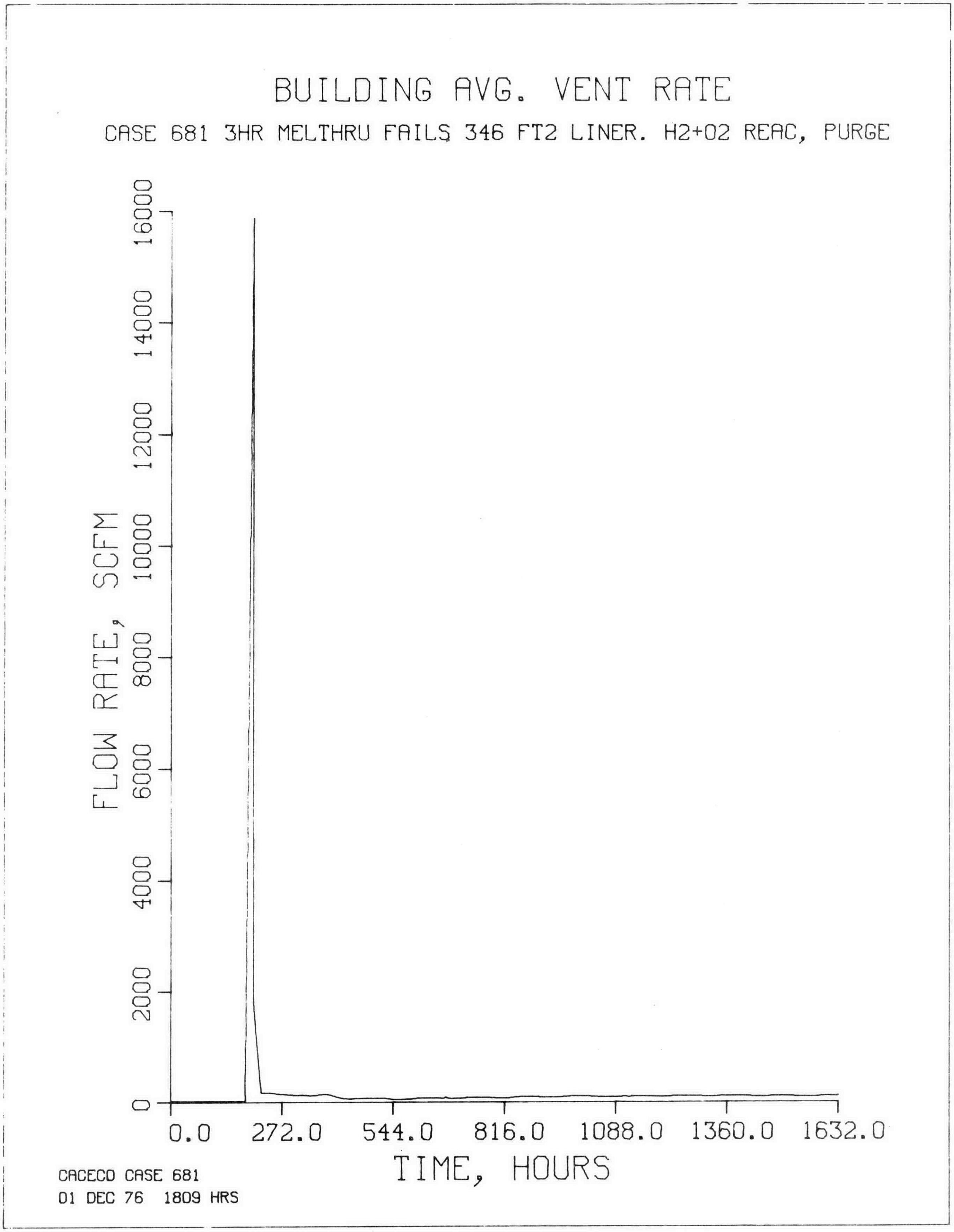

FIGURE 6-33. Case 681 - Building Avg. Vent Rate.

The sodium pool in the reactor cavity never boiled. Further, the water release into the sodium pool from the failed floor liner was not sufficient to make enough hydrogen to require an air purge. The RCB hydrogen concentration never exceeded 2.1 percent.

6.8.2 Radiological Evaluation

The radiological evaluation of Case 681 is quite similar to that of Case 675 with the exception of the building vent at 200 hours. The resulting radioactivity release is shown in Figure 6-34. The fact that the sodium never boiled reduced the concentration of suspended radioactivity release considerably. All doses shown in Figure 6-35 are smaller than in Case 675.

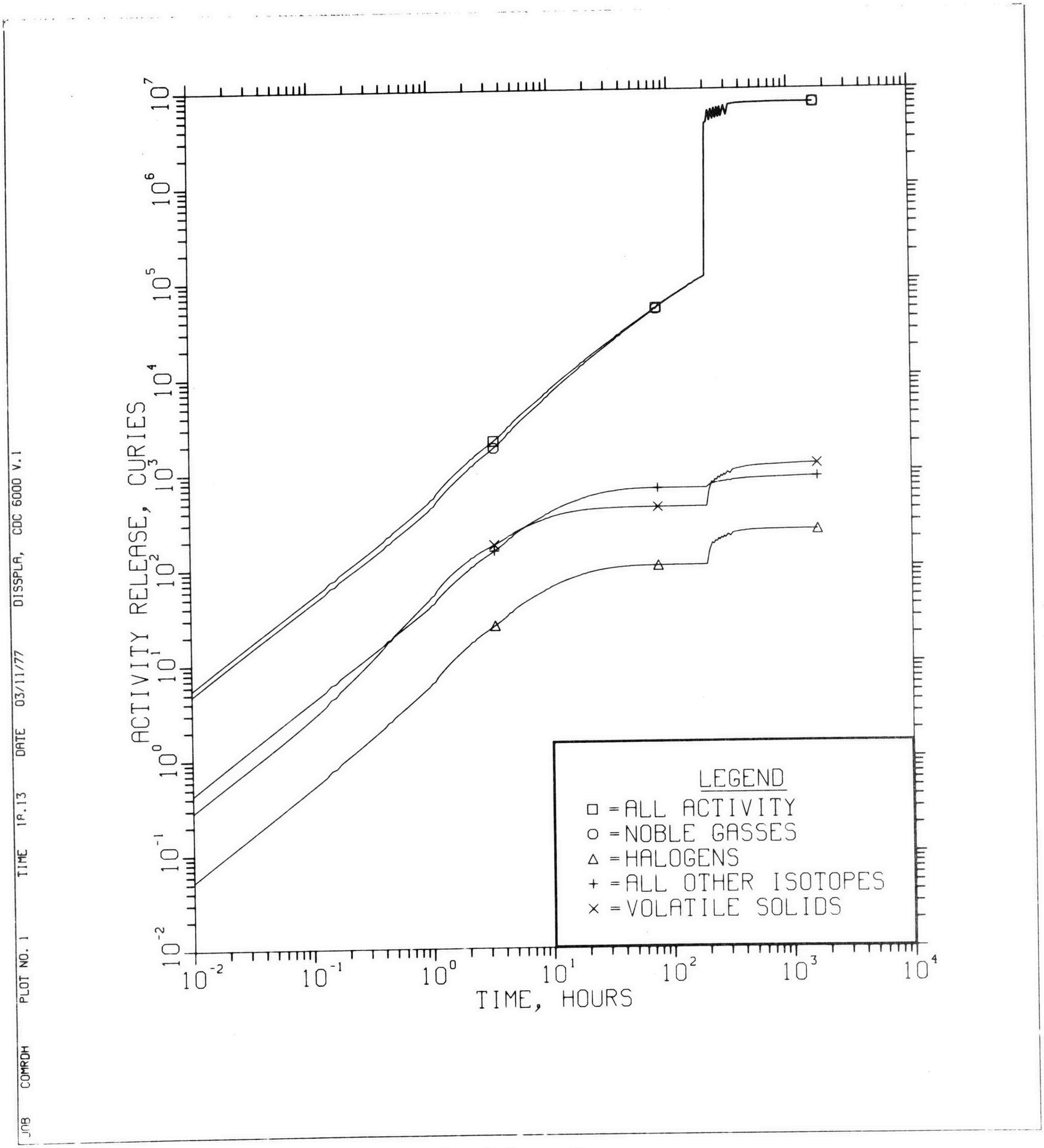

FIGURE 6-34. Case 681 - Activity Release Curves.

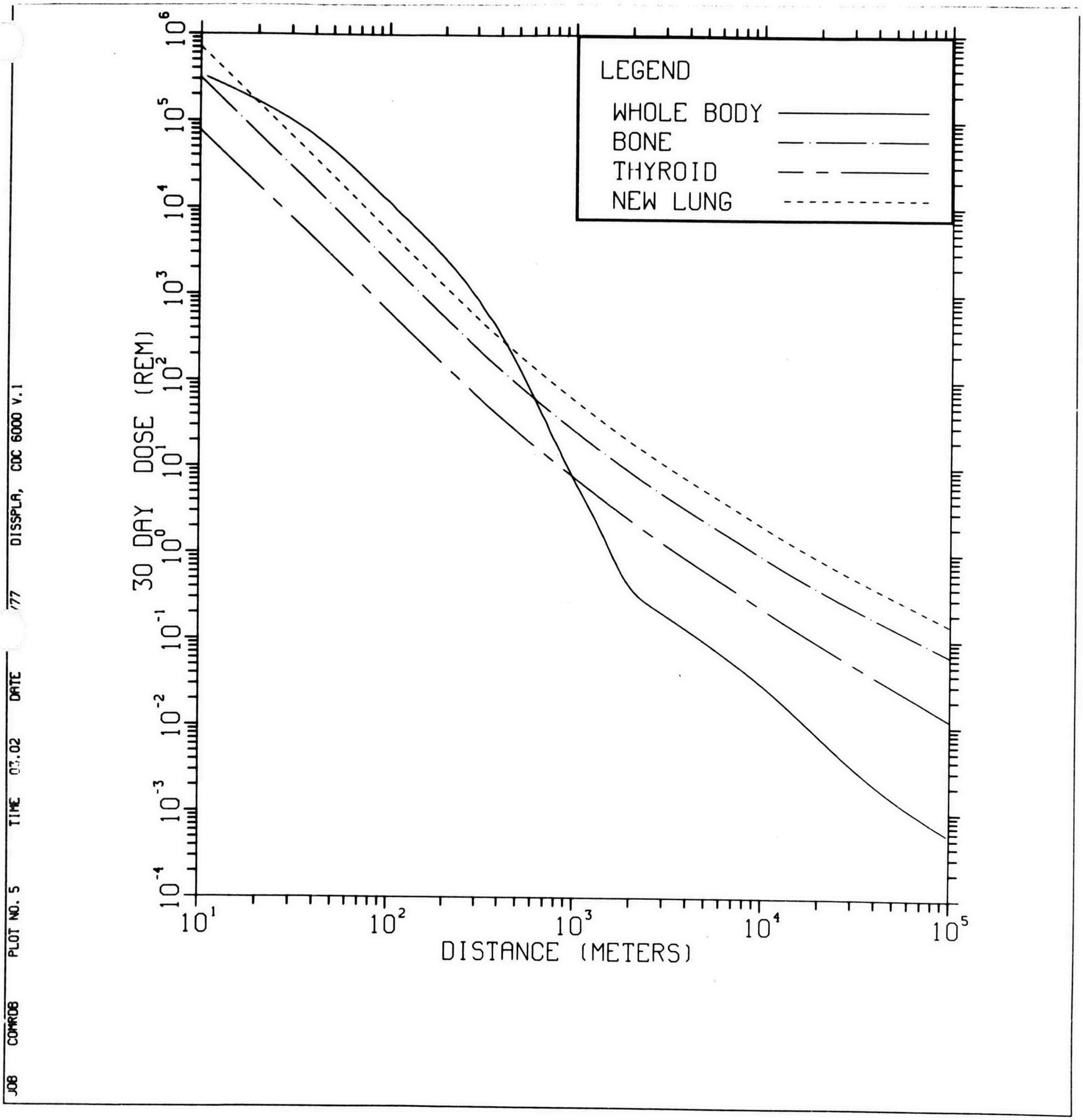

FIGURE 6-35. Case 681 - Dose vs. Distance Curves.

6.9 Case 677

6.9.1 Containment Transients

Case 677 is an ex-vessel case similar to Case 681 but without the natural hydrogen recombination of the latter. Without natural hydrogen recombination, the hydrogen accumulated from water released from the 346 ft^2 failed liner area. The RCB conditions for Case 677 are shown in Figure 6-36. The RCB was vented at 42.2 hours in order to begin the air purge to limit hydrogen concentration to 4 percent. This ventdown released 26 percent of the RCB atmosphere to the outside at an average vent rate, shown in Figure 6-37 at 42-43 hours, of 10,000 ft^3/min.

As in Case 681, the sodium pool in the reactor cavity never boiled. At the end of the case, at 1,632 hours, the RCB atmosphere was 98 percent steam at 222°F.

6.9.2 Radiological Evaluations

In Case 677, the fact that the natural recombination of hydrogen was not included in the CACECO model required that the building would be vented and purged at 42 hours. At that time, the suspended concentration of sodium oxide and fission products from the initial expulsion was still relatively high. Resulting activity release curves are shown in Figure 6-38. The bone and lung doses (Figure 6-39) were therefore the highest of any case run. As in Case 675, the thyroid dose was quite low because the sodium in the reactor cavity never boiled dry and, as a result of the Castleman release model, the iodine would be released toward the conclusion of the sodium release.

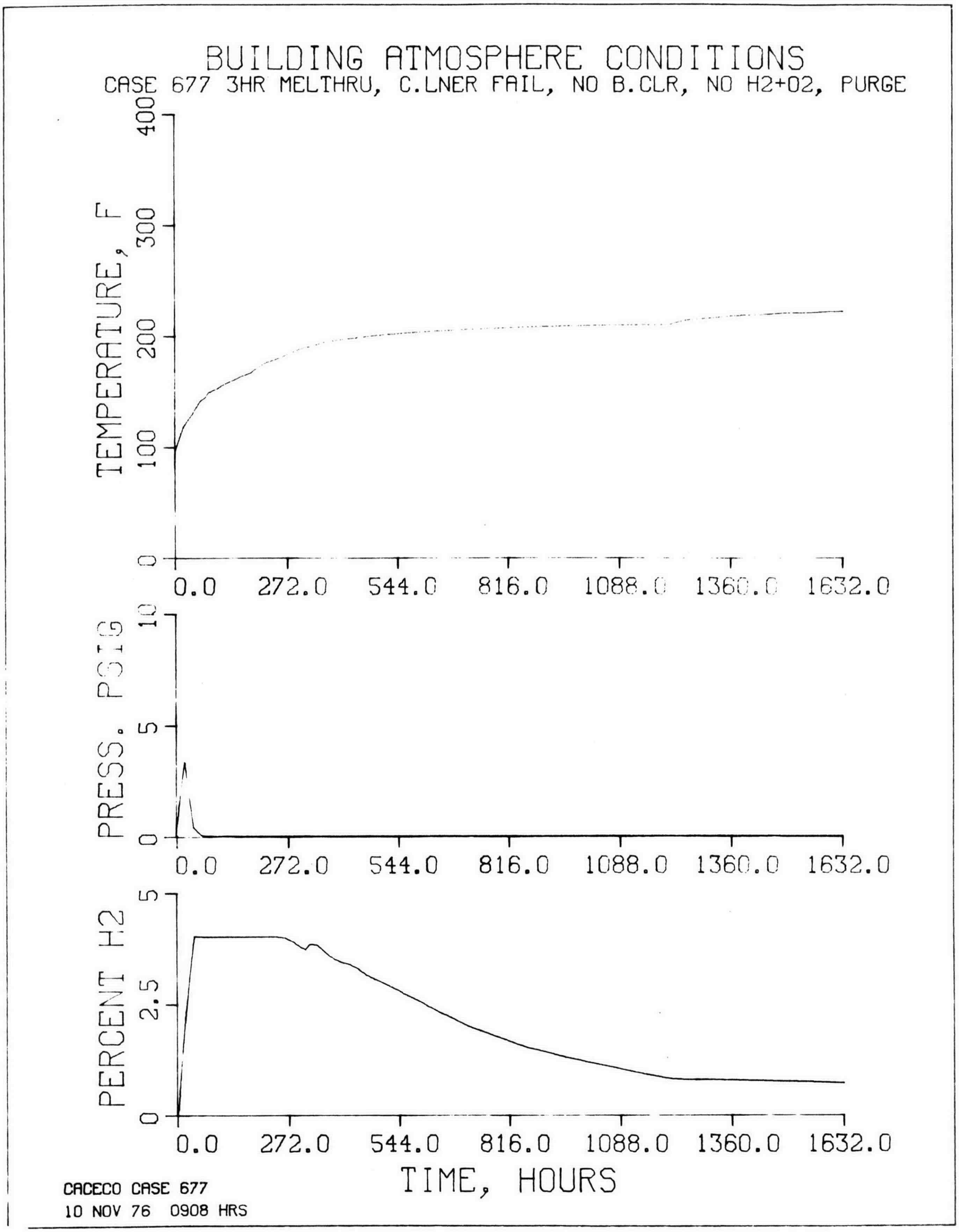

FIGURE 6-36. Case 677 - Building Atmosphere Conditions.

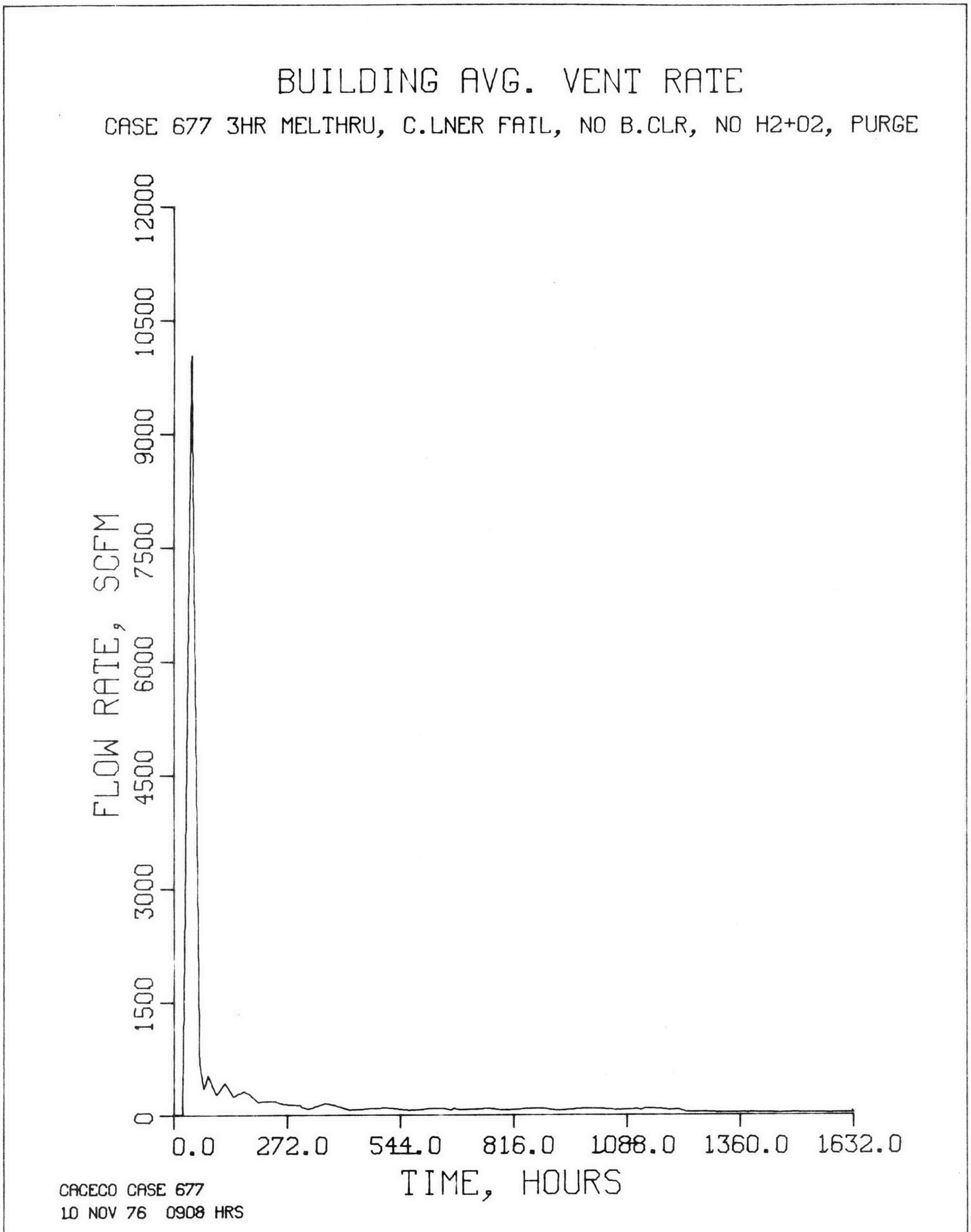

FIGURE 6-37. Case 677 - Building Avg. Vent Rate.

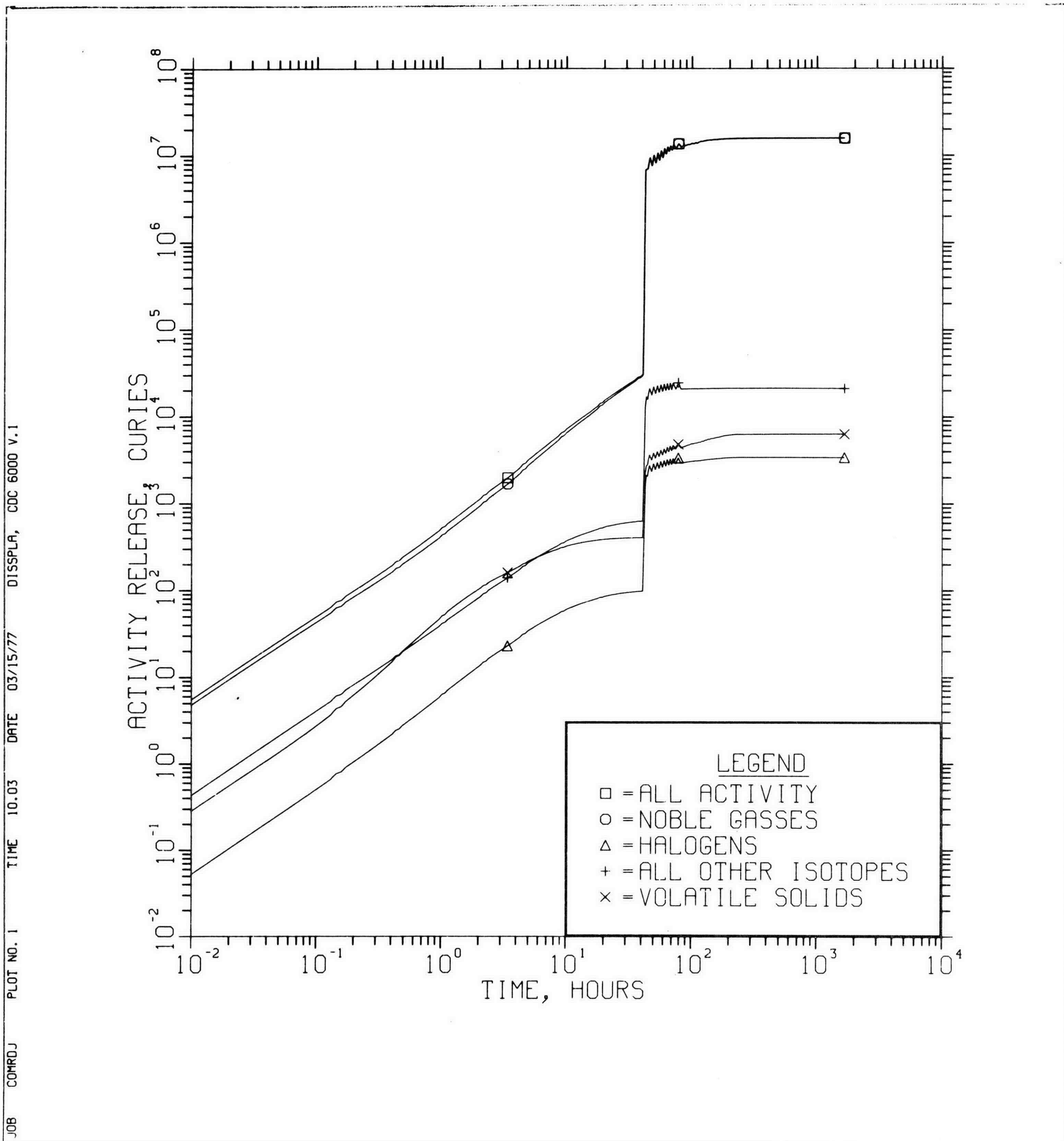

FIGURE 6-38. Case 677 - Activity Release Curves.

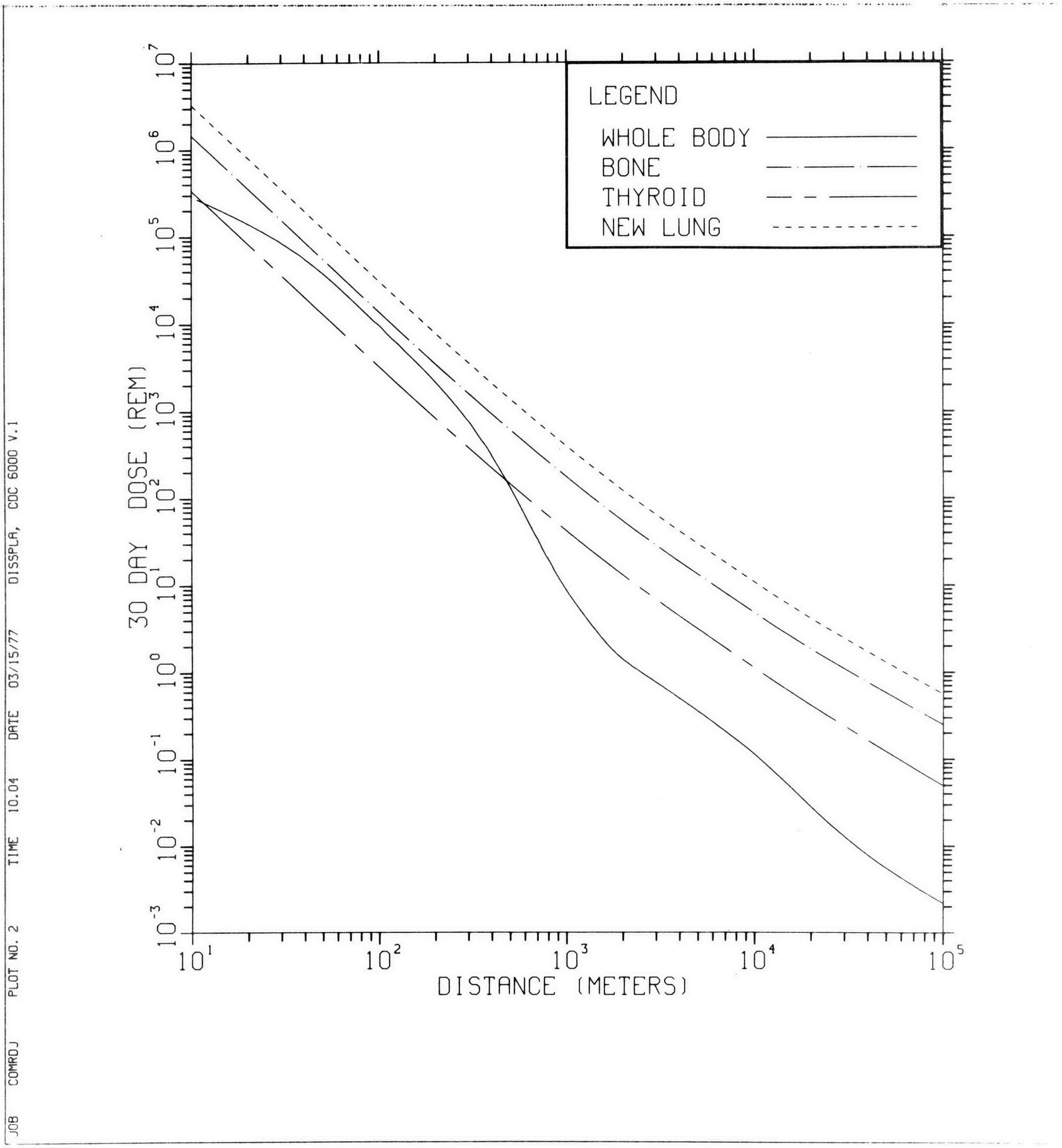

FIGURE 6-39. Case 677 - Dose Vs. Distance Curves.

6.10 Case 678

6.10.1 Containment Transients

Case 678 arbitrarily failed the RCB at a pressure of 20 psig. The analysis assumed natural hydrogen recombination, and no credit for RCB H&V space coolers. There was no air purge to limit hydrogen concentration in the RCB. A failed floor liner area of 346 ft^2 was assumed.

The RCB conditions for Case 678 are shown in Figure 6-40. The steam release from the cavity structures heated and pressurized the RCB. This steam release diluted the hydrogen accumulation and kept its concentration at about 2.2 percent. At 960 hours, the RCB was heated to 219°F, pressurized to 20 psig and the hydrogen concentration was 2.2 percent. The RCB was vented at 960 hours to simulate the overpressure failure. The ventdown is shown in Figure 6-40: by the sharp dip in temperature from 219°F to 187°F; by the sharp fall in pressure from 20 psig to zero; and by the sharp rise in hydrogen concentration from 2.2 percent to 2.7 percent. The ventdown, off the scale of Figure 6-41 at 960-961 hours, released 40,000 ft^3/min.

In Case 678, the sodium pool in the reactor cavity never boiled. After the RCB ventdown at 960 hours, the steam release from the cavity structures replaced the air atmosphere of the RCB. At the end of the case, at 1,632 hours, the RCB atmosphere was 98 percent steam at 217°F.

6.10.2 Radiological Evaluation

Case 678 is similar to Case 675 as far as the radiological evaluation is concerned, except that as pointed out above, the RCB is closed until it reaches twice the design pressure at 960 hours.

Figure 6-42 presents the radioactivity release curves. Oxygen was not depleted in this case, so unlike cases 658 and 659, fallout continued past

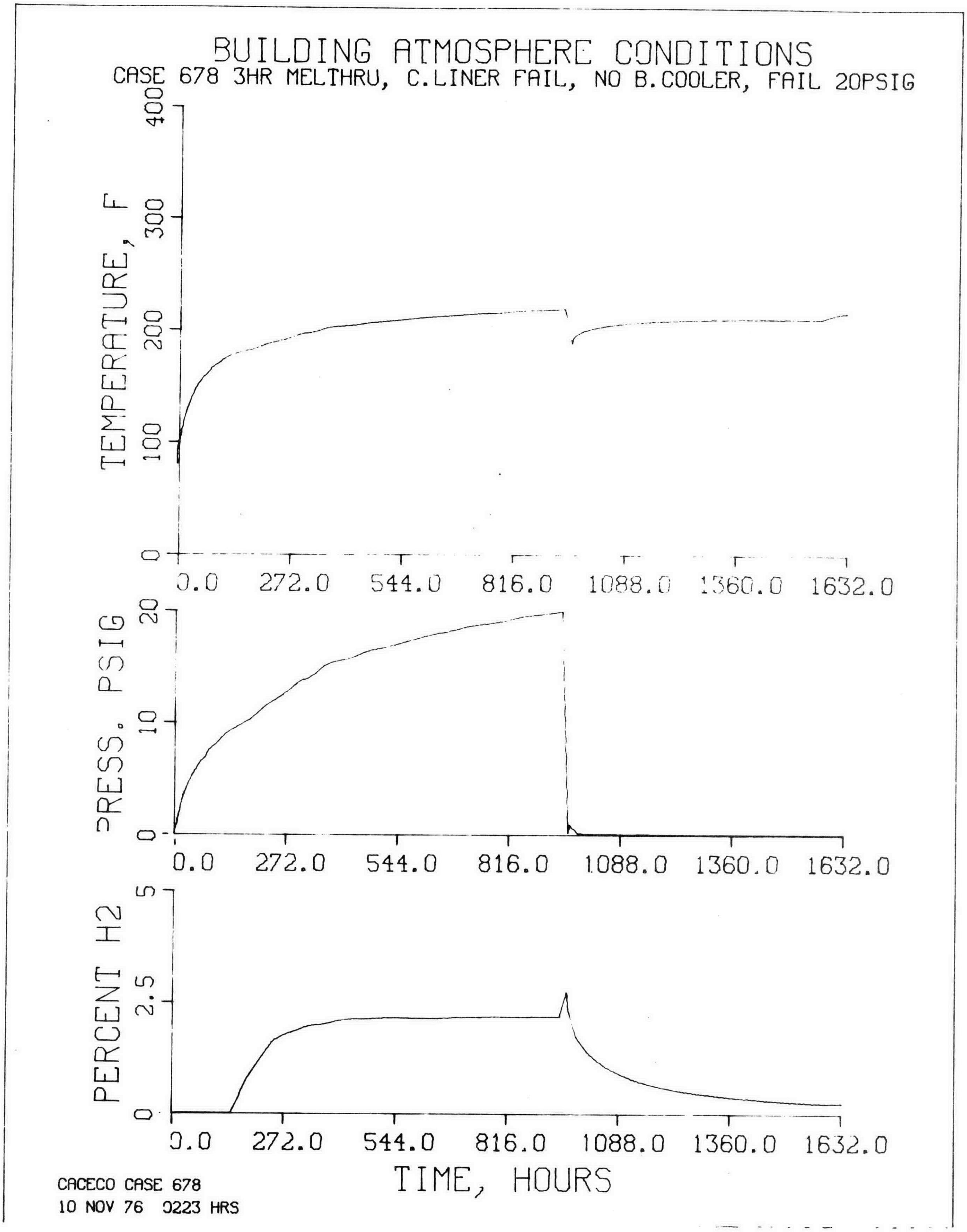

FIGURE 6-40. Case 678 - Building Atmosphere Conditions.

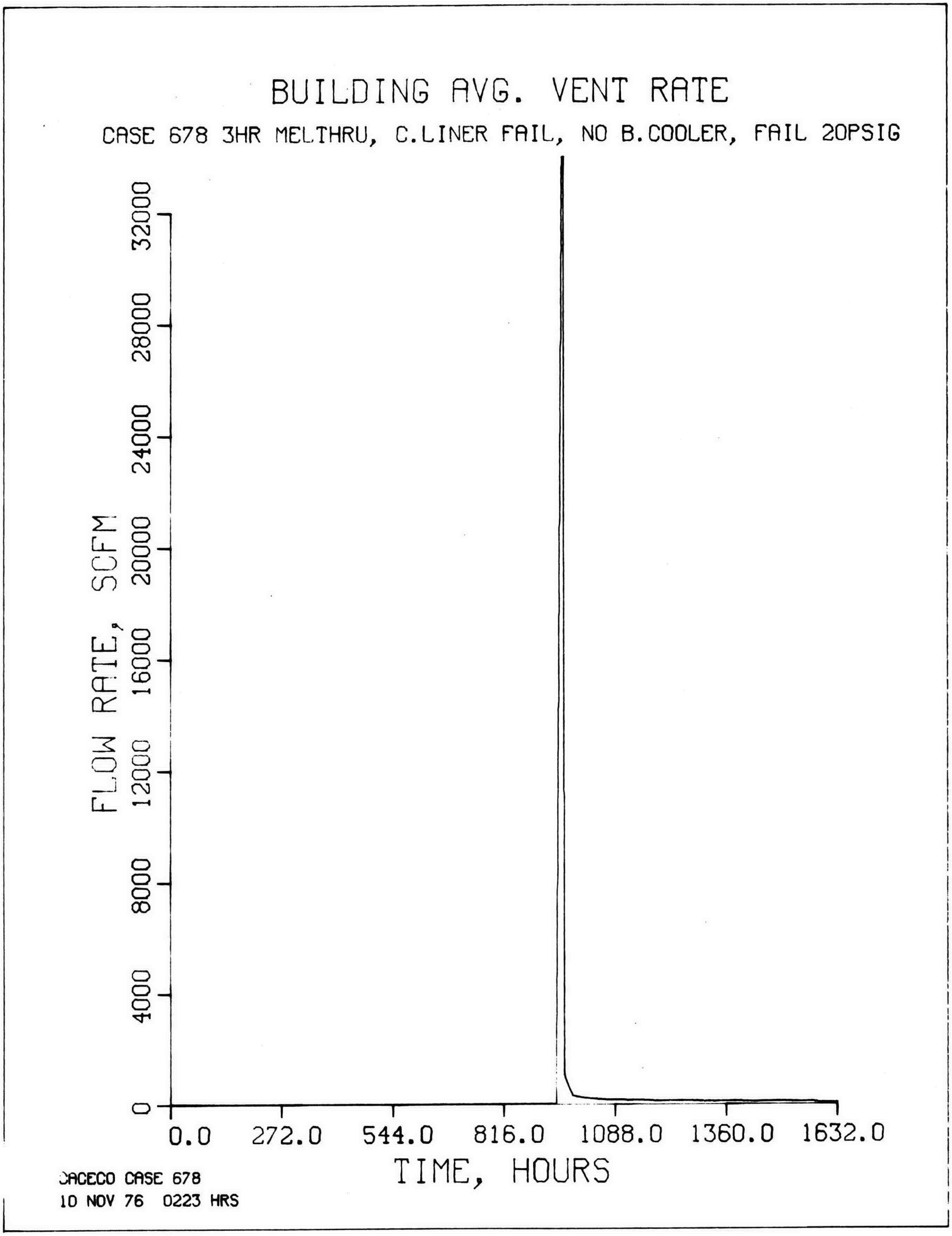

FIGURE 6-41. Case 678 - Building Avg. Vent Rate.

the time of building failure. However, there was little sodium evaporation during that period.

The fallout and decay of sodium and fission products reduced the airborne radioactivity in the containment vessel , so that releases which occurred as a result of the postulated building failure were very small. There was no air purge to sweep out the radioactivity following this time, so calculated doses were low. Thirty day dose vs. distance curves would not have shown the ultimate doses which were increased by the building failure at 40 days. Consequently, Figure 6-43 presents 68-day doses.

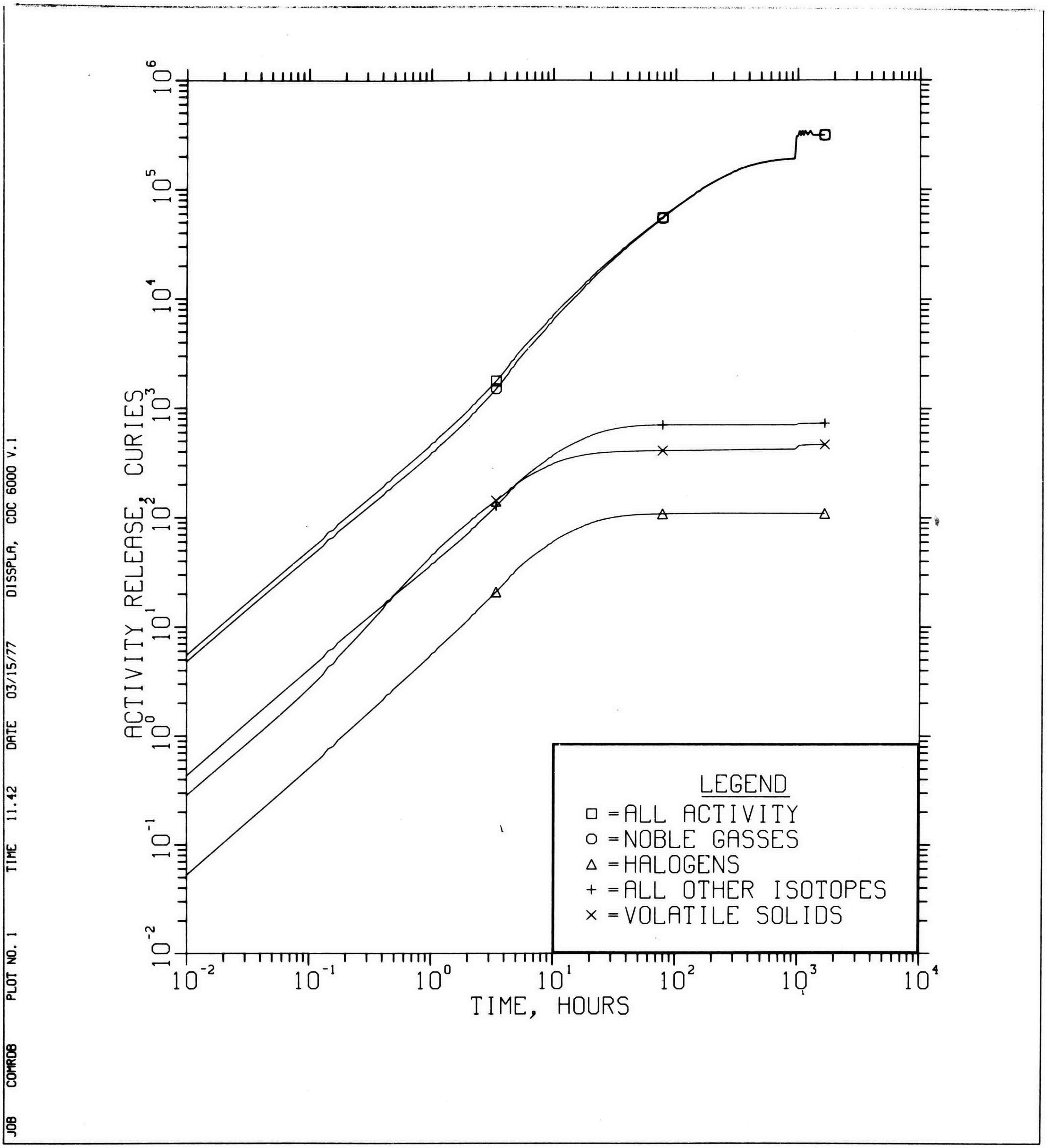

FIGURE 6-42. Case 678 - Activity Release Curves.

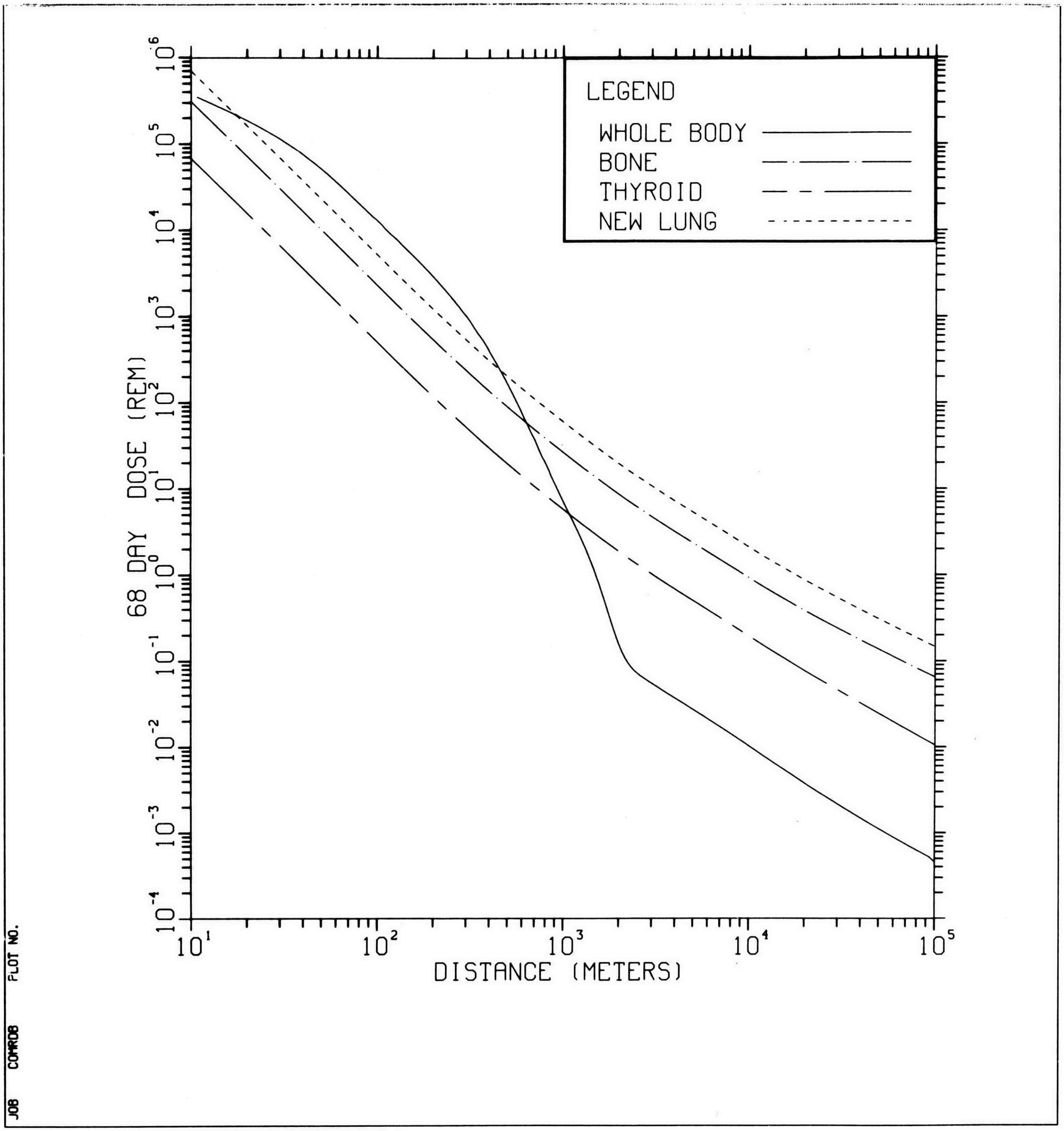

FIGURE 6-43. Case 678 - Dose Vs. Distance Curves.

6.11 Case 682

6.11.1 Containment Transients

Case 682 is an ex-vessel case similar to Case 681 but the assumed cavity floor liner failure allowed the sodium-concrete reaction across 1,402 ft^2 of floor and wall area. The RCB conditions for Case 682 are shown in Figure 6-44. At 55.1 hours the RCB was heated to 182°F and pressurized to 6.4 psig. The RCB was vented at 55.1 hours in order to begin the air purge to limit the hydrogen concentration to 4 percent. This ventdown released 12,800 ft^3/min as shown in Figure 6-45.

A characteristic of the Case 682 air purge following the RCB ventdown at 55.1 hours was the cycle of hydrogen concentrations: flash recombination to zero percent, accumulation, air purge at 4 percent limit and flash to zero again, repeatedly. These hydrogen flash recombination cycles heated the RCB as shown in Figure 6-44 and caused the irregular pattern of hydrogen concentrations and the irregular vent rates shown on Figure 6-45. These cycles were initiated by the code requirement for 11 percent oxygen concentration to initiate the hydrogen-oxygen (recombination) reaction.

In Case 682, the sodium pool in the reactor cavity never boiled. After the air purge stopped at 712 hours, the steam release from the cavity structures replaced the air atmosphere of the RCB. At the end of the case, at 1,632 hours, the RCB atmosphere was 96 percent steam at 226°F.

6.11.2 Radiological Evaluations

The radioactivity release curves for this case are shown in Figure 6-46, and resultant doses at the site boundary are provided in Figure 6-47.

This case is similar to Case 681 except that fission product release proceeds for some time after the vent. Half of the noble gases are released during the vent. The rest are released during the first several hours of purging. The continued evaporation from the cavity during the air purge caused the ramp between 55 and 384 hours on the volatile solids, halogens and the "all other isotopes" curves. "All other isotopes" are released during this period due to formation of isotopes in this group as a result of the decay of volatiles.

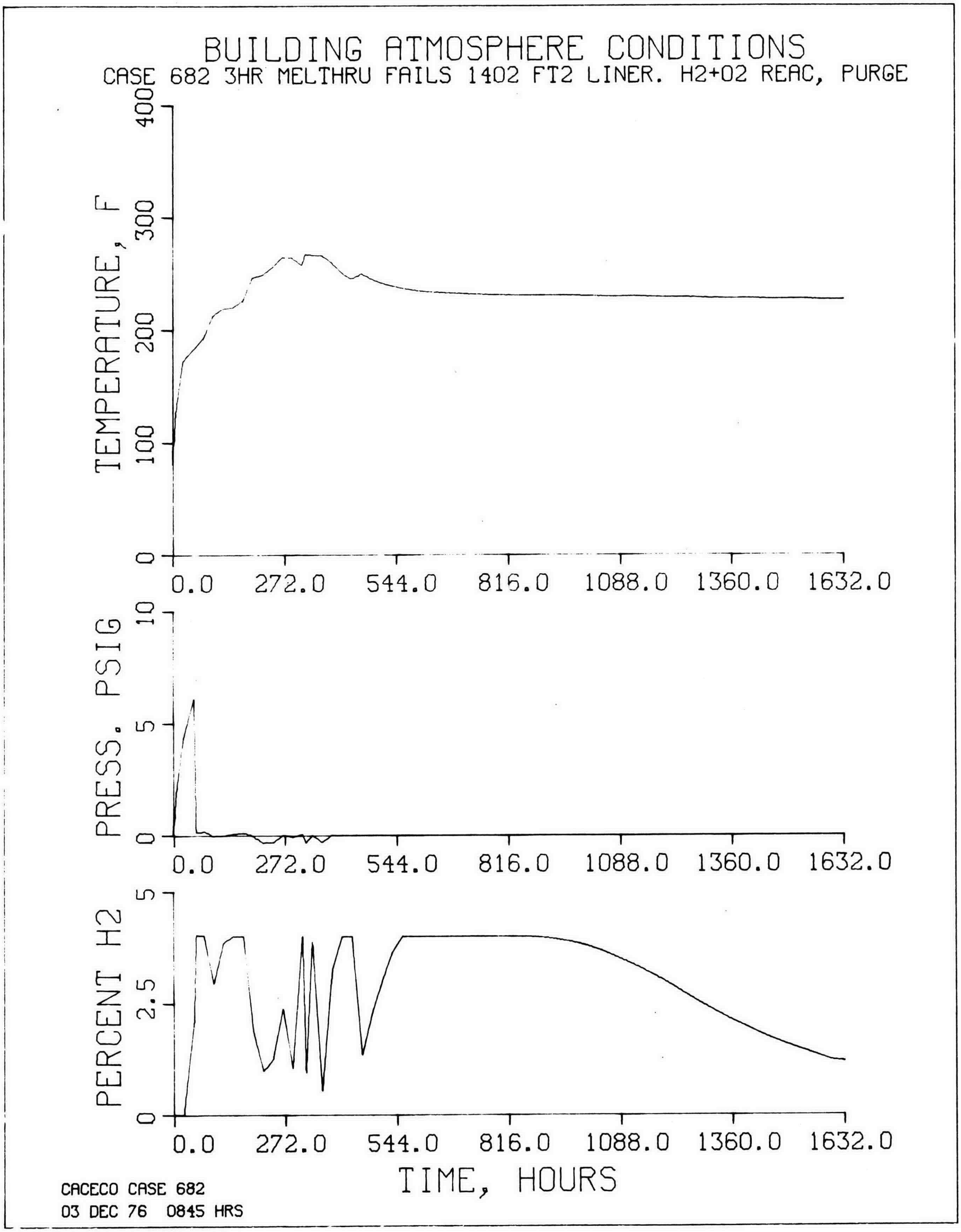

FIGURE 6-44. Case 682 - Building Atmosphere Conditions.

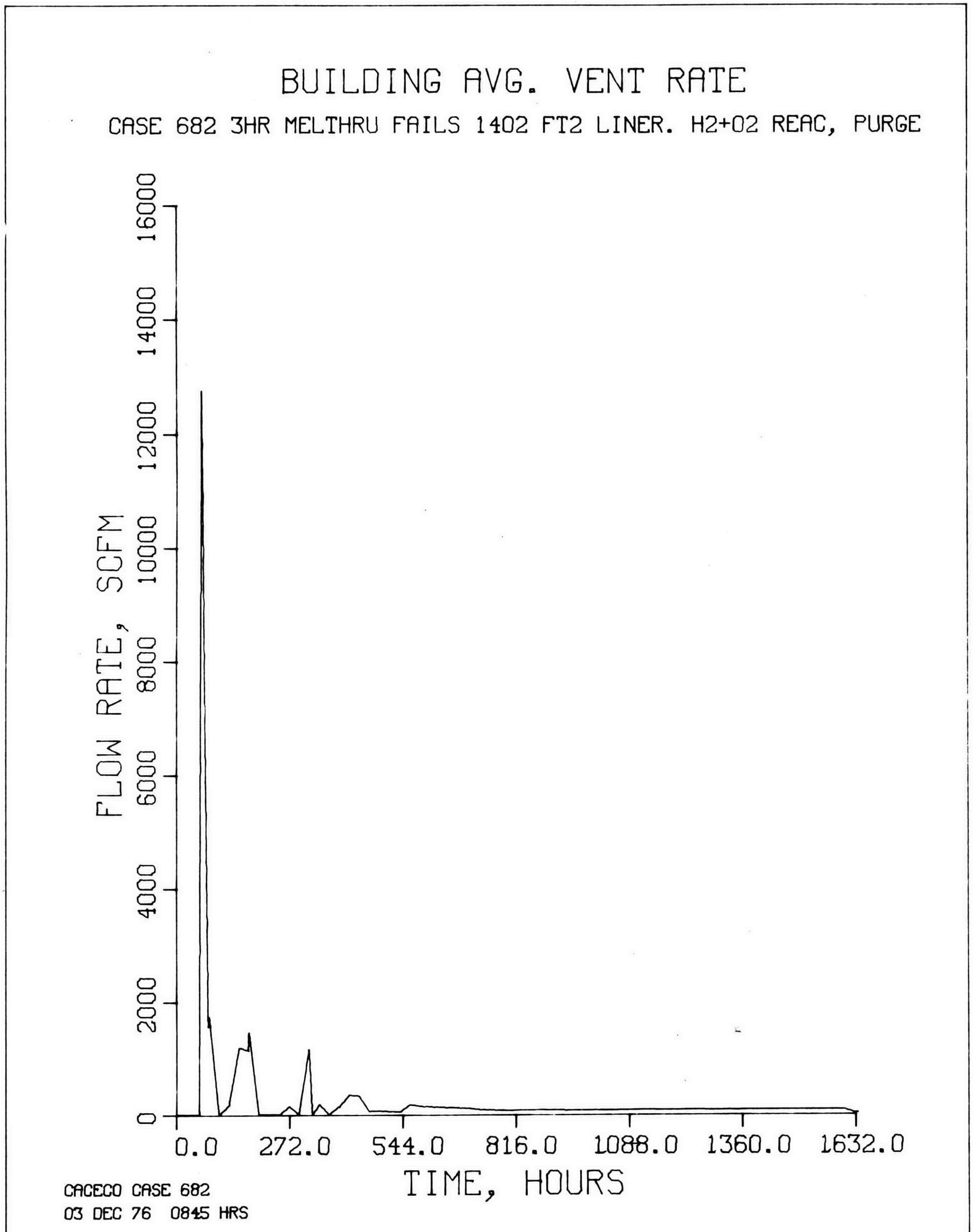

FIGURE 6-45. Case 682 - Building Avg. Vent Rate.

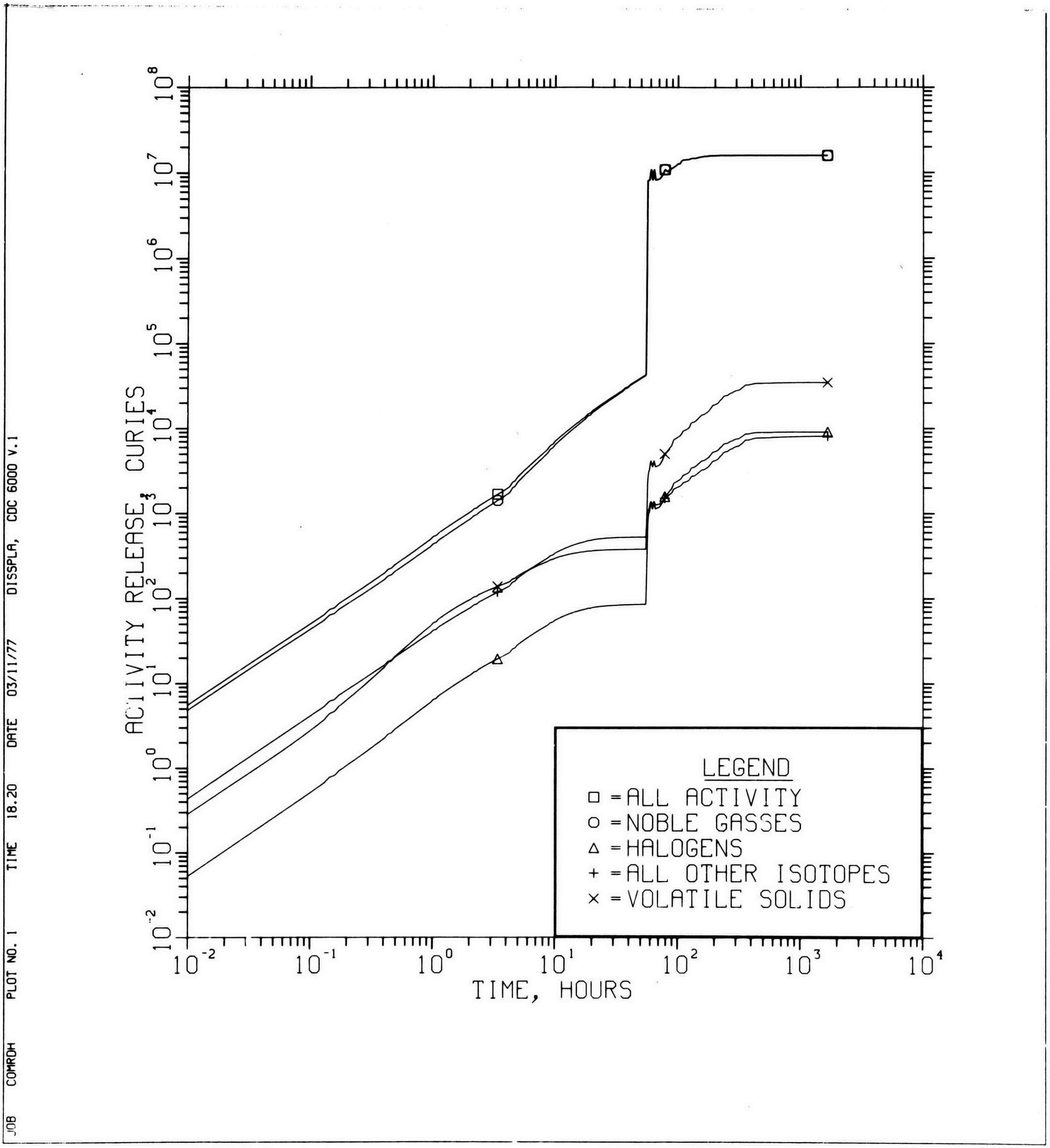

FIGURE 6-46. Case 682 - Activity Release Curves.

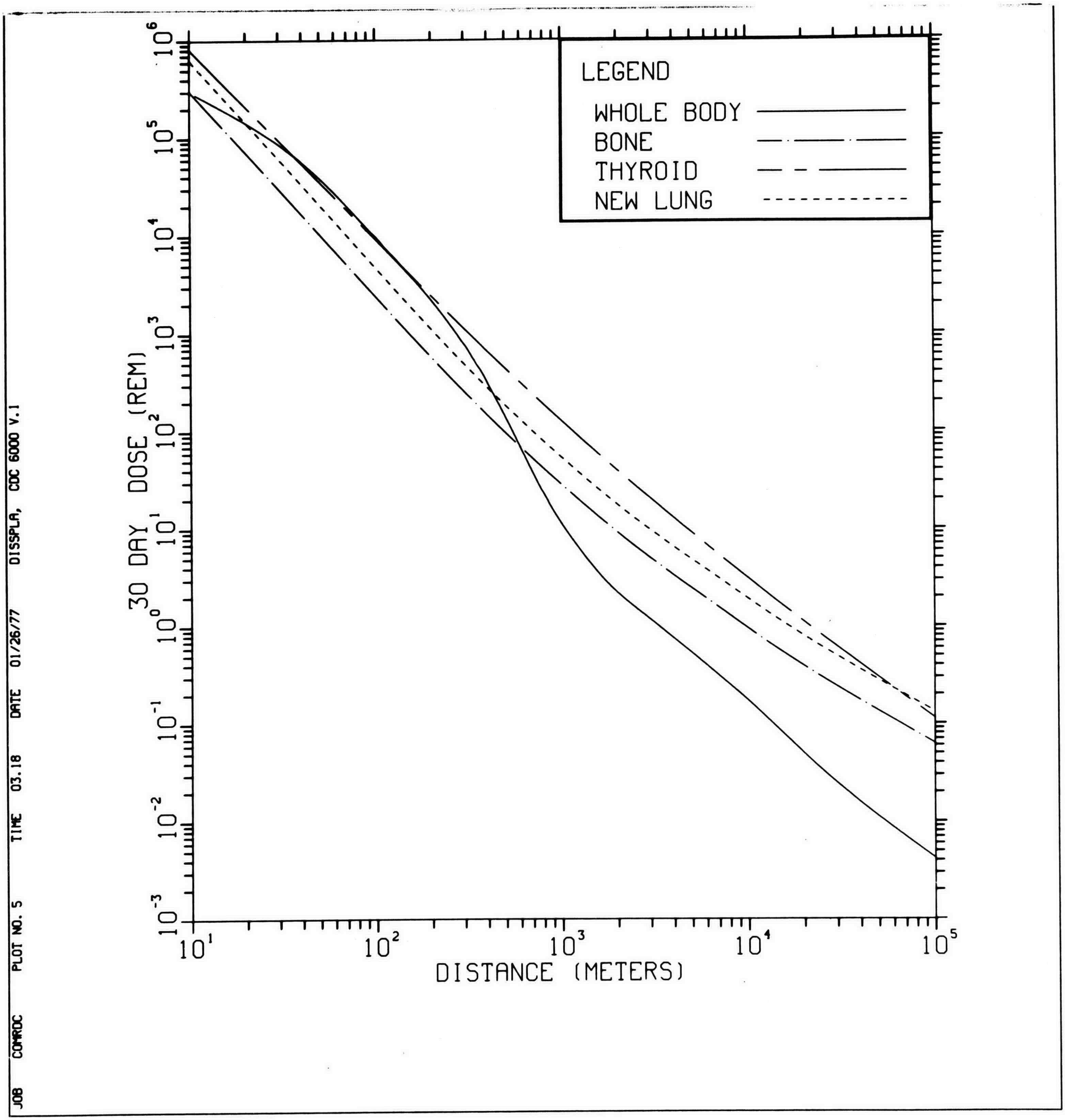

FIGURE 6-47. Case 682 - Dose vs. Distance Curves.

6.12 Case 683

6.12.1 Containment Transients

Case 683 is identical to Case 682 up to 384 hours. The RCB conditions for Case 683 shown in Figures 6-48 and 6-49 are identical to the Case 682 figures up to 384 hours. At 384 hours the Case 683 departed from Case 682 by postulating collapse of the reactor cavity floor. At this time the sodium pool in the cavity was at 1475°F and, with 475,000 lbs of sodium, was about 13.3 feet deep. The floor collapse filled the subcavity with sodium so that the new pool surface was only about 9 feet above the previous floor level. At that time, 1,392 ft^2 of bare concrete was exposed to sodium attack. The sodium-concrete reactions and the attendant sodium-water reactions heated the sodium to boiling in 7 hours (by 391 hours). By 428.7 hours the sodium in the cavity-subcavity had boiled dry; some 33 percent (203,900 lbs) had evaporated-boiled into RCB, 26 percent (162,800 lbs) had reacted with the water release to form sodium oxide in the cavity and sub-cavity and 41 percent (253,000 lbs) had reacted with the concrete.

The cavity boilup period from 384 to 428.7 hours resulted in a steep rise in RCB temperature from 291°F to 1461°F. The air purge and recombination had limited the hydrogen concentration to 4 percent during this period as shown in the bottom curve of Figure 6-48. Associated air purge and vent rates peaked at 19,100 ft^3/min as shown in Figure 6-49. At the end of the boiloff, the vent rate dropped to about 2,800 ft^3/min.

The ex-vessel case scenario assumed, following boil-dry time, that the core debris would melt onto the subcavity floor forming a pool of molten fuel and concrete. The transient temperatures and final disposition of the core debris was the subject of AYER code analysis which is discussed later.

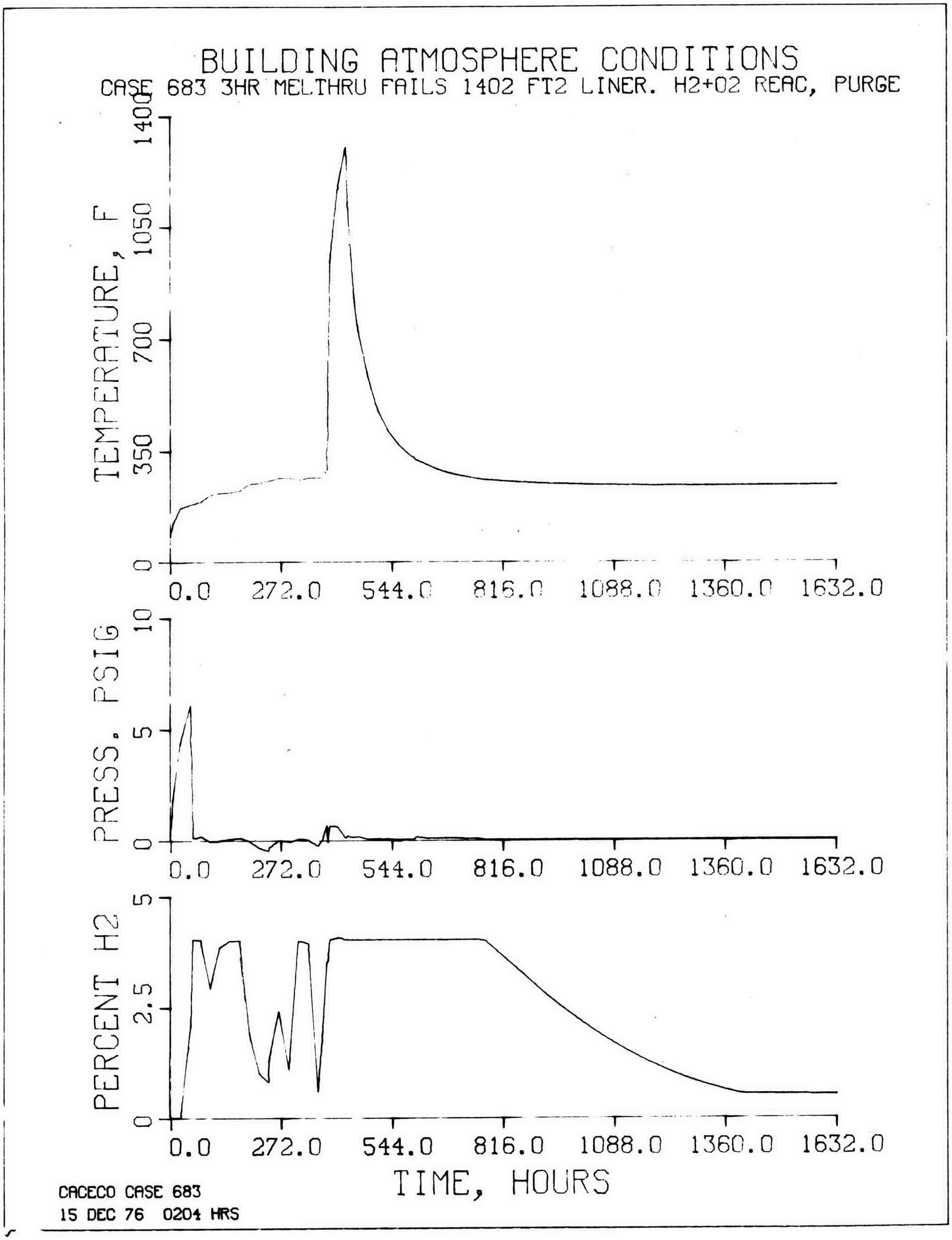

FIGURE 6-48. Case 683 - Building Atmosphere Conditions.

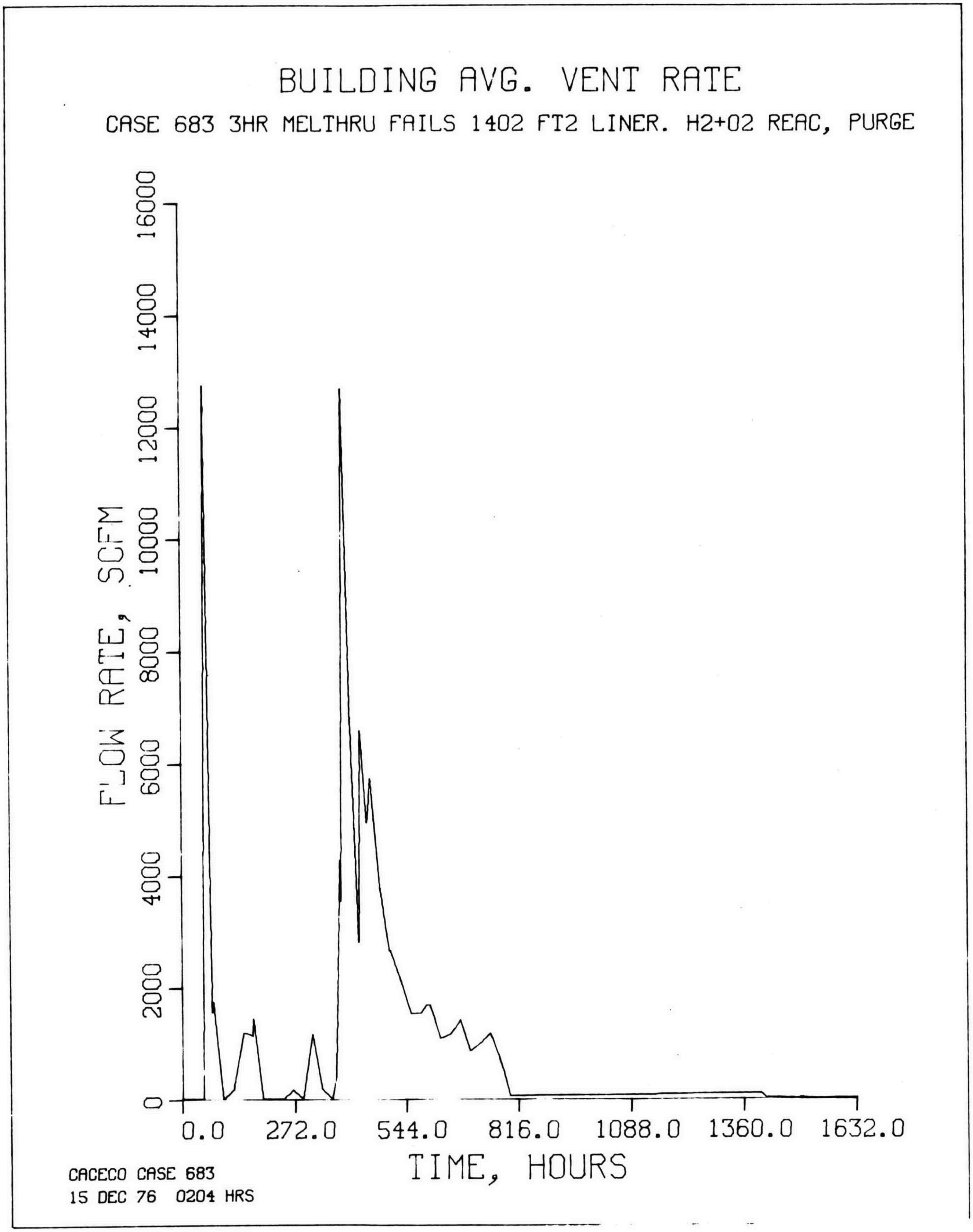

FIGURE 6-49. Case 683 - Building Avg. Vent Rate.

The CACECO code analysis was continued past this boil-dry time in order to predict the RCB conditions that follow. This CACECO analysis assumed a pool of molten stainless steel at 2600°F on the floor of the subcavity, as in previous cases.

This source heated the concrete walls and floor, driving off water vapor which reacted with the 114,000 lbs of stainless steel associated with the debris. At first the water release rate and hydrogen production rate were rapid and the required air purge was reflected in Figure 6-49 by the sharp jump in vent rate to more than 6,000 ft^3/min. The cessation of the sodium boiloff permitted the RCB to cool off as shown in the top curve of Figure 6-48 by the temperature decrease following 428 hours. The water release from the subcavity decreased with time and, at 770 hours, the stainless steel was consumed and the associated hydrogen production, air purge and vent ceased. Thereafter, as shown in the bottom curve of Figure 6-48, the hydrogen concentration was diluted by the water vapor released from the RCB floor, the H&V cooler room, the cavity and subcavity walls, and the subcavity floor. At the end of the case, at 1,632 hours, the RCB atmosphere was 89 percent steam at 238°F.

The AYER code analysis of Case 683 started at 429 hours with the core debris on the 346 ft^2 subcavity floor buried under 5.5 feet of concrete debris from the cavity floor and subcavity walls. The initial conditions for the AYER analysis were arbitrarily set with the fuel debris at its melting point (5160°F). A more realistic temperature would have been that of molten steel (2600°F). Even with the conservative assumption of molten fuel, the core debris, when spilled onto the 1610°F subcavity floor, cooled quickly to 3190°F, as shown in Figure 6-50, at 430 hours. This fuel subsequently heated and melted into the basalt concrete above and below it, forming a molten fuel-concrete pool. The pool size increased by melting upward, sideways and downward into the basalt concrete (melting point taken at 2100°F) until the pool reached the surface at 750 hours. Prior to this time the heat loss from the molten-fuel-concrete pool was limited by the covering of concrete debris. After the pool broke through, 75 percent of the decay power was assumed to be dissipated from the surface.

The average molten fuel-concrete pool temperature, shown in Figure 6-50 increased to a maximum of 4400°F at 1,200 hours (50 days) and then decreased as the molten fuel-concrete pool continued to grow. At 6,220 hours (254 days), the average pool temperature had decreased to 2790°F when the pool volume attained its maximum size of 8,150 ft^3. Also at this time the pool reached its maximum penetration of about 13 feet below the former surface of the subcavity floor.

6.12.2 Radiological Evaluations

Figures 6-51 and 6-52 show the radioactivity release from containment and the 30 day doses for Case 683. Up to the time of floor failure this case is quite similar to Case 682. At 384 hours the assumed failure of the cavity floor causes a sudden boilup and release of the remaining volatiles, mostly I-131. It will be noticed that doses attributed to this case are lower than any of the in-vessel purged cases. This is because decay and fallout had more opportunity to reduce the quantity of material released.

Potential radioactivity release following the sodium boil-dry time was considered, as discussed in Appendix D. It was concluded that releases in the post-boiloff period would not dominate hypothetical accident consequences.

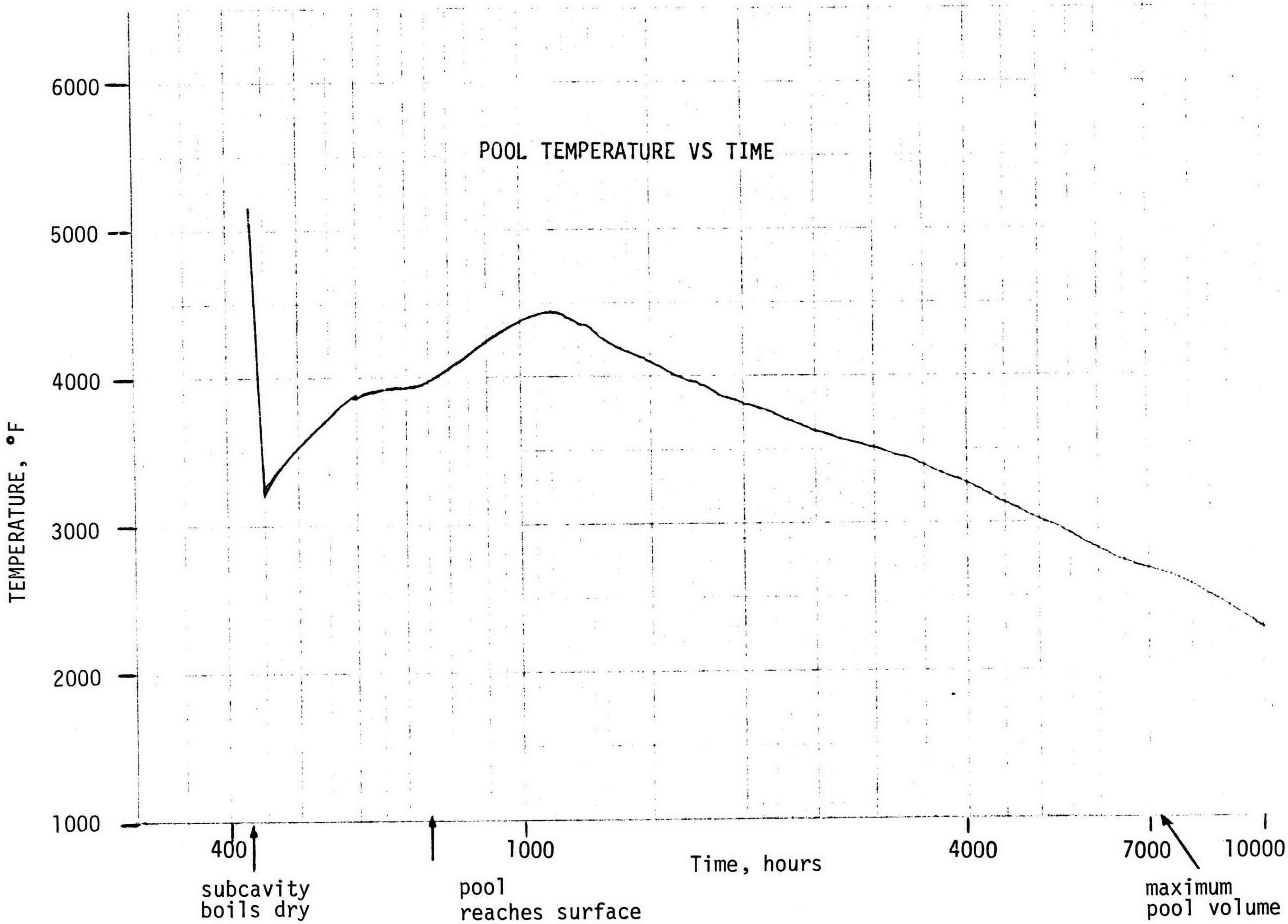

FIGURE 6-50. Case 683 - Average Pool Temperature Vs. Time.

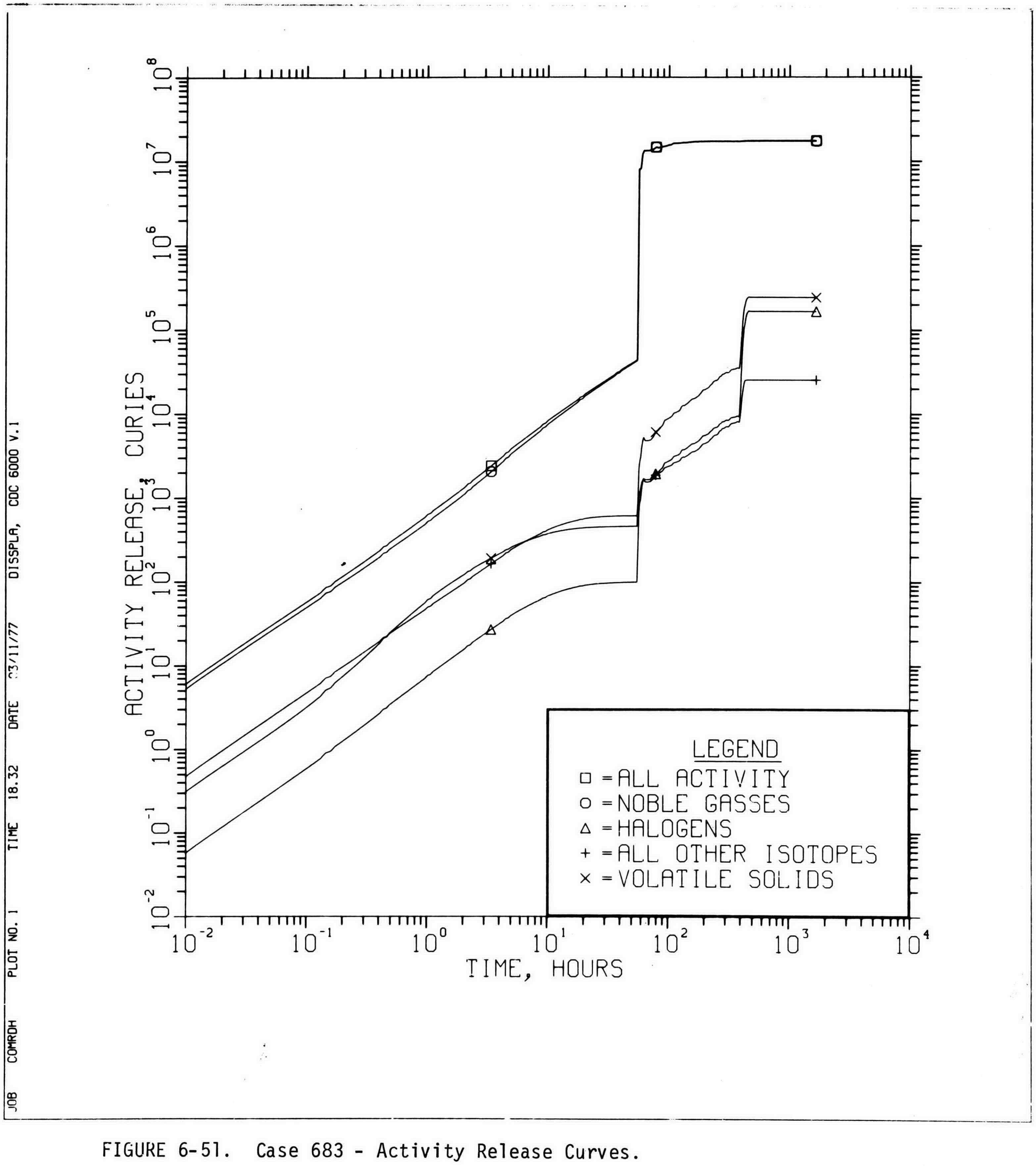

FIGURE 6-51. Case 683 - Activity Release Curves.

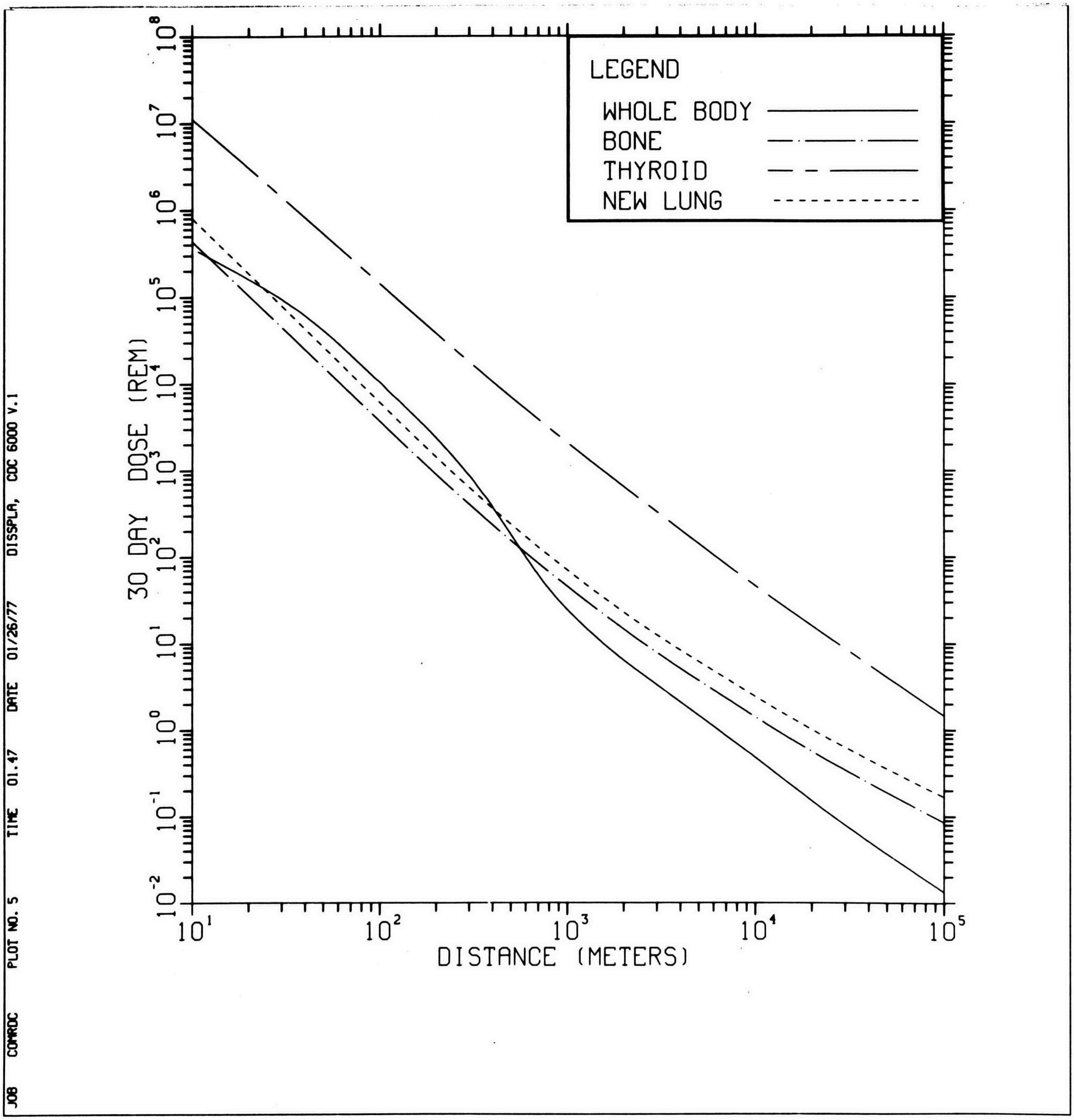

FIGURE 6-52. Case 683 - Dose vs. Distance Curves.

6.13 Case 688

6.13.1 Containment Transients

In Case 688 the RCB was arbitrarily assumed to fail at a pressure of 20 psig (twice the design pressure). The analysis assumed natural recombination, without benefit of RCB H&V space coolers. There was no air purge to limit the hydrogen concentration in the RCB. A cavity floor liner failure area of 346 ft^2 was assumed. Case 688 is identical to Case 678 up to 1,008 hours. At 150 hours the hydrogen recombination in the RCB stopped and at 960 hours the RCB was vented to simulate the overpressure failure.

The RCB conditions for Case 688 are shown in Figures 6-53 and 6-54. Up to 1,008 hours, the interpretation of these Case 688 figures is identical to the comparable Case 678 figures. At 1,008 hours Case 688 departed from Case 678 by incorporating the calculated collapse of the reactor cavity floor. At this time the sodium pool in the cavity was 1474°F and, with 589,200 lbs of sodium, was about 15.5 feet deep. The floor collapse spilled core debris and sodium into the subcavity and resulted in a new pool surface about 11 feet above the previous floor level (the surface dropped about 4.5 feet) and exposed 1,392 ft^2 of bare concrete to sodium attack. The sodium-concrete reactions and the attendant sodium-water reactions heated the sodium to boiling in 3 hours (by 1,011 hours). By 1,062.4 hours the sodium in the cavity-subcavity had boiled dry; some 42 percent (247,800 lbs) had evaporated-boiled into the RCB, 5 percent (31,400 lbs) had reacted with the water release to form sodium oxide in the cavity and subcavity and 53 percent (309,900 lbs) had reacted with the concrete.

This cavity boilup period from 1,008 to 1,062.4 hours is shown in the top curve of Figure 6-53 by the steep rise in RCB temperature from 201°F to 1204°F and in the bottom curve of Figure 6-53 by the steep rise in hydrogen concentration from 1.4 percent to 99.7 percent. This surge in hydrogen production had two sources: the 80 percent steam atmosphere in the RCB just before the floor collapse and the water release from the bare

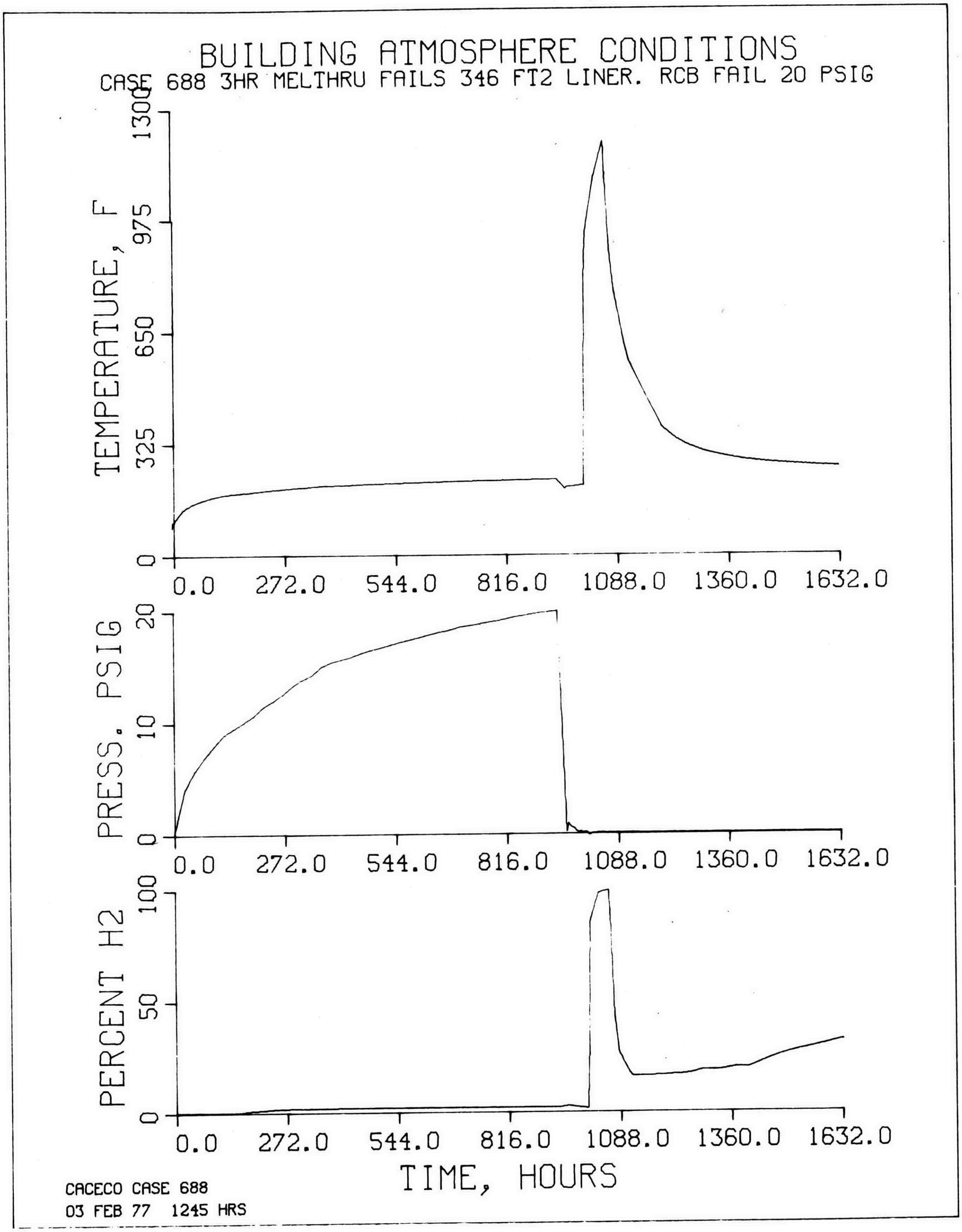

FIGURE 6-53. Case 688 - Building Atmosphere Conditions.

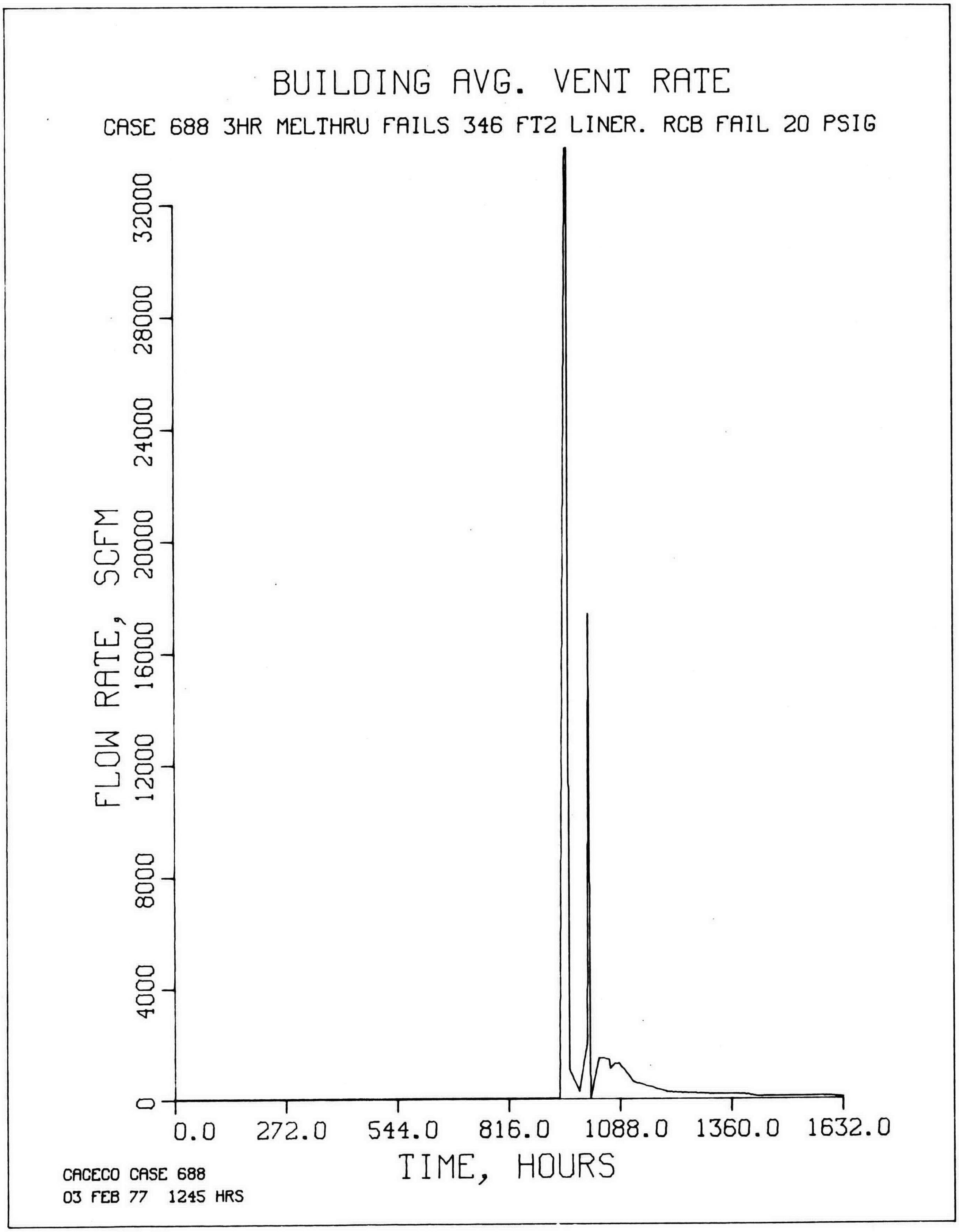

FIGURE 6-54. Case 688 - Building Avg. Vent Rate.

concrete in the subcavity just after the collapse. The peaks in the RCB vent rate shown on Figure 6-54 occur at 960 hours at ventdown and again during the boiloff period after floor failure.

In Case 683 the floor was postulated to collapse at 384 hours, when the subcavity had heated to 245°F; some 26 percent of the sodium reacted with the water release from the bare concrete and the boiloff period lasted 44.7 hours. In comparison, in Case 688 the floor collapsed at 1,008 hours when the subcavity had heated to 335°F. Thus, the delay permits greater dehydration of subcavity concrete, so that only 5 percent of the sodium reacted with the water release from the bare concrete and the boiloff period was extended to 54.4 hours.

In Case 688 from 1,008 hours to the end, the 2600°F source simulated, in CACECO, the molten core debris on the subcavity floor. This source heated the concrete walls and floor, driving off water vapor which reacted with the 114,000 lbs of stainless steel associated with the debris. The heat soaked through cavity and subcavity walls into the H&V cooler room and boiled the condensate pool. The cessation of the sodium boiloff permitted the RCB to cool off as shown in the top curve of Figure 6-53 by the temperature decrease following 1,062 hours. Water release from the cavity walls and the boilup from the H&V cooler room diluted the hydrogen in the RCB, although this dilution was lessened by the hydrogen production in the subcavity. The hydrogen concentration shown in the bottom curve of Figure 6-53 dropped to a minimum of 16 percent at 1,201 hours and then increased. The steel was consumed by about 1,620 hours, which terminated the hydrogen production.

At case end, 1,632 hours, the RCB atmosphere was cooled to 250°F and the hydrogen concentration diluted to 32 percent.

6.13.2 Radiological Evaluation

Case 688 is similar to Case 678 until 1,008 hours, when the reactor cavity floor fails; this can be seen from the radioactivity release curves in Figure 6-55. The building vented at 960 hours and the cavity floor failed at 1,008 hours; the 48-hour time differential is lost in the COMRADEX time step size, so only one step change is seen. TRIMIT has integrated all points under the leak rate curve, so that no leakage has been overlooked. The expulsion of noble gases is the same as for Case 678, but the concentrations of the volatiles that are airborne due to vigorous reaction in the reactor subcavity are increased two orders of magnitude. The solids (all other isotopes), which are daughters of the volatiles, are increased by about a factor of 30. The dose distance curve (Figure 6-56) is for 68 days, to reflect the increases which occurred during building failure. Like Case 658, rainout was neglected, but the effect upon the already small thyroid dose would be negligible.

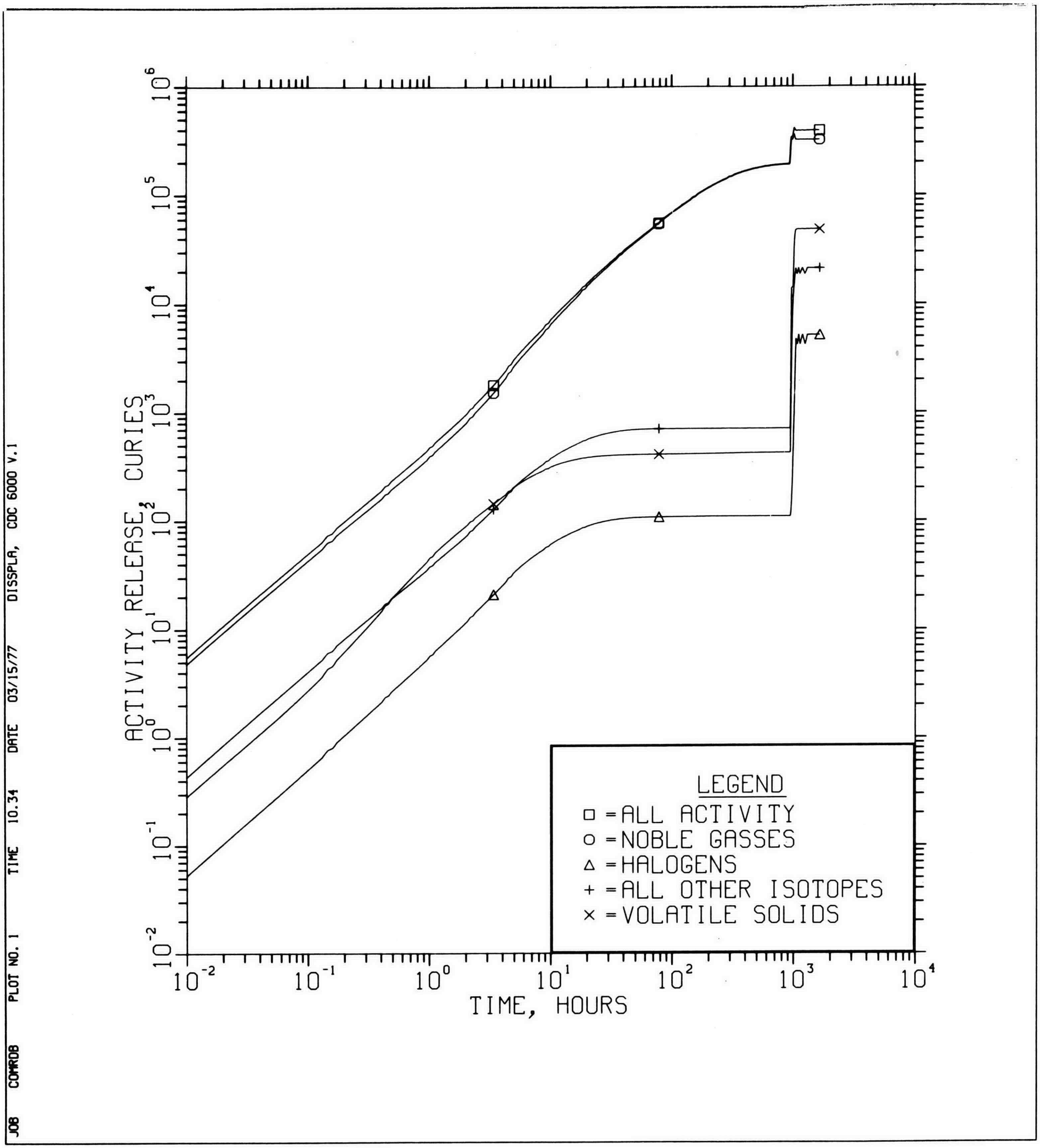

FIGURE 6-55. Case 688 - Activity Release Curves.

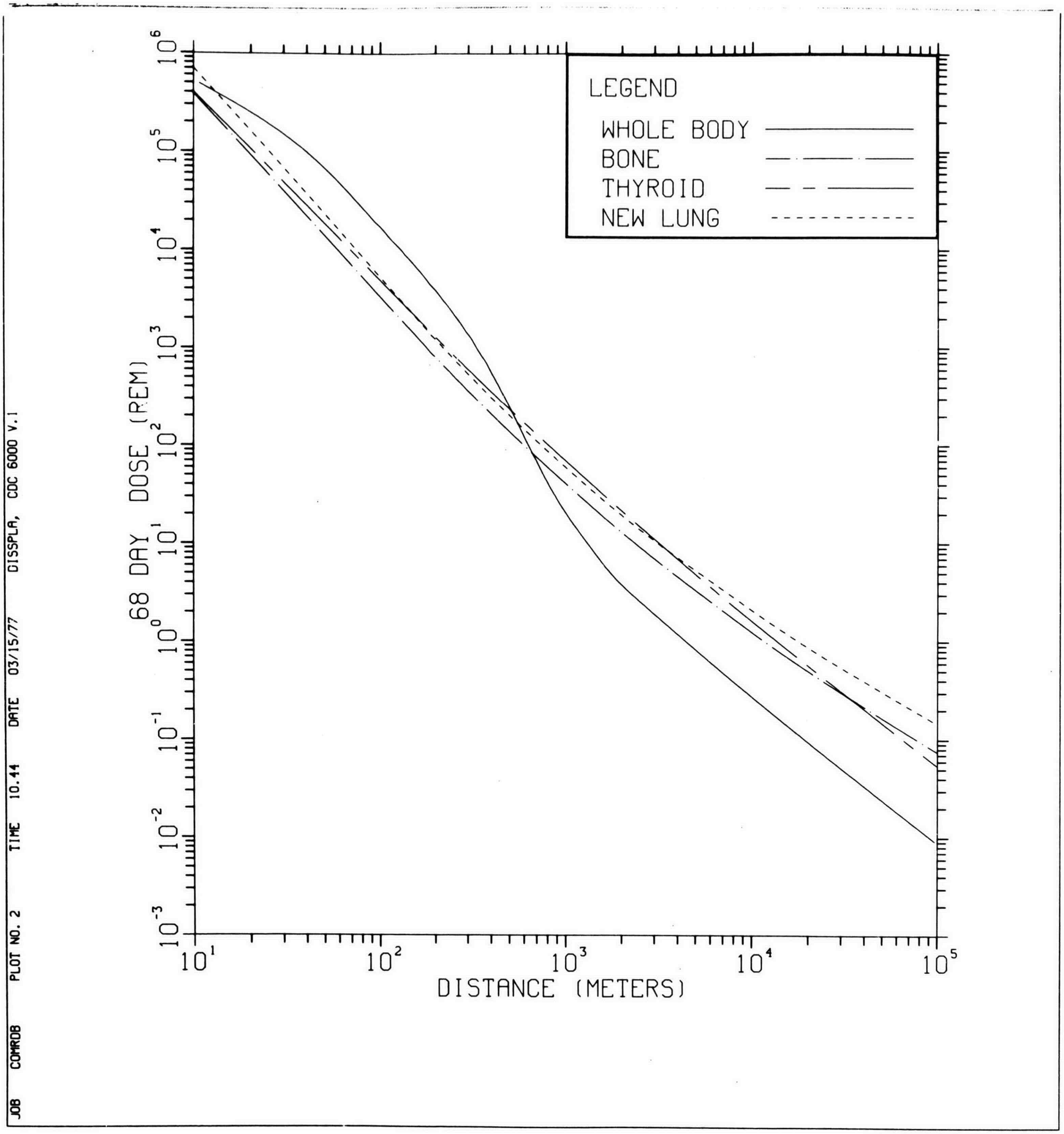

FIGURE 6-56. Case 688 - Dose Vs. Distance Curves.

6.14 Effect of Filtration on Release and Doses

A further variation in the analyses was introduced to determine the effect of filtering the containment building vent and purge exhausts. The building leakage cannot be collected, thus cannot be filtered. It was assumed that filtration began at the time of vent and continued throughout the remainder of the run. The "F" suffix on the Case number denotes filtration. Cases 658, 678, and 688 assume that the building fails at twice design pressure, so filtration is not applicable. In all cases, the portions of the release curves prior to the vent time are identical to their nonfiltered counterparts. A typical example is shown in Figure 6-57. At the time of vent, the effluent is assumed to pass through a filtration system which removes 99.0 percent of the particulates. The halogens were assumed to exist as halides of sodium and, therefore, were assumed to be equally subject to filtering. The rise in the curves for halogens, volatile solids, and "all other isotopes" was reduced two orders of magnitude. Since no filtration efficiency was assumed, the noble gas curve continued to be the same as for the nonfiltered cases. (Case 659 was an exception; since the relief valve maintained a relatively constant pressure of 10 psi within the building following the initial relief, a finite leakage from the building did not pass through the filters. It was estimated that this bypass leakage would not exceed 2 percent of the exhaust flow, so the filter efficiency was reduced accordingly to 97 percent). Figure 6-58 shows a dose distance curve as an example of a filtered case. The remainder of the activity release curves and the dose vs. distance curves for the filtered cases are provided in Appendix B-3.

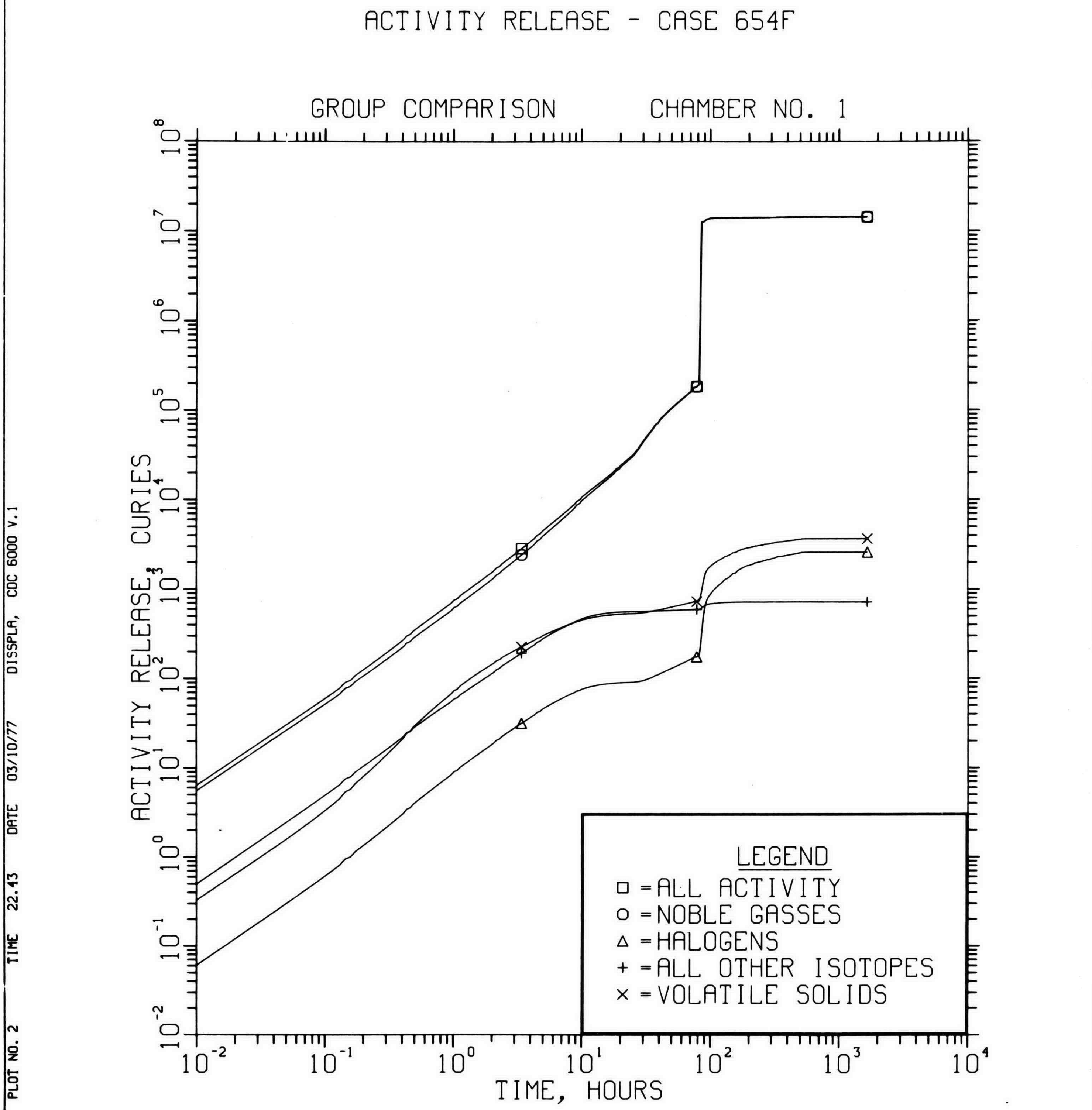

FIGURE 6-57. Case 654F - Activity Release Curves.

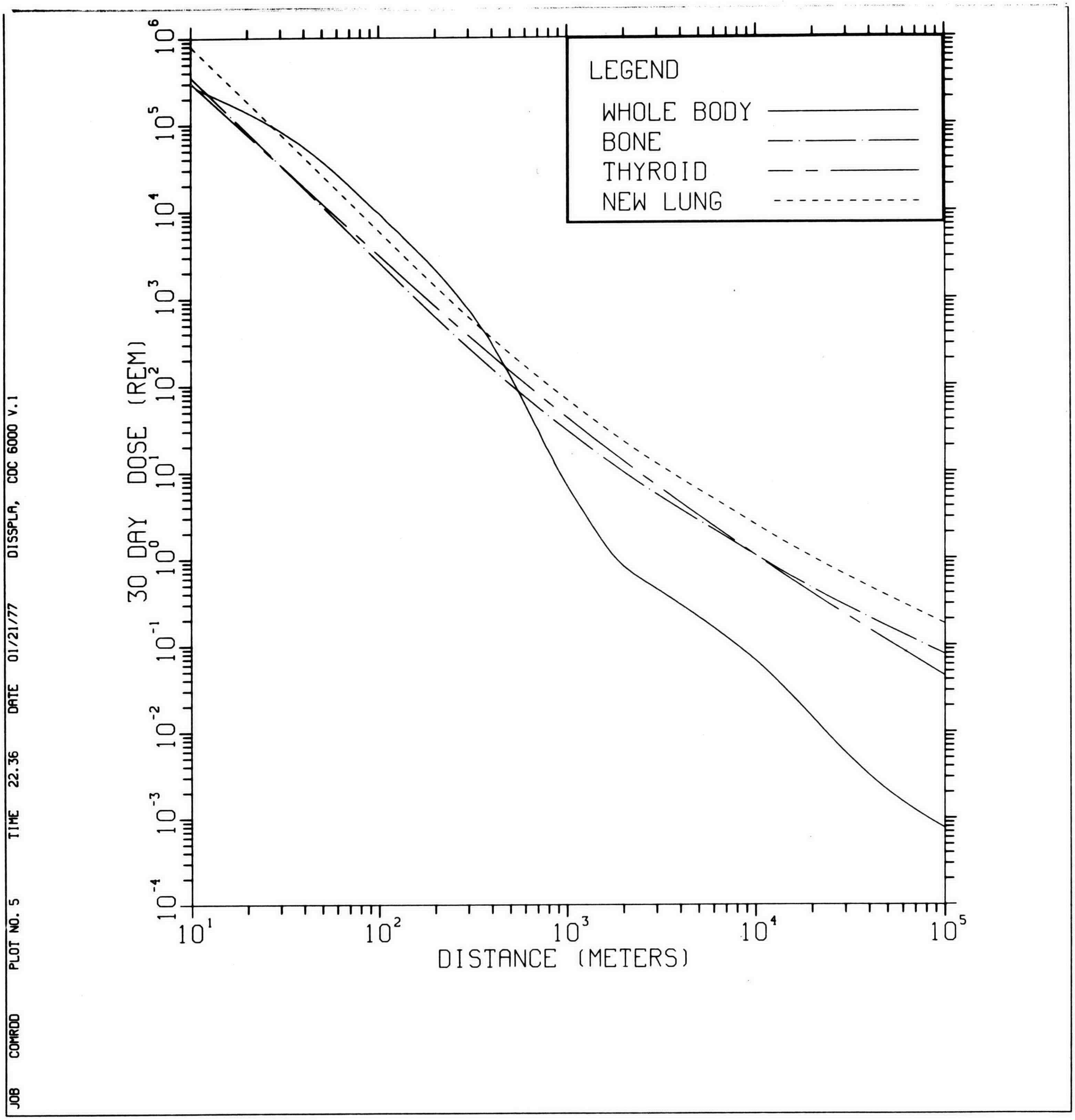

FIGURE 6-58. Case 654F - Dose vs. Distance Curves.

7.0 REFERENCES

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APPENDIX A

CALCULATION BASES FOR CONTAINMENT CONDITIONS

The CACECO code analysis of the containment conditions considers postulated phenomena related to the post-accident heat removal events. These phenomena, including heating by isotope decay, concrete properties, chemical reactions, and heat adsorption in structures, are described in detail in this appendix.

These calculational details are followed by the case summaries for each of the 13 cases and then by the figures for each case. The contents of this appendix follow.

Contents of Appendix A

Section	Title
I	HCDA Release into the Reactor Building
II	Total Fission Product Decay Power
III	Sodium Radioactivity
IV	Concrete Data
V	Chemical Reactions of Sodium
VI	Hydrogen Recombination
VII	Heat Transfer Models
VIII	Mass Transfer (Leakage) Models
IX	References
X	Case Summaries
XI	Case Figures

I. HCDA Release into the Reactor Building

The HCDA scenario of phenomena include the following nonmechanistic releases through the reactor head into the atmosphere of the head compartment-reactor containment building (RCB):

(1) 300 lbs of sodium at 1050°F

(2) 1 percent of the core fuel

(3) 1 percent of core fission products

(4) 100 percent of the noble gas fission products from the core.

This CACECO analysis covered the immediate effects of the foregoing releases which heat the RCB atmosphere to 214°F. These effects fade, and by 3 hours the atmosphere is at 98°F. Thereafter, radioactive decay of this initial release contributes to the heating of the RCB atmosphere. This calculation was made to establish structural temperatures. Initial conditions for the radiological evaluation were computed as described in Section 5.

II. Total Fission Product Decay Power

The total fission product decay power assumes operation at 400 MW(t) to attain an "equilibrium core" prior to the HCDA. In this study, this core fission product decay power is supplemented by the decay powers of other fuel in storage, heavy metal (plutonium and uranium) and hardware of the vessel and core. These items are listed in Table A-1 with their power contribution at 24 hours.

The fuel storage locations, the HCDA release (of Section I) and the volatile solids fission products that follow sodium boiloff result in these four groups of decay power contributors being divided into three analysis groups. These analysis groups are listed in Table A-2 with their power contributions at 24 hours.

Thus at 24 hours, some 16.6 percent of the decay power could be in the vessel and cavity or in the building, according to the location of the 6.2×10^5 lbs of sodium inventory of the study. The analysis of each case tracked this sodium inventory in the vessel, the cavity, and the building. The decay power contributors and groups from the HCDA time to 100 days are listed in Table A-3.

The analysis situation at the beginning of each case had the sodium inventory split with 2.9×10^5 lbs in the upper vessel (above the thermal baffle) and 3.3×10^5 lbs in the combined middle and lower vessels. Further, the assumption was made that the HCDA distributed the core debris and associated decay power as 1 percent into the building, 9/10 of the remainder

TABLE A-1

DECAY POWER CONTRIBUTORS

	Decay Power Group	Decay Power kW	Decay Power Fraction
A.	Reactor Core with 1/3 run 300 days, 1/3 run 200 and 1/3 run 100 days:		
	Fission Products	1,782 kW	0.8434
	Heavy Metals	24.7	0.0117
	Fuel Hardware	15.8	0.0075
B.	Other hardware in vessel such as reflectors, inner shields, core restraint modules, core basket, outer shields, etc.	132.3	0.0626
C.	In-Vessel Storage with 1/3 core run 300 days and decayed 100 days:		
	Fission Products	49.2	0.0233
	Heavy Metals	8.2	0.0039
	Fuel Hardware	5.3	0.0025
D.	Intermediate Decay Storage in RCB	94.8	0.0449
	TOTAL	2,113	1.0000

TABLE A-2

DECAY POWER GROUPS

	Analysis Group	Decay Power kW	Decay Power Fraction
I.	Remains in reactor vessel and cavity:		
	99% of core materials and of most fission products	1,399.6	0.6624
	Other Hardware in Vessel	132.3	0.0626
	In-Vessel Storage	62.7	0.0297
	TOTAL	1,594.6	0.7547
II.	Volatile Solids that follow the sodium (As, Br, Cd, Cs, I, Rb, and Se)	350.3	0.1658
III.	Always in RCB after HCDA:		
	Intermediate Decay Storage	94.8	0.0449
	1% of Core Fission Products and Materials	18.2	0.0086
	100% of Noble Gas Fission Products	54.9	0.0260
	TOTAL	167.9	0.0795

TABLE A-3

DISTRIBUTION OF DECAY POWER IN FFTF
(Decay Power kW)

ITEM	Time, Hours	0	1	2	4	8	24	48	96	192	298	480	720	960	1200	2400
A. CORE IN-VESSEL																
Fission Products		21,260	4,700	3,693	2,979	2,465	1,782	1,401	1,052	74.1	591.3	441.0	343.7	284.2	244.0	148.8
Heavy Metals		24.8	24.8	24.8	24.8	24.8	24.7	24.7	24.5	23.2	23.9	23.3	22.5	21.7	21.0	17.8
Fuel Hardware		15.9	15.9	15.9	15.9	15.8	15.8	15.7	15.5	15.2	14.9	14.3	13.5	12.8	12.1	9.3
	Total	21,301	4,741	3,374	3,020	2,506	1,823	1,441	1,092	781	630	479	380	319	277	176
B. ALL OTHER HARDWARE AND STRUCTURES		133.4	133.4	133.3	133.2	133.0	132.3	131.2	129.0	124.8	120.8	113.0	104.0	95.7	88.1	58.2
C. IN-VESSEL STORAGE																
Fission Products		49.6	49.6	49.6	49.5	49.4	49.2	49.2	48.7	47.9	46.3	42.2	39.3	36.8	34.6	26.8
Heavy Metals		8.3	8.3	8.3	8.3	8.3	8.2	8.2	8.2	8.1	8.0	7.8	7.5	7.3	7.1	6.0
Fuel Hardware		5.3	5.3	5.3	5.3	5.3	5.3	5.2	5.2	5.1	5.0	4.8	4.5	4.2	4.0	3.1
	Total	63	63	63	63	63	63	62	61	60	58	55	51	48	46	36
D. INTERMEDIATE DECAY STORAGE		95.2	95.2	95.2	95.2	95.1	94.8	94.4	93.6	92.0	90.5	87.7	84.3	81.2	78.3	66.4
Total (A+B+C+D)		21,593	5,033	4,026	3,311	2,797	2,133	1,729	1,376	1,058	899	735	619	544	489	337
E. POWER ALWAYS IN VESSEL-CAVITY-SUBCAVITY		19,961	4,690	3,726	3,049	2,571	1,595	1,336	1,089	867	751	623	523	459	408	269
F. POWER OF VOL. SOLIDS THAT FOLLOW SECTION		--	--	--	--	--	350	255	163	80	44	17	7	4	2	1
G. POWER ALWAYS IN RCB AFTER HCDA		1,632	343	300	262	226	168	138	124	111	104	95	89	85	81	68

in the upper vessel and 1/10th in the middle and lower vessel. With the further assumption that no sodium had boiled from the vessels by 24 hours, the appropriate split of decay power among the analysis cells would be as follows:

Cell Group	Decay Power Fraction
Cell A, Upper Vessel with 2.9×10^5 lbs of sodium	0.745
Cell D, Combined middle plus lower vessels with 3.3×10^5 lbs sodium	0.175
Cell C, Reactor Containment Building	0.080

The analysis situation during each case either combined the upper, middle and lower vessels into the reactor vessel or else, because of assumed melt through of the vessel, spilled the sodium and associated core debris into the cavity. With the assumption that no sodium had boiled from the vessel and cavity by 24 hours, the appropriate split of decay power among the analysis cells would be as follows:

Cell Group	Decay Power Fraction
Cell A, Reactor Vessel or Cavity with 6.2×10^5 lbs of sodium	0.920
Cell C, Reactor Containment Building	0.080

III. Sodium Radioactivity

The decay of Na-24 activity in the sodium inventory adds heat to vessel, cavity and building according to the location of this sodium and its chemical reaction products; sodium hydride, sodium hydroxide and sodium oxide. The initial activity was taken to be 9.7 millicuries per cubic centimeter, equivalent to 0.434 Btu/hr-lb of sodium. This activity decayed with a 15 hour half-life.

IV. Concrete Data

Two main concretes have been used in the FFTF facility. These are identified according to their aggregate and fines as being basalt or magnetite. Typical compositions of these concretes are summarized in Table A-4.

TABLE A-4

FFTF CONCRETE MIXES

Item	Basalt	Magnetite
3/4 in aggregate, lb/cu yd	1,804.0	2,935.0
Fines, lb/cu yd	1,471.0	2,180.0
Cement, lb/cu yd	494.0	635.0
Pozzilith and other agents, lb/cu yd	1.88	1.5
Water, lb/cu yd	246.0	318.0
Density, lb/ft^3	148.8	224.8
Water content, lb/ft^3	9.11	11.78

The roof, walls and outer floor of the reactor cavity are composed of magnetite concrete; much of the floor of the reactor building, particularly over the HTS and CL cells and pipeways is composed of magnetite. The top part of the wall of the subcavity is composed of magnetite as are some 43% of the roof, walls and floor of the H&V cooler equipment room. This identification of the locations of magnetite concrete is important because it has the higher volumetric heat capacity, the higher water content, and the higher energy release in the sodium-concrete reaction. The analysis models of the roof, wall, and floor structures referred to magnetite or basalt concrete according to the conservative use of heat capacity and sodium-concrete reaction energy. Accordingly, it was conservative to assume the water content of magnetite concrete for all of the concrete.

The thermal properties of the concrete were based on the data reported by Harmathy and Allen.[A-1] These data show that concrete heat capacity increases linearly from about 0.21 Btu/lb-°F at 50°F to 0.26 at 400°F and 0.40 at 1600°F. Much of the FFTF concrete is subjected to heating through this same temperature range, so that a data correlation temperature of 400°F is reasonable. The thermal conductivity and volumetric heat capacity for the two concretes are listed in Table A-5.

TABLE A-5

CONCRETE THERMAL PROPERTIES

Temperature °F	Thermal Conductivity Btu/hr-ft-°F	Basalt Heat Capacity Btu/ft^3-°F	Magnetite Heat Capacity Btu/ft^3-°F
50	0.99	38.7	58.5
200	0.87	38.7	58.5
400	0.72	38.7	58.5
1000	0.52	38.7	58.5
1600	0.46	38.7	58.5
2000	0.23	38.7	58.5

These concretes will release water when heated in an atmosphere not already saturated with water vapor. Generally, all of the FFTF concrete will release water when heated. However, in this analysis, the concrete in the roof, walls, and floor of the H&V cooler room did not release water because these concrete surfaces are heated by condensing water vapor released from the concrete of the cavity and subcavity. The amounts of water released upon heating the basalt and magnetite concrete have been measured by McCormack, et al.[A-2] The measurements have been correlated with the assumption that the water release is a function of temperature and independent of the composition of the concrete. The water release requires energy similar to the latent heat of water.

In the CACECO code analysis of this water release, the energy required is input as a heat capacity term which is added to the fixed heat capacity of Table A-5. The water release and associated heat capacity term are listed in Table A-6.

The CACECO code analysis of concrete water release has the assumption that the only significant resistance to water release is the conduction heating of the concrete. The code treats the conduction heating (and cooling) of heat structures, such as concrete roofs, walls, and floors, by solving

TABLE A-6

CONCRETE WATER RELEASE

Temperature °F	Water Release lb water/ft^3	Heat Capacity Term Btu/ft^3-°F
50	0.00	
		0.0
192	0.00	
		17.0
214	0.35	
		78.9
276	4.68	
		78.9
300	6.58	
		16.7
400	8.07	
		4.4
500	8.45	
		4.4
750	9.36	
		10.8
830	10.03	
		3.6
1500	11.70	
		0.0
2000	11.70	

one-dimensional, multilayer, transient heat conduction equations, one equation for each structure. In these equations for concrete structures, the code uses the temperature-dependent thermal conductivity listed in Table A-5. Also, during the first heating, the code adds the temperature-dependent heat capacity term of the water release to the concrete heat capacity. The code keeps track of the maximum temperature ever attained at each temperature node in the structures and, for concrete structures, uses this maximum temperature to look up the water release.

In effect, the code calculates the water release throughout the concrete thickness and, without delay for vapor diffusion, releases the water vapor at the concrete surface temperature.

Code input can direct the disposition of the released water vapor from the concrete. In all cases, the water released from the concrete of the building floor was directed into the building atmosphere. In most situations, the disposition of the water released from the concrete of the cavity followed the design of the cavity liner vent system and directed the water vapor into the adjacent H&V cooler room. Likewise, the disposition of the water released from the subcavity followed its vent and directed the water vapor into the adjacent H&V cooler room. The exceptions for the cavity and subcavity involved failures of the floor liner in the cavity and failure of the floor itself, which is the roof of the subcavity. In these failure situations, water released from the concrete associated with the failed liner and/or from the whole subcavity was directed into the sodium pool that covered or flooded the concrete surfaces. Once the sodium had been consumed, either by boilaway or by chemical reaction, this water release was directed into a steel-water reaction that consumed the 1.14×10^5 lbs of stainless steel associated with the core debris.

The failure of the cavity floor liner and the failure of the floor itself subjected some of the concrete to the sodium-concrete reaction. The scientific description of the sodium-concrete reaction depends upon the kind of concrete and its previous history. The code description of this reaction is nonmechanistic. The code input used heats of reaction obtained by Witkowski, et al.,(A-3) by differential thermal analysis (DTA) and the results are shown in Table A-7.

TABLE A-7

SODIUM-CONCRETE REACTION ENERGIES

Reaction	Experimental DTA Data Btu/lb Concrete	CACECO Input Btu/ft^3 Concrete
Sodium-magnetite concrete	900	2.0E+5
Sodium-basalt concrete	242 $\pm$ 100%	7.3E+4

The rates of these sodium-concrete reactions were conservative estimates based on small-scale tests reported by Hassburger, et al.,(a-4) and summarized in Table A-8.

TABLE A-8

SODIUM-CONCRETE REACTION RATES

Rates	Experimental	Used in CACECO
Bare Magnetite	1 inch/hour	1 inch/hour
Lined Magnetite	Ca. 1/3 *	1/2 **
Bare Basalt	1/2	1/2
Lined Basalt	---	1/2 **

* Total reaction ~ 1 inch in boiling sodium.

** Limited to 2 inch reaction.

The cavity floor center is lined basalt concrete. The cavity floor perimeter (outer floor) and lower wall are lined magnetite concrete. In the analysis, when these liners failed, a reaction rate of 1/2 inch/hour was used for both basalt and magnetite concrete to obtain a common depth of concrete reaction of 2 inches behind the failed liner. That is, these sodium-concrete reactions lasted for 4 hours and then stopped. The sodium-water reaction, however, was assumed to continue as the concrete continues to dehydrate.

When the cavity floor failed (Cases 683 and 688), the sodium attacked the bare concrete of the subcavity and under side of the cavity floor. The reaction rate for magnetite was taken as 1 inch/hour and for basalt as 1/2 inch/hour for as long as there was sodium to react. The sodium consumption in these sodium-concrete reactions was not calculated by the code. Instead, it was calculated by hand using consumption rates of 126.4 lbs Na/ft^3 for magnetite concrete and 36.3 lbs Na/ft^3 for basalt concrete. The consumption rates are independent of the sodium boilaway and of the consumption by the sodium-water reaction; these are calculated by the code.

V. Chemical Reactions of Sodium

The code analysis for chemical reactions follows the sequence outlined below:

1. Sodium pool reactions with concrete are first. These reactions with basalt and magnetite concrete occur in the cavity when the steel floor liner fails and in the subcavity when the cavity floor, itself, fails. The code modeling of these reactions was described in Section IV. They have the following energy release:

Pool Reaction	Energy Release (Btu/lb Na)
Sodium-Basalt Concrete	2,005
Sodium-Magnetite Concrete	1,600

2. Sodium pool reactions with carbon dioxide and water vapor are second. The carbon dioxide would be released from heating concrete if limestone had been used instead of basalt and magnetite in the FFTF concrete. Water vapor is released upon heating concrete (basalt, limestone and magnetite). When carbon dioxide and/or water vapor react with the sodium pool, the situation assumed has the concrete submerged by the sodium pool so that carbon dioxide and/or water vapor, released by the concrete heating, bubble up through the pool. The code has the following reactions:

Pool Reaction	Energy Release (Btu/lb Na)
$4Na + CO_2 \rightarrow 2Na_2O + C$	1,988
$2Na + H_2O \rightarrow Na_2O + H_2$	1,600

The sodium reacts with carbon dioxide and water according to their molar ratios and until either the sodium or the carbon dioxide-water vapor is used up.

3. A special version of the CACECO code included the reaction between stainless steel and water vapor, once the sodium pool had disappeared by boiloff and chemical reaction. The stainless steel was associated with the molten core debris and came from the following sources:

73 Fuel Assemblies	21,500 lbs
Core Support Plate	11,400
Lower Core Support Dome	11,300
Reactor Vessel and Guard Tank Bottoms	70,000
Total	114,000 lbs

This stainless steel was assumed to have 19 percent chromium, 9 percent nickel and 72 percent iron. Only the chromium and iron reacted with the water vapor.

Stainless Steel Reaction	Energy Release
$3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$	276.1 Btu/lb stainless steel
$2Cr + 3H_2O \rightarrow Cr_2O_3 + 3H_2$	313.7

The 114,000 lbs of stainless steel consumed 46,560 lbs of water vapor and produced 5,210 lbs of hydrogen. The water in the cavity floor (830 ft_2 area and 32 inches thick) is enough to react with only 43 percent of this stainless steel.

4. Water vapor reacts with sodium oxide next. The situation occurs in both the reactor building and in the subcavity. The situation in the reactor

building occurs with the accumulation of a sodium oxide deposit on the concrete floor. The sodium oxide comes from atmospheric reactions (described below) with the sodium boiled up out of the reactor vessel-cavity. These atmospheric reactions heat the building floor and cause the release of water vapor which must pass through the oxide deposit to get into the atmosphere. The code has the following reaction:

Deposit Reaction	Energy Release
$H_2O + Na_2O \rightarrow 2\ NaOH$	1,500 Btu/lb Na

Water vapor in excess of that necessary to convert all of the oxide to the hydroxide will pass into the building atmosphere.

The situation for water vapor to react with sodium oxide also occurs in the subcavity, once all the sodium and stainless steel have disappeared. The sodium disappeared by boiloff and by reaction with concrete and water vapor, the latter producing sodium oxide. The stainless steel disappeared by reaction with water vapor. Again, water vapor in excess of that necessary to convert all of the oxide to the hydroxide would pass into the subcavity atmosphere.

5. Sodium vapor reactions are next. The sodium vapor reacts with carbon dioxide, oxygen and water vapor. The carbon dioxide would come from limestone concrete if any had been used in the FFTF. Oxygen is present initially in the nitrogen of the cavity at 1 percent concentration and in the air of the building, subcavity and H&V cooler room at 21 percent concentration. The code permits oxygen (and other gases and vapors) to flow (as leakage) from one analysis space into another. Thus, oxygen in the subcavity air can flow into the H&V cooler room and thence into the building and vent outside. Also, the oxygen can be injected into the building by the code in the purge air in order to hold the hydrogen concentration to 4 percent. Water vapor present initially in the building at 50 percent relative humidity is released from heating the building floor concrete and is leakage from the H&V cooler room. The code has the following reactions:

Atmosphere Reaction	Energy Release (Btu/lb Na)
$4Na + CO_2 \rightarrow 2Na_2O + C$	3,799
$2Na + H_2O \rightarrow Na_2O + H_2$	3,400
$4Na + O_2 \rightarrow 2Na_2O$	5,700

Previously the code had the sodium reacting with carbon dioxide, oxygen and water vapor, according to their molar ratios, with either the sodium or the carbon dioxide-oxygen-water vapor being used up. However, the experiences of the recent hydrogen-oxygen recombination tests, described by Armstrong, et al.,[A-15] and in Section VI, indicated a change in this reaction modeling. The reaction with CO_2, O_2, and H_2O occurs only when the concentration of oxygen is less than the concentration of water vapor. In the alternative, when the concentration of oxygen is greater than, or equal to the concentration of water vapor, the sodium-water reaction is omitted. That is, the sodium vapor reacts with carbon dioxide and oxygen according to their molar ratios until either the sodium or the carbon dioxide-oxygen is used up.

6. Hydrogen may react with oxygen next. The situation for this "hydrogen recombination (to water)" reaction occurs in the reactor building. The hydrogen is generated by the sodium-water reaction wherever this reaction occurs: (1) in the cavity when the floor liner or the floor itself fails and water vapor is released into the sodium pool by the heating concrete, and (2) in the building atmosphere from sodium boilup from the reactor vessel-cavity and water vapor from the building floor and H&V cooler rooms. Oxygen is present initially, flows into the building from the H&V cooler room, and may be injected in the purge air to hold the hydrogen to 4 percent.

The conditions for this hydrogen recombination reaction have been the subject of recent experiments at HEDL. Preliminary results of these experiments have been described by Armstrong, et al.[A-5] Many of the experiments used a sodium-hydrogen (-nitrogen) jet as occurs when the reactor vessel fails, releasing sodium into the cavity which, in turn, experiences a floor liner failure. In nomenclature consistent with the experimental apparatus and data, the cavity would be called Cell A and the building Cell C. The experimental results show that hydrogen ignites, and is completely consumed when:

a. Cell A is at 500°F or hotter,

b. Cell A has sodium vapor and aerosol concentration of 5.5 g/m^3 (3.4 x 10^{-4} lb/ft^3) or greater,

c. and Cell C has oxygen concentration of 11 percent or more.

In the code analysis, the hydrogen reaction is as follows:

Atmosphere Reaction	Energy Release
$2H_2 + O_2 \rightarrow 2H_2O$	52,425 Btu/lb H_2

When hydrogen and oxygen react, the hydrogen is used up.

7. Lastly, sodium reacts with hydrogen to form sodium hydride. This situation occurs in the reactor cavity when the liner fails and hydrogen is generated by the sodium-water reaction. This reaction delays the escape of hydrogen from the cavity and its accumulation in the building. In the code analysis, this reaction is as follows:

Pool Reaction	Energy Release
$2Na + H_2 \rightarrow 2NaH$	915 to 1,010 Btu/lb Na

The sodium hydride, as solid and/or dissolved in the sodium pool, is in equilibrium with the hydrogen in the atmosphere over the pool. That is, by changing the pool temperature but not the amounts of hydrogen and sodium present, the amount of sodium hydride will change.

Further, as sodium is consumed, the sodium hydride will disassociate back to hydrogen and sodium.

The equations for the equilibrium between sodium hydride and hydrogen and for the solubility of sodium hydride in sodium were taken from the correlations of Whittingham.[A-6]

In the cases that assume the failure of the reactor vessel, either at 3 hours with the melt-through of the vessel bottom (Cases 675 through 688) or at 384 hours with the failure associated with the vessel support arms (Case 655), the sodium accompanying the core debris will consume all of the oxygen in the cavity atmosphere and react with the calcium silicate insulation covering the reactor vessel and guard tank. The code analysis covers the oxygen reaction. There is about 18,300 lbs of insulation on the vessel and tank.

The sodium reactions with calcium silicate insulation have been the subject of experiments at LMEC.[A-7,A-8] The results of these experiments are summarized below:[A-8]

> "Sodium reactions with all calcium-silicate-base insulation materials were characterized by an initial flash flare developing from the first fire and lasting up to 10 sec. A shower of sparks, particles of burning sodium, was ejected at the start of the flare... The flame subsequently subsided and burned quietly until extinction... In spite of the impressive flare that occurred at the start of the reaction, the calcium-silicate materials were not significantly damaged; reaction was mostly on the surface of the material..."

The sodium reaction with the insulation was assumed to be the following:

Insulation Reaction	Energy Release
$2Na + CaSiO_3 \rightarrow Na_2SiO_3 + Ca$	286.5 Btu/lb Na

This reaction will consume about 1.2 percent of the sodium spill and heat the pool about 11°F. It was neglected.

VI. Hydrogen Recombination

Hydrogen is generated by the sodium-water reaction wherever it occurs. There is potential for the formation of flammable-explosive mixtures of hydrogen by the accumulation of hydrogen in the air atmospheres of the RCB and H&V cooler rooms. Usually the analysis scenarios assume that the hydrogen concentration is controlled by an air purge, calculated by the code to limit the hydrogen concentration in the RCB to 4 percent maximum. This air purge assumes equipment not presently available in the FFTF. The air purge promotes the leakage of radioactivity from the building and, therefore, is undesirable.

To some extent, the hydrogen accumulation could be delayed, or even eliminated, if the hydrogen were to recombine (with oxygen) to form water vapor. The preliminary test results of recent experiments at HEDL on the conditions for hydrogen recombination have been discussed by Armstrong, et al.[A-5] The code modeling of these experimental results has two aspects.

1. First is the avoidance of hydrogen formation. The general model of the sodium vapor reactions with an atmosphere is that the sodium will react with (carbon dioxide)-oxygen-water vapor in proportion to their molar concentrations. The reaction with water produces hydrogen. However, the conditions of Test H-17 indicate that the sodium (-nitrogen) jet will not react with the water vapor unless this water vapor has a concentration higher than the oxygen concentration.

2. Second is the conditions for the hydrogen-oxygen reaction. The situation assumes a sodium-hydrogen (-nitrogen) jet into an atmosphere containing oxygen. The conditions for this reaction have been listed in Section V.6 above.

VII. Heat Transfer Models

The CACECO code uses heat structures to simulate the heat absorption and heat loss capabilities of the roof, walls, floor and equipment of each containment space. The code permits detailed simulation of these items within the limitation of one-dimensional heat conduction analysis. These heat structures are described by one-dimensional, multilayer, transient heat conduction equations, one equation for each structure. The heat conduction equations are solved over each time step by using an implicit calculational method.

The heat structures are defined by input data. Each structure has from 3 to 25 temperature nodes in a one-dimensional geometry, either planar (linear), cylindrical, or spherical. Each structure can be multilayer with successive layers for different materials, temperature node spacing, and/or volumetric heat generation rates. The boundary conditions for each structure are specified by input data that cover: (1) the temperature in convection contact with the boundary surface, (2) the heat transfer coefficient at the surface, (3) the temperatures in radiation contact, and (4) the radiation area-view emissivity factors. The temperature in convection or radiation can be the outside air or any atmosphere, pool, sink, or other structure surface temperature. The heat transfer coefficients can be constants or dependent upon either time or temperature. The radiation area-view-emissivity factors are usually constants.

The materials for each structure are specified by input data. Normally, the thermal conductivity and heat capacity of each material are constants. However, because of the effects of water release on the properties of concrete, the code was modified for these PAHR studies so that concrete properties were dependent upon temperature. These concrete properties are described in Section IV.

The structures used to model the cavity roof, walls, and floor are covered with steel liners. These liners and an assumed 1/8 to 1/4" thick air gap behind the liner were homogenized into the first (inside) layer of these heat structures. The extensive steel and copper embedments, penetrations and reinforcements through the cavity roof result in a homegenized thermal conductivity of 30.2 Btu/hr/ft°F for the roof concrete. The angle irons and "I" embedments that support the cavity cold liners constitute a region, 3 inches thick behind the liners, that has a conductivity higher than the deeper concrete. This region heats faster than does the rest of the concrete. For the cavity upper and middle walls, generally the area covered by the cold liners, this region had a homogenized thermal conductivity of 1.29 Btu/hr/ft°F. For the lower walls, generally the area covered by the hot liner, the lined wall and outer floor were analyzed as a liner homogenized with a 1/4-inch thick air gap against 6 inches of firebrick and 5.5 feet of magnetite concrete.

The heat transfer coefficients used in different applications are summarized in Table A-9.

TABLE A-9

HEAT TRANSFER COEFFICIENTS

Type	Typical Values	Application
1	0 Btu/hr-ft^2-°F	Adiabatic surface for bottom of building floor and for outsides of various walls and floors.
2	1.2	Air outside containment building.
3	1.13 at 76°F	Atmosphere inside containment building, cavity and H&V cooler room.
	1.6 at 300°F	Also, initial atmosphere of nitrogen and oxygen inside reactor cavity.
4	1.05 at 150°F	Atmosphere of nitrogen and sodium vapor inside reactor cavity.
	5.7 at 1530°F	Coefficient takes into account sodium vapor condensation effect.
	50.0 at 1620°F	
	200.0 at 1700°F	
5	200	Sodium pool in reactor vessel, reactor cavity, and in subcavity.

The sodium that boils up from the reactor vessel and cavity reacts with the oxygen and water vapor in the RCB to form sodium oxide. This oxide will fall out, collect on the floor and separate the concrete floor from the atmosphere. The density of freshly deposited sodium oxide was measured at the Harvard Air Cleaning Laboratory[A-9] as 20 lb/ft^3. With this oxide density, the boilup of 6.2 x 10^5 lbs of sodium into the RCB would form a deposit 3.2 feet deep across the RCB floor. This thick oxide deposit, accumulating as the sodium boils up into the RCB, was the basis for two assumptions of this study.

(1) The heat transfer from the RCB atmosphere to the floor passes through the resistance of the accumulating oxide deposit.

(2) All water vapor released upon heating the RCB floor passes up through the oxide deposit. The water reacts to form sodium hydroxide. Only water vapor in excess of that necessary to convert sodium oxide to sodium hydroxide escapes the deposit into the atmosphere.

These two assumptions delay and reduce the heating of the RCB floor and the attendant water release from this floor. Much of the water release is captured by the sodium oxide and is not available to react with the sodium vapor (of the boilup) to form hydrogen. Also, the formation of sodium hydroxide collapses the deposit and reduces its thermal resistance. This study assumed the accumulation of a hydroxide deposit 7.4 inches deep on the RCB floor from the boilup of 6.2×10^5 lbs of vessel sodium. This deposit and its attendant thermal resistance increased from zero to the maximum value as the boilup proceeded. The overall coefficients, atmosphere to floor surface, are listed in Table A-10.

TABLE A-10

OVERALL HEAT TRANSFER COEFFICIENT, RCB ATMOSPHERE TO FLOOR

Sodium Boiloff	Thickness Hydroxide Deposit	Overall Coefficient
40,000 lbs	0.04 feet	1.04 Btu/hr-ft^2-°F
254,000	0.26	0.72
404,000	0.41	0.60
523,000	0.53	0.52
620,000	0.62	0.48

Generally, this sodium oxide-hydroxide deposit reduced the hydrogen formation and raised the RCB atmosphere temperature. The sodium hydroxide does not react with concrete. In fact, concrete is a recommended material of construction for the electrolytic manufacture of sodium hydroxide.(A-10)

The insulation on the roof and outside walls of the RCB inhibits heat loss to the outside air. This foam insulation was assumed to degrade upon heating listed as follows:

Steel Temperature	Foam Insulation Thermal Conductivity
80°F	0.013 Btu/hr-ft-°F
650	0.026
950	0.052

The floor of the subcavity, when heated by convection, hot sodium or core debris, will lose heat via conduction paths through the surrounding ground to the ground surfaces surrounding the RCB and, thence, into the outside air. An estimate of the minimum heat lost by these conduction paths was made using the Green's function and source-sink image theory described by Kellogg.[(A-11)] This estimate used a heat source 80 ft below the ground surface and a ground thermal conductivity of 1.0 Btu/hr-ft°F to give a minimum conduction loss of $q/\Delta T$ = 78 Btu/hr-°F. With a subcavity floor area of 346 ft^2, this conduction loss was represented in the code analysis as a conduction coefficient of 78/346 = 0.23 Btu/hr-ft°F to the outside air.

The floor of the H&V cooler room, when heated by condensing the steam from the cavity and subcavity concrete, will lose heat via conduction paths through the ground to the ground surfaces surrounding the RCB and thence into the outside air. An estimate of the minimum heat by these conduction paths was made using the Green's function and source-sink image theory. This estimate, like the one for the subcavity floor, gave a minimum conduction loss of $q/\Delta T$ = 70 Btu/hr-°F. With a H&V cooler room floor area of 7,100 ft^2, this conduction loss was represented in the code analysis as a conduction coefficient of 70/7100 = 0.01 Btu/hr-ft^2-°F to the outside air. This coefficient was used only for Cases 681 through 688.

VIII. Mass Transfer (Leakage) Models

The code analysis of leakage based on leak rate specifications uses the following equation:

$$L_c = C_t \sqrt{(\rho \Delta P)}$$

where: L_c = Leak rate, lbs/hr of cavity or RCB atmosphere.
C_t = Leakage coefficient, code input data, lb/hr - $\sqrt{\text{psid-lb/ft}^3}$.
ρ = Atmosphere density, lbs/ft^3.
ΔP = Differential pressure, psid.

Leakage according to this equation can be in either direction. The coefficients used with this equation are as follows:

Table A-11

LEAKAGE COEFFICIENTS

Leakage	Purpose	Coefficient, C_t
RCB to outside	Design leakage of 0.1%/day at 10 psig	6.6
	Rapid vent to depressurize building	150,000

In one "relief valve" analysis, Case 659, the pressure increased to operate a relief valve which vented through filters to the outside. This relief valve was simulated by leakage coefficients that provided the following flow ratings:

RCB Pressure	Relief Valve Flow
0 to 9.2 psig	0.1 percent/day nominal leakage
9.6	1.0
10.0	10.0
10.4	100.0

The code analysis of gas-vapor flow from the reactor vessel and/or cavity to the RCB from the subcavity to the H&V cooler room, from the H&V cooler room to the RCB and, after building depressurization, from the RCB to the outside uses modified nozzle equations. The analysis assumes that the nozzle is large enough that the gas-vapor flow will equalize the pressures of the two spaces each time step. The analysis uses the nozzle equation for incompressible flow as written below:

$$L_n = 346{,}538\ C_n A_n \sqrt{\rho \Delta P}$$

where: L_n = Leak rate, lbs/hr

C_n = Nozzle coefficient, code input data, nominally 0.817

A_n = Nozzle area, code input data, ft^2

ρ = Atmosphere density, lbs/ft^3

ΔP = Differential pressure, psid

This nozzle leakage is one-directional. The nozzle areas used with this equation were adjusted to obtain smooth code analysis.

IX. References

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A-7 J. J. Auleta, D. J. Kniley and H. J. Bomelburg, Thermal Insulation Sodium Compatability and Corrosion Tests and Chemical Analyses, LMEC-TDR-72-7, October 23, 1972.

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A-10 E. Rabald, Corrosion Guide, Second, Revised Edition, Elsevier Publishing Company, New York, 1968, p. 701.

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X. CACECO Case Summaries

Data summaries for each of the CACECO cases in this report are given in the tables which follow.

Notes

Case 675: From 4 to 229 hours, the RCB Mixed-Atmosphere Leakrate values are high because these include flow back into the reactor cavity as well as normal leakage to the outside. Use the leakrates for Case 678 during this time period.

Case 683: From 384 to 428.7 hours, the reactor cavity Sodium Mass values are high because these include sodium that has reacted with the concrete as well as the unreacted sodium. Hand calculations showed that the cavity and subcavity boiled dry at 428.7 hours with 253,054 lbs of sodium reacted with the concrete. This amount of sodium was removed from the analysis at this time.

Case 688: From 1008 to 1062.4 hours, the reactor cavity Sodium Mass values are high because these include sodium that has reacted with the concrete as well as the unreacted sodium. Hand calculations showed that the cavity and subcavity boiled dry at 1062.4 hours with 309,906 lbs of sodium reacted with the concrete. This amount of sodium was removed from the analysis at this time.

CASE 654 CORE IN VESSEL, NO B.COOLER, H2+O2 REAC, VENT-PURGE
CASE 654 12 NOV 76 1323 HRS

HCDA TIME (HRS)	REACTOR VESSEL UPPER TEMP. (DEG.F)	LOWER TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	REACTOR CAVITY TEMP. (DEG.F)	H&V ROOMS ATM. TEMP. (DEG.F)	WATER MASS (LBS)	REACTOR CONTAINMENT BUILDING ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	SODIUM INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	MIXED-ATM LEAKRATE FRACTION (1/SEC)
0.0	1050.0	980.0	0.00	620007.	120.0	N/A	N/A	80.0	0.00	0.00	20.71	1.38	0.0	0.	0.0	0.
.2	1084.8	984.4	.49	620000.	145.2	N/A	N/A	124.7	1.17	0.00	20.67	1.20	0.0	0.	6.1	7.24E-08
3.0	1273.8	1023.7	.48	619998.	153.2	N/A	N/A	97.8	.45	0.00	20.66	1.20	1.0	4.52E-10	.3	3.22E-09
60.0	1699.4	1539.7	7.04	592547.	204.2	N/A	N/A	425.0	5.94	0.00	13.49	0.00	1014.3	4.54E-07	3.9	4.65E-08
72.0	1716.4	1606.9	9.03	580116.	211.4	N/A	N/A	554.7	9.01	0.00	9.65	0.00	1066.9	4.78E-07	4.6	5.48E-08
82.0	1728.9	1655.7	10.20	568775.	216.9	N/A	N/A	632.9	10.03	0.00	5.78	1.07	1178.1	5.28E-07	3.7	4.39E-08
83.0	1618.9	1639.8	.02	558203.	217.2	N/A	N/A	1005.3	0.00	.59	0.00	0.00	10577.6	4.74E-06	28134.6	3.35E-04
120.0	1619.7	1619.7	.03	476437.	230.2	99.3	5899.	984.3	.00	4.02	9.27	9.30	1694.1	8.49E-07	2183.1	2.60E-05
144.0	1620.3	1620.3	.12	433627.	238.1	102.2	8692.	1005.7	.07	4.00	9.98	9.99	1714.0	7.58E-07	2876.7	3.42E-05
180.0	1620.9	1620.9	.17	375135.	248.1	108.7	12882.	1011.7	.07	4.00	8.46	8.44	1537.8	6.89E-07	2003.7	2.39E-05
216.0	1621.2	1621.2	.19	322269.	256.5	115.5	17935.	1001.2	.06	4.00	6.96	6.95	1358.4	6.09E-07	2091.9	2.49E-05
240.0	1619.6	1619.6	.07	289399.	261.6	118.7	21036.	993.1	.00	4.02	4.70	4.70	1333.0	5.97E-07	963.7	1.15E-05
300.0	1619.9	1619.9	.09	215346.	274.0	125.5	29029.	951.2	.00	4.01	.89	.91	1162.1	5.21E-07	1022.1	1.22E-05
360.0	1620.0	1620.0	.10	149881.	286.9	129.8	36254.	902.0	.04	4.00	.23	.20	1018.2	4.56E-07	765.2	9.11E-06
384.0	1619.4	1619.4	.05	125634.	292.7	130.2	38805.	883.9	.00	4.01	2.50	2.51	992.6	4.45E-07	977.1	1.16E-05
420.0	1619.4	1619.4	.05	91265.	301.1	133.1	42554.	856.6	.00	4.00	2.36	2.36	928.5	4.16E-07	588.4	7.00E-06
467.1	1619.1	1619.1	.03	49466.	311.3	138.2	47905.	821.4	.00	4.00	2.61	2.62	856.3	3.84E-07	682.0	8.12E-06
480.0	1619.8	1619.8	.03	38423.	313.9	139.7	49403.	813.6	.00	4.00	2.91	2.90	846.0	3.79E-07	456.9	5.44E-06
516.0	1619.2	1619.2	.04	9647.	320.9	144.0	53783.	792.3	.00	4.01	1.20	1.20	803.0	3.60E-07	456.5	5.43E-06
526.5	1619.5	1619.5	0.00	402.	322.9	145.2	55075.	785.5	.00	4.00	.85	.85	781.2	3.50E-07	423.7	5.04E-06

HCDA TIME (HRS)	R.CAVITY FOLLOWING VESSEL MELT-THRU CAVITY TEMP. (DEG.F)	VESSEL TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	SUB-CAVITY TEMP. (DEG.F)	H&V ROOMS ATM. TEMP. (DEG.F)	WATER MASS (LBS)	REACTOR CONTAINMENT BUILDING ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
527.5	1227.7	1227.7	2.33	0.	138.2	154.9	55974.	773.2	.01	4.00	1.27	2.03	0.0	0.	877.0	1.04E-05
540.0	1238.5	1238.5	.13	0.	146.1	193.9	64978.	668.8	.11	4.02	18.34	4.78	0.0	0.	5049.3	6.01E-05
600.0	1198.5	1198.5	.06	0.	202.2	212.2	89284.	465.4	.02	4.01	17.33	13.48	0.0	0.	1766.1	2.10E-05
660.0	1189.4	1189.4	.02	0.	315.8	211.8	101364.	341.9	.01	4.00	15.24	23.44	0.0	0.	515.0	6.13E-06
696.0	1188.9	1188.9	.00	0.	399.2	212.3	106797.	302.7	.00	3.99	12.15	38.16	0.0	0.	287.5	3.42E-06
720.0	1361.0	1361.0	.02	0.	441.9	212.4	109015.	283.2	.00	3.66	8.82	54.35	0.0	0.	274.7	3.27E-06
780.0	1397.6	1397.6	.01	0.	528.7	212.2	111281.	249.4	.00	2.98	4.27	76.70	0.0	0.	268.4	3.19E-06
792.0	1413.1	1413.1	.01	0.	547.0	212.3	111113.	245.1	.00	2.81	3.66	79.73	0.0	0.	288.1	3.43E-06
840.0	1464.6	1464.6	.01	0.	522.0	212.3	110080.	230.1	.00	2.20	2.10	87.81	0.0	0.	240.8	2.87E-06
888.0	1497.3	1497.3	.01	0.	559.3	212.2	108460.	220.1	.00	1.75	1.30	92.04	0.0	0.	209.7	2.50E-06
900.0	1606.5	1606.5	.13	0.	129.7	212.5	110394.	215.3	.05	4.01	13.38	32.26	0.0	0.	2618.4	3.12E-05
960.0	1732.0	1732.0	.05	0.	130.5	212.3	112781.	207.7	.02	4.01	18.55	7.65	0.0	0.	1491.0	1.78E-05
1020.1	1664.0	1664.0	.10	0.	131.5	212.3	114317.	204.9	.04	4.01	18.34	8.65	0.0	0.	788.6	9.39E-06
1080.1	1692.9	1692.9	.00	0.	131.8	212.2	116388.	204.9	.00	3.70	16.85	16.07	0.0	0.	77.4	9.21E-07
1120.1	1707.7	1707.7	.00	0.	132.1	212.2	117141.	204.3	.00	3.31	15.03	25.12	0.0	0.	64.1	7.63E-07
1140.0	1720.3	1720.3	.00	0.	132.3	212.4	117404.	204.3	.00	3.13	14.20	29.25	0.0	0.	62.5	7.44E-07
1200.0	1734.4	1734.4	.00	0.	132.8	212.4	117878.	204.6	.00	2.69	12.16	39.41	0.0	0.	60.6	7.21E-07
1260.0	1753.1	1753.1	.00	0.	133.4	212.2	118140.	203.8	.00	2.37	10.69	46.70	0.0	0.	39.2	4.67E-07
1320.0	1772.9	1772.9	.00	0.	134.0	212.2	118614.	204.0	.00	2.18	9.79	51.22	0.0	0.	36.0	4.29E-07
1344.0	1780.1	1780.1	.00	0.	134.3	212.1	118801.	203.9	.00	2.12	9.51	52.58	0.0	0.	28.6	3.40E-07
1380.1	1786.6	1786.6	0.00	0.	134.7	212.2	119072.	203.2	.00	2.05	9.15	54.36	0.0	0.	21.5	2.57E-07
1440.1	1801.1	1801.1	.00	0.	135.3	212.1	119438.	203.5	.00	1.94	8.67	56.79	0.0	0.	22.4	2.67E-07
1500.1	1816.0	1816.0	0.00	0.	136.0	212.1	119781.	202.8	.00	1.87	8.32	58.49	0.0	0.	12.8	1.52E-07
1560.1	1828.2	1828.2	.00	0.	136.7	212.1	120008.	203.3	.00	1.82	8.03	59.93	0.0	0.	14.8	1.76E-07
1620.1	1838.7	1838.7	0.00	0.	137.4	212.1	120067.	202.7	.00	1.76	7.75	61.35	0.0	0.	11.9	1.42E-07
1632.1	1841.8	1841.8	.00	0.	137.6	212.1	120061.	203.2	.00	1.74	7.69	61.63	0.0	0.	15.7	1.87E-07

CASE 655, 384HR MELTHRU, NO B.COOLER, H2+O2 REAC, VENT-PURGE
CASE 655 01 DEC 76 1802 HRS

	REACTOR VESSEL				REACTOR	H&V ROOMS		REACTOR CONTAINMENT BUILDING						SODIUM		MIXED-ATM
HCDA TIME (HRS)	UPPER TEMP. (DEG.F)	LOWER TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
0.0	1050.0	980.0	0.00	620007.	120.0	N/A	N/A	80.0	0.00	0.00	20.71	1.38	0.0	0.	0.0	0.
.2	1084.8	984.4	.49	620000.	143.7	N/A	N/A	124.7	1.17	0.00	20.67	1.20	0.0	0.	6.2	7.32E-08
3.0	1275.8	1023.7	.48	619938.	151.1	N/A	N/A	97.8	.45	0.00	20.66	1.20	1.0	4.52E-10	.3	3.21E-09
50.0	1684.9	1474.7	5.62	602323.	193.8	N/A	N/A	338.5	5.50	0.00	16.28	0.00	914.0	4.39E-07	3.9	4.58E-08
72.0	1718.4	1606.7	9.03	580125.	206.7	N/A	N/A	554.7	9.01	0.00	9.66	0.00	1068.9	4.79E-07	4.7	5.54E-08
82.0	1728.8	1655.6	10.20	568783.	211.9	N/A	N/A	632.3	10.03	0.00	5.78	1.08	1177.3	5.27E-07	3.7	4.43E-08
83.0	1618.8	1639.7	.01	558216.	212.1	N/A	N/A	1005.4	0.00	.59	0.00	0.00	10571.7	4.74E-06	28128.6	3.35E-04
100.0	1620.7	1620.7	.15	515608.	218.0	95.8	3567.	918.4	.06	4.02	10.81	10.85	2176.3	9.75E-07	4004.5	4.77E-05
144.0	1620.3	1620.3	.12	433712.	231.7	98.4	8522.	1005.2	.02	4.02	9.95	10.01	1711.3	7.67E-07	2911.8	3.47E-05
150.0	1619.5	1619.5	.05	423514.	233.5	99.1	9033.	1016.5	.01	4.02	9.30	9.30	1751.0	7.85E-07	1342.8	1.60E-05
200.0	1620.5	1620.5	.13	345204.	246.5	106.5	14785.	1011.9	.06	4.00	6.46	6.40	1451.1	6.50E-07	859.2	1.02E-05
216.0	1620.7	1620.7	.15	322333.	250.0	107.8	16909.	1002.5	.01	4.02	6.89	6.89	1381.1	6.19E-07	2115.5	2.52E-05
250.0	1619.6	1619.6	.07	276475.	256.7	111.6	20991.	985.7	.05	4.00	4.30	4.26	1302.2	5.83E-07	1082.0	1.29E-05
300.0	1619.7	1619.7	.08	215503.	266.7	114.9	26860.	951.0	.00	4.00	.85	.86	1159.3	5.19E-07	1019.4	1.21E-05
350.0	1619.4	1619.4	.05	160469.	276.9	118.1	32207.	911.2	.00	4.01	1.04	1.05	1053.4	4.72E-07	411.5	4.90E-06
384.0	1619.5	1619.5	.05	125966.	284.4	118.7	35405.	883.1	.04	4.00	2.52	2.51	991.1	4.44E-07	971.9	1.16E-05

	R.CAVITY FOLLOWING VESSEL MELT-THRU				SUB-	H&V ROOMS		REACTOR CONTAINMENT BUILDING								
HCDA TIME (HRS)	CAVITY TEMP. (DEG.F)	VESSEL TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
385.0	1490.4	1490.4	3.87	122015.	121.5	174.1	39464.	859.4	.38	4.01	9.47	2.53	486.2	2.18E-07	10859.1	1.29E-04
388.0	1549.2	1549.2	.71	115430.	123.4	200.8	45166.	868.8	.53	4.03	10.99	6.55	1128.5	5.05E-07	7435.7	8.85E-05
400.0	1209.6	1209.6	.07	102490.	122.3	211.3	57788.	765.5	.05	4.01	9.56	24.92	19.0	8.50E-09	3130.4	3.73E-05
408.0	1188.3	1188.3	.22	97821.	122.6	211.0	63609.	711.6	.14	4.02	10.18	28.65	23.5	1.05E-08	5032.1	5.99E-05
450.0	1193.9	1193.9	.04	81068.	130.4	211.9	85492.	570.2	.00	1.38	8.65	40.82	13.9	6.21E-09	285.4	3.40E-06
456.0	1205.5	1205.5	.03	78437.	132.1	212.0	88045.	543.7	.04	4.01	8.09	42.55	17.2	7.69E-09	2646.8	3.15E-05
500.0	1229.1	1229.1	.05	65453.	145.7	212.2	103339.	421.7	.03	4.01	10.53	35.35	16.4	7.35E-09	1904.2	2.27E-05
504.0	1224.1	1224.1	.03	64509.	147.2	212.2	104502.	423.3	.00	.61	8.91	39.86	11.0	4.92E-09	532.6	6.34E-06
552.0	1247.7	1247.7	.07	53064.	164.4	212.3	116473.	345.6	.03	4.00	9.60	37.99	15.8	7.08E-09	961.7	1.14E-05
603.5	1257.2	1257.2	.04	42118.	184.1	212.2	125130.	304.2	.00	1.84	7.95	46.37	11.4	5.11E-09	237.7	2.83E-06
656.0	1258.1	1258.1	.04	31051.	216.1	212.3	131631.	273.6	.01	4.00	8.32	44.91	8.5	3.82E-09	644.0	7.67E-06
706.0	1260.5	1260.5	.03	23365.	235.4	212.1	135202.	254.4	.00	2.88	7.48	50.16	8.7	3.90E-09	152.0	1.81E-06
711.1	1260.7	1260.7	.03	23442.	235.4	212.1	135376.	253.0	.00	3.15	7.31	50.92	8.6	3.87E-09	158.9	1.89E-06
760.0	1272.9	1272.9	.04	18803.	247.6	212.2	137510.	235.2	.01	4.00	8.97	47.80	6.1	2.75E-09	399.7	4.76E-06
812.0	1269.1	1269.1	.01	15912.	257.8	212.2	139231.	222.8	.00	4.00	9.55	47.31	2.5	1.12E-09	163.5	1.95E-06
864.0	1270.0	1270.0	.00	14054.	267.3	212.2	139825.	214.3	.00	4.00	8.56	52.83	2.2	1.00E-09	144.5	1.72E-06
916.0	1270.0	1270.0	.01	12857.	274.6	212.4	139892.	207.6	.00	3.97	7.19	59.97	1.4	6.32E-10	95.1	1.13E-06
968.0	1272.1	1272.1	.01	11814.	280.0	212.2	139308.	202.0	.00	4.00	6.21	64.87	1.3	5.74E-10	75.6	9.00E-07
1020.0	1273.2	1273.2	.01	11002.	286.9	212.2	138368.	197.6	.00	3.98	5.49	68.55	.9	4.24E-10	62.2	7.40E-07
1070.0	1274.5	1274.5	.00	10361.	291.2	212.2	136910.	195.5	0.00	3.99	4.89	71.55	.9	3.81E-10	4.4	5.29E-08
1120.1	1276.1	1276.1	.01	9788.	297.5	212.2	135136.	194.0	.00	4.00	5.37	69.36	.8	3.59E-10	47.3	5.63E-07
117_.0	1277.7	1277.7	.01	9256.	301.2	212.3	133381.	192.6	.00	4.00	5.80	67.39	.7	3.08E-10	42.0	5.00E-07
1220.0	1279.3	1279.3	.01	8801.	306.6	212.4	130578.	191.8	.00	4.00	6.08	66.15	.6	2.60E-10	38.4	4.58E-07
1270.0	1280.6	1280.6	.01	8394.	310.7	212.4	127762.	191.7	.00	3.99	6.10	66.09	.6	2.53E-10	41.2	4.90E-07
1320.0	1281.9	1281.9	.01	8028.	315.5	212.4	124626.	192.3	.00	3.98	5.93	66.97	.5	2.28E-10	45.2	5.38E-07
1370.0	1283.2	1283.2	.01	7704.	320.2	212.4	121245.	193.4	.00	3.97	5.63	68.45	.5	2.07E-10	45.9	5.46E-07
1376.0	1283.3	1283.3	.00	7667.	320.7	212.4	120825.	193.5	.00	3.98	5.60	68.59	.5	2.05E-10	22.7	2.70E-07
1420.1	1284.4	1284.4	.01	7412.	323.2	212.4	117662.	194.6	.00	3.94	5.29	70.17	.4	1.88E-10	47.5	5.66E-07
1470.1	1285.5	1285.5	.00	7150.	328.4	212.4	113964.	195.7	.00	3.87	4.95	71.88	.4	1.72E-10	44.7	5.32E-07
1520.1	1286.6	1286.6	.00	6914.	331.8	212.4	110188.	196.8	.00	3.79	4.62	73.57	.3	1.56E-10	39.6	4.71E-07
1570.1	1287.5	1287.5	.00	6726.	335.1	212.4	106262.	198.0	.00	3.64	4.28	75.42	.3	1.13E-10	15.9	1.89E-07
1620.1	1288.3	1288.3	.00	6564.	341.0	212.4	102209.	199.2	.00	3.45	3.93	77.32	.2	1.03E-10	18.2	2.16E-07
1632.1	1288.6	1288.6	.01	6527.	342.1	212.4	101230.	199.6	.00	3.39	3.83	77.87	.2	1.07E-10	67.3	8.01E-07

	REACTOR VESSEL				REACTOR	H&V ROOMS		REACTOR CONTAINMENT BUILDING					SODIUM		MIXED-ATM	
HCDA TIME (HRS)	UPPER TEMP. (DEG.F)	LOWER TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
0.0	1050.0	980.0	0.00	620007.	120.0	N/A	N/A	80.0	0.00	0.00	20.71	1.38	0.0	0.	0.0	0.
.2	1084.8	984.4	.49	620000.	145.2	N/A	N/A	124.5	1.17	.01	20.68	1.20	0.0	0.	6.1	7.21E-08
3.0	1275.8	1023.7	.48	619998.	153.2	N/A	N/A	97.8	.45	.01	20.66	1.20	1.0	4.52E-10	.3	3.21E-09
60.0	1699.4	1539.7	7.05	592555.	204.2	N/A	N/A	424.8	6.94	.03	13.50	0.00	1014.1	4.54E-07	3.9	4.65E-08
72.0	1718.5	1606.9	9.04	580128.	211.4	N/A	N/A	554.6	9.02	.03	9.67	0.00	1069.1	4.79E-07	4.6	5.49E-08
83.0	1729.6	1660.1	10.31	567546.	217.5	N/A	N/A	629.1	10.19	.15	5.35	2.27	1171.4	5.25E-07	3.7	4.46E-08
84.0	1618.2	1641.6	0.00	556758.	217.7	N/A	N/A	1012.6	0.00	.57	0.00	0.00	10795.6	4.84E-06	28319.4	3.37E-04
120.0	1619.8	1619.8	.09	476930.	230.2	98.7	5752.	963.1	.04	4.01	13.08	5.13	1934.3	8.53E-07	3127.9	3.72E-05
144.0	1619.7	1619.7	.08	434055.	238.1	102.1	8528.	989.8	.06	4.01	12.19	6.87	1719.7	7.70E-07	3558.3	4.24E-05
180.0	1619.9	1619.9	.09	375816.	248.1	108.3	12670.	1009.0	.08	4.00	8.56	8.48	1565.4	7.01E-07	1895.6	2.26E-05
216.0	1620.9	1620.9	.15	323065.	256.5	115.4	17726.	999.7	.06	4.00	6.33	6.32	1420.5	6.36E-07	2003.2	2.38E-05
240.0	1619.6	1619.8	.03	290236.	261.5	118.0	20785.	990.4	.00	4.00	5.12	5.14	1305.2	5.85E-07	1315.7	1.21E-05
300.0	1620.0	1620.0	.10	216263.	273.8	125.1	28809.	948.9	.05	4.00	.42	.40	1149.4	5.15E-07	959.0	1.14E-05
360.0	1619.5	1619.5	.05	150785.	286.6	129.6	36091.	903.6	0.00	4.00	.00	.01	1031.6	4.62E-07	441.2	5.25E-06
383.2	1619.4	1619.4	.06	127469.	292.1	130.0	38591.	884.3	.00	4.00	1.67	1.67	992.4	4.45E-07	824.5	9.61E-06
420.0	1619.3	1619.3	.05	92262.	300.8	132.9	42414.	855.6	.00	4.01	2.41	2.42	928.1	4.16E-07	572.0	6.81E-06
468.0	1620.5	1620.5	.13	49637.	311.1	138.0	47867.	819.5	0.00	4.00	2.61	2.59	831.7	3.73E-07	633.6	7.54E-06
480.0	1619.8	1619.8	.08	39450.	313.6	139.4	49251.	812.4	.02	4.00	3.00	2.98	845.2	3.79E-07	635.7	7.57E-06
516.0	1619.2	1619.2	.04	9668.	320.6	143.7	53625.	791.2	.02	4.00	1.34	1.32	805.2	3.61E-07	450.1	5.36E-06
527.8	1619.3	1619.3	0.00	402.	322.3	145.0	55082.	783.8	.01	4.00	.94	.93	782.0	3.50E-07	420.2	5.00E-06

	R.CAVITY FOLLOWING VESSEL MELT-THRU				SUB-	H&V ROOMS		REACTOR CONTAINMENT BUILDING								
HCDA TIME (HRS)	CAVITY TEMP. (DEG.F)	VESSEL TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
528.8	1226.4	1226.4	2.31	0.	138.2	154.4	55943.	771.8	.01	4.00	1.34	2.06	0.0	0.	811.0	9.65E-06
540.0	1247.6	1247.6	.35	0.	147.5	190.5	64063.	675.5	.23	4.03	18.16	4.39	0.0	0.	5375.8	6.40E-05
600.0	1199.2	1199.2	.04	0.	200.7	212.2	88992.	467.5	.01	4.01	17.40	13.11	0.0	0.	2067.9	2.46E-05
660.0	1189.6	1189.6	.01	0.	312.1	211.7	101268.	342.5	.01	4.00	15.43	22.51	0.0	0.	524.4	6.24E-06
696.0	1189.2	1189.2	.01	0.	396.0	212.3	106755.	302.8	.00	4.00	12.44	36.75	0.0	0.	312.9	3.72E-06
720.0	1360.5	1360.5	.01	0.	437.9	212.1	108985.	283.3	.00	3.66	9.06	53.18	0.0	0.	303.9	3.62E-06
780.0	1397.1	1397.1	.01	0.	527.0	212.2	111352.	249.3	.00	2.99	4.38	76.17	0.0	0.	267.7	3.19E-06
792.0	1412.5	1412.5	.01	0.	544.0	212.2	111206.	245.0	.00	2.83	3.76	79.26	0.0	0.	287.4	3.42E-06
840.0	1464.4	1464.4	.01	0.	520.7	212.3	110196.	230.1	.01	2.22	2.16	87.52	0.0	0.	240.1	2.86E-06
888.0	1496.8	1496.8	.01	0.	559.4	212.2	108586.	220.0	.00	1.76	1.34	91.86	0.0	0.	212.9	2.53E-06
900.0	1606.2	1606.2	.13	0.	129.7	212.5	110224.	215.2	.05	4.01	13.47	31.83	0.0	0.	2629.3	3.13E-05
960.0	1731.6	1731.6	.05	0.	130.5	212.3	112913.	207.6	.03	4.01	18.55	7.64	0.0	0.	1512.8	1.80E-05
1020.1	1663.6	1663.6	.10	0.	131.4	212.3	115055.	204.7	.04	4.01	18.34	8.64	0.0	0.	787.2	9.37E-06
1080.1	1692.9	1692.9	.00	0.	131.7	212.2	116537.	204.7	.00	3.69	16.81	16.27	0.0	0.	77.0	9.16E-07
1120.1	1707.5	1707.5	.00	0.	132.0	212.2	117293.	204.2	.00	3.30	15.00	25.29	0.0	0.	63.8	7.60E-07
1140.0	1720.1	1720.1	.00	0.	132.1	212.3	117528.	204.2	.00	3.12	14.16	29.46	0.0	0.	67.5	8.03E-07
1200.0	1734.0	1734.0	.00	0.	132.6	212.3	117979.	204.4	.00	2.68	12.12	39.61	0.0	0.	59.9	7.14E-07
1260.0	1753.0	1753.0	.00	0.	133.2	212.1	118228.	203.6	.00	2.36	10.65	46.92	0.0	0.	40.0	4.76E-07
1320.0	1772.7	1772.7	.00	0.	133.8	212.1	118700.	203.8	0.00	2.17	9.75	51.42	0.0	0.	36.3	4.32E-07
1380.0	1786.4	1786.4	.00	0.	134.5	212.1	119141.	203.1	0.00	2.04	9.11	54.57	0.0	0.	21.7	2.59E-07
1440.0	1801.0	1801.0	.00	0.	135.2	212.1	119508.	203.4	.00	1.94	8.62	57.00	0.0	0.	22.5	2.68E-07
1457.1	1807.4	1807.4	.00	0.	135.4	212.1	119613.	202.9	.00	1.91	8.52	57.54	0.0	0.	16.6	1.97E-07
1500.1	1815.9	1815.9	0.00	0.	135.9	212.1	119886.	202.8	.00	1.87	8.23	58.67	0.0	0.	12.5	1.50E-07
1560.1	1828.1	1828.1	.00	0.	136.7	212.1	120132.	203.1	0.00	1.81	8.00	60.09	0.0	0.	15.8	1.89E-07
1620.1	1838.5	1838.5	0.00	0.	137.5	212.1	120203.	202.6	.00	1.75	7.72	61.49	0.0	0.	12.0	1.43E-07
1632.1	1841.6	1841.6	.00	0.	137.6	212.1	120199.	203.1	.00	1.74	7.66	61.77	0.0	0.	16.7	1.99E-07

HCDA TIME (HRS)	REACTOR VESSEL UPPER TEMP. (DEG.F)	LOWER TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	REACTOR CAVITY TEMP. (DEG.F)	H&V ROOMS ATM. TEMP. (DEG.F)	WATER MASS (LBS)	REACTOR CONTAINMENT BUILDING ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	SODIUM INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	MIXED-ATM LEAKRATE FRACTION (1/SEC)
0.0	1050.0	980.0	0.00	620007.	120.0	N/A	N/A	80.0	0.00	0.00	20.71	1.38	0.0	0.	0.0	0.
.2	1084.5	984.4	.49	620000.	145.2	N/A	N/A	125.1	1.10	0.00	20.78	.68	0.0	0.	6.0	7.17E-08
3.0	1275.5	1023.6	0.00	619997.	153.1	N/A	N/A	80.4	0.00	0.00	20.91	0.00	1.1	4.73E-10	0.0	0.
60.0	1678.2	1533.5	4.99	588464.	203.7	N/A	N/A	349.9	4.88	0.00	12.27	0.00	1079.4	4.64E-07	2.9	3.42E-08
72.0	1691.0	1598.0	6.21	575062.	210.6	N/A	N/A	446.7	6.18	0.00	8.01	0.00	1121.1	5.02E-07	3.5	4.13E-08
91.0	1706.0	1681.7	7.94	552568.	220.6	N/A	N/A	605.1	7.89	.28	0.00	.02	1318.3	5.91E-07	2.2	2.61E-08
92.0	1623.1	1627.3	.33	540800.	221.0	N/A	N/A	761.0	.29	4.05	0.00	0.00	11985.0	5.37E-06	13683.2	2.25E-04
120.0	1620.1	1620.1	.11	478826.	230.1	100.8	4804.	931.3	.00	4.02	.01	.01	1843.9	8.25E-07	1286.3	1.53E-05
144.0	1619.8	1619.8	.08	436274.	237.7	105.2	7774.	987.6	.04	4.00	.04	.05	1742.2	7.81E-07	1149.9	1.37E-05
180.0	1619.4	1619.4	.06	378196.	247.6	108.0	12014.	1030.5	0.00	4.01	0.00	0.00	1603.8	7.19E-07	1125.4	1.34E-05
216.0	1620.8	1620.8	.16	325618.	256.1	116.3	16845.	973.3	0.00	4.00	.01	.00	1384.8	6.20E-07	764.3	9.10E-06
240.0	1619.9	1619.9	.09	293006.	261.0	117.1	20016.	971.3	0.00	4.00	.01	.01	1320.9	5.92E-07	993.4	1.18E-05
300.0	1619.9	1619.9	.09	219491.	273.1	124.1	27923.	880.0	0.00	4.00	0.00	0.00	1152.4	5.16E-07	543.9	6.48E-06
360.0	1619.3	1619.3	.04	155199.	285.4	129.6	35286.	822.3	.00	4.00	.04	.00	1005.2	4.50E-07	593.9	7.07E-06
384.0	1619.5	1619.5	.05	131732.	290.6	130.3	37991.	785.7	.00	4.00	.03	.00	962.9	4.31E-07	548.3	6.53E-06
420.0	1619.7	1619.7	.03	98540.	298.9	132.2	41640.	746.5	.00	4.02	0.00	0.00	895.7	4.01E-07	408.9	4.87E-06
468.0	1619.9	1619.9	.09	57742.	308.8	137.1	45894.	701.0	.00	4.00	.03	0.00	616.3	3.55E-07	411.7	4.90E-06
480.0	1619.6	1619.6	.07	47830.	311.1	136.3	48224.	693.5	.00	4.00	.03	0.00	809.6	3.63E-07	429.1	5.11E-06
516.0	1619.3	1619.3	.04	19505.	317.6	142.3	52418.	661.5	.00	4.00	0.00	0.00	764.5	3.43E-07	380.5	4.53E-06
540.0	1619.6	1619.6	.07	1725.	321.8	145.1	55275.	638.4	0.00	4.00	.01	0.00	730.9	3.27E-07	368.3	4.38E-06
541.8	1620.5	1620.5	0.00	405.	322.1	145.3	55503.	636.7	0.00	4.00	.00	0.00	723.9	3.24E-07	359.4	4.28E-06

HCDA TIME (HRS)	R.CAVITY FOLLOWING VESSEL MELT-THRU CAVITY TEMP. (DEG.F)	VESSEL TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	SUB-CAVITY TEMP. (DEG.F)	H&V ROOMS ATM. TEMP. (DEG.F)	WATER MASS (LBS)	REACTOR CONTAINMENT BUILDING ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
542.8	1224.4	1224.4	2.23	0.	138.8	154.7	56367.	626.8	.01	4.00	.63	0.00	0.0	0.	690.2	8.22E-06
600.0	1195.8	1195.8	.11	0.	186.8	212.4	85255.	429.4	.03	4.01	20.14	.05	0.0	0.	1583.3	1.88E-05
612.0	1202.8	1202.8	.12	0.	198.8	212.2	88672.	398.3	.04	4.01	20.15	.03	0.0	0.	2377.6	2.83E-05
660.0	1403.2	1403.2	.01	0.	269.0	212.2	97825.	318.9	.01	4.01	20.15	.05	0.0	0.	1192.2	1.42E-05
720.0	1406.9	1406.9	.01	0.	414.4	212.4	103005.	269.7	.01	4.00	20.14	.11	0.0	0.	188.5	2.24E-06
780.0	1472.7	1472.7	.01	0.	507.1	212.1	103623.	241.3	.00	3.18	9.46	51.78	0.0	0.	302.6	3.60E-06
816.0	1492.0	1492.0	.01	0.	556.2	212.1	102517.	230.9	.00	2.69	6.12	68.18	0.0	0.	222.9	2.65E-06
840.0	1507.2	1507.2	.01	0.	515.1	212.3	101841.	225.2	.00	2.47	4.79	74.73	0.0	0.	244.9	2.92E-06
900.0	1549.3	1549.3	.01	0.	559.7	212.2	99697.	214.6	.00	1.91	2.77	84.89	0.0	0.	177.1	2.11E-06
912.0	1557.2	1557.2	.01	0.	563.7	212.2	99215.	213.7	.00	1.85	2.51	86.19	0.0	0.	191.8	2.28E-06
960.0	1738.8	1738.8	.06	0.	130.5	212.4	103470.	205.8	.04	4.01	18.98	5.63	0.0	0.	2121.3	2.53E-05
1020.1	1671.9	1671.9	.12	0.	131.9	212.4	106518.	203.2	.05	4.01	18.84	6.29	0.0	0.	1064.3	1.27E-05
1080.1	1685.2	1685.2	.17	0.	132.5	212.3	108574.	202.9	.04	4.01	18.67	7.08	0.0	0.	869.9	1.04E-05
1120.1	1709.8	1709.8	.00	0.	132.6	212.3	109521.	202.9	.00	3.65	17.08	15.02	0.0	0.	61.2	7.28E-07
1140.0	1718.6	1718.6	.00	0.	132.7	212.4	109847.	203.2	.00	3.47	16.20	19.37	0.0	0.	58.4	6.95E-07
1200.0	1738.8	1738.8	.00	0.	133.2	212.4	110543.	203.9	.00	3.02	14.07	29.99	0.0	0.	60.7	7.22E-07
1260.0	1762.6	1762.6	.00	0.	133.7	212.2	111199.	203.3	0.00	2.73	12.65	37.01	0.0	0.	34.7	4.14E-07
1320.0	1775.1	1775.1	.00	0.	134.3	212.1	111905.	203.8	.00	2.53	11.73	41.62	0.0	0.	27.3	3.25E-07
1344.0	1783.5	1783.5	.00	0.	134.5	212.1	112170.	203.7	.00	2.47	11.44	43.06	0.0	0.	28.3	3.36E-07
1380.1	1790.8	1790.8	0.00	0.	134.8	212.2	112531.	203.2	.00	2.39	11.06	44.95	0.0	0.	20.6	2.45E-07
1440.1	1804.4	1804.4	.00	0.	135.4	212.1	113059.	203.7	.00	2.28	10.56	47.45	0.0	0.	18.2	2.16E-07
1500.1	1819.4	1819.4	0.00	0.	136.1	212.1	113536.	203.1	.00	2.21	10.20	49.23	0.0	0.	12.4	1.48E-07
1560.1	1831.3	1831.3	0.00	0.	136.7	212.1	113865.	203.6	.00	2.14	9.89	50.78	0.0	0.	15.0	1.78E-07
1620.1	1841.1	1841.1	0.00	0.	137.4	212.1	114003.	203.2	.00	2.07	9.57	52.35	0.0	0.	12.4	1.48E-07
1632.1	1842.7	1842.7	0.00	0.	137.5	212.1	114014.	203.7	.00	2.06	9.51	52.67	0.0	0.	15.6	1.85E-07

CASE 658 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, FAIL 20PSIG

CASE 658 12 NOV 76 1551 HRS

	REACTOR VESSEL				REACTOR	H&V ROOMS		REACTOR CONTAINMENT BUILDING					SODIUM		MIXED-ATM
HCDA TIME (HRS)	UPPER TEMP. (DEG.F)	LOWER TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
0.0	1050.0	980.0	0.00	620007.	120.0	N/A	N/A	80.0	0.00	0.00	20.71	1.38	0.0	0.	0.0	0.
.2	1084.8	984.4	.49	620000.	145.2	N/A	N/A	124.7	1.17	0.00	20.67	1.20	0.0	0.	6.1	7.24E-08
3.0	1275.8	1023.7	.48	619998.	153.2	N/A	N/A	97.9	.45	0.00	20.66	1.20	1.0	4.52E-10	.3	3.22E-09
72.0	1719.4	1606.9	9.03	580116.	211.4	N/A	N/A	554.7	9.01	0.00	9.65	0.00	1066.9	4.78E-07	4.6	5.48E-08
80.0	1726.6	1646.4	9.95	571083.	215.8	N/A	N/A	625.8	9.83	0.00	6.64	0.00	1196.5	5.35E-07	3.5	4.20E-08
123.0	1806.0	1806.7	20.09	525516.	237.7	N/A	N/A	691.1	20.01	16.58	.69	13.50	1105.6	4.95E-07	5.9	6.97E-08
124.0	1620.9	1619.8	.15	495847.	237.5	N/A	N/A	1140.3	0.00	25.84	.00	0.00	31705.1	1.42E-05	53002.1	6.31E-04
144.0	1620.0	1620.0	.10	442030.	240.6	101.5	6668.	888.5	.07	51.36	0.00	0.00	1791.7	8.03E-07	[illegible]	5.88E-06
160.0	1619.4	1619.4	.05	414467.	244.4	98.7	8605.	858.0	.02	63.14	0.00	0.00	1663.9	7.45E-07	[illegible]	3.76E-06
216.0	1620.4	1620.4	.13	331747.	257.1	107.2	14955.	779.7	.02	82.93	0.00	0.00	1354.6	6.07E-07	[illegible]	4.71E-06
240.0	1613.9	1613.9	0.00	298812.	261.7	112.6	18106.	769.1	0.00	72.19	0.00	0.00	1012.9	4.54E-07	.2	1.81E-07
296.8	1619.8	1619.8	.08	233994.	272.4	117.7	24922.	712.8	0.00	64.09	0.00	0.00	1082.3	4.85E-07	.0	2.30E-10
320.0	1616.5	1616.5	0.00	208971.	276.7	120.0	27801.	693.8	0.00	60.30	0.00	0.00	1078.5	4.83E-07	.0	1.14E-10
384.0	1614.9	1614.9	0.00	146591.	288.0	125.1	35074.	647.4	0.00	45.33	0.00	0.00	927.5	4.15E-07	.0	7.50E-11
400.0	1618.6	1618.6	0.00	132927.	290.9	125.9	35755.	635.9	0.00	39.70	0.00	0.00	860.3	3.85E-07	.3	3.72E-09
458.6	1619.2	1619.2	.04	84464.	301.6	130.8	43084.	618.1	.01	27.82	0.00	0.00	781.1	3.50E-07	17.7	2.11E-07
480.0	1619.1	1619.1	.03	67602.	305.4	132.4	45293.	610.6	0.00	23.16	0.00	0.00	762.8	3.42E-07	16.6	1.97E-07
492.0	1618.6	1618.6	0.00	58414.	307.5	133.9	46601.	608.7	0.00	20.22	0.00	0.00	760.8	3.41E-07	8.5	1.01E-07
516.0	1619.3	1619.3	.05	40443.	311.5	136.4	49255.	596.9	0.00	14.50	0.00	0.00	725.1	3.25E-07	13.7	1.63E-07
540.0	1619.2	1619.2	.04	23294.	315.3	138.8	51953.	591.8	0.00	13.09	0.00	0.00	712.3	3.19E-07	7.8	9.28E-08
560.0	1619.6	1619.6	.07	9373.	318.3	141.5	54355.	574.9	0.00	11.69	0.00	0.00	695.5	3.12E-07	.0	2.30E-11
572.9	1611.8	1611.8	0.00	404.	320.2	142.9	55910.	567.7	0.00	10.19	0.00	0.00	692.7	3.10E-07	.0	2.19E-11

	R.CAVITY FOLLOWING VESSEL MELT-THRU				SUB-	H&V ROOMS		REACTOR CONTAINMENT BUILDING								
HCDA TIME (HRS)	CAVITY TEMP. (DEG.F)	VESSEL TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
573.9	1221.8	1221.8	2.25	0.	140.2	152.3	56778.	562.2	.03	10.97	0.00	0.00	0.0	0.	275.2	3.28E-06
640.0	1201.4	1201.4	.09	0.	196.2	212.2	89197.	446.3	.01	65.37	0.00	0.00	0.0	0.	232.3	2.77E-06
648.0	1192.3	1192.3	.03	0.	205.0	212.3	91461.	437.8	.02	68.25	0.00	0.00	0.0	0.	252.4	3.01E-06
720.0	1404.7	1404.7	.03	0.	351.6	212.1	103444.	424.7	.00	88.48	0.00	0.00	0.0	0.	285.4	3.40E-06
744.0	1392.7	1392.7	.03	0.	403.4	212.4	105492.	430.9	.01	91.85	0.00	0.00	0.0	0.	405.3	4.82E-06
800.0	1455.6	1455.6	.03	0.	424.8	212.4	107136.	432.2	.00	96.41	0.00	0.00	0.0	0.	350.4	4.17E-06
840.0	1490.3	1490.3	.03	0.	462.9	212.2	105246.	442.2	.00	98.11	0.00	0.00	0.0	0.	327.5	3.90E-06
880.0	1513.8	1513.8	.02	0.	496.7	212.2	105200.	376.5	.01	69.37	0.00	29.53	0.0	0.	261.2	3.11E-06
936.0	1554.7	1554.7	.02	0.	549.9	212.1	103231.	299.3	.01	36.29	0.00	63.17	0.0	0.	209.3	2.49E-06
960.0	1690.7	1690.7	.08	0.	128.7	212.1	105944.	282.5	.01	39.81	.00	59.77	0.0	0.	216.5	2.58E-06
1040.0	1654.0	1654.0	.02	0.	130.9	212.2	110784.	247.6	.01	39.13	.00	60.65	0.0	0.	146.5	1.75E-06
1120.0	1700.4	1700.4	.00	0.	133.2	212.2	113622.	230.4	.00	33.17	.00	66.69	0.0	0.	73.0	8.69E-07
1200.1	1734.8	1734.8	0.00	0.	135.7	212.3	115153.	222.1	.00	25.41	.01	74.44	0.0	0.	67.7	8.06E-07
1280.1	1759.5	1759.5	0.00	0.	137.8	212.2	115990.	217.6	.00	20.47	.02	79.36	0.0	0.	49.3	5.87E-07
1344.1	1772.6	1772.6	.00	0.	139.2	212.1	116732.	215.7	.00	18.15	.02	81.68	0.0	0.	40.9	4.87E-07
1360.0	1779.4	1779.4	.00	0.	139.6	212.2	116937.	214.7	.00	17.71	.03	82.08	0.0	0.	37.4	4.45E-07
1440.0	1797.9	1797.9	0.00	0.	141.3	212.1	117733.	213.7	.00	15.83	.09	83.69	0.0	0.	30.4	3.61E-07
1520.0	1818.7	1818.7	0.00	0.	142.8	212.1	118384.	212.5	0.00	14.54	.19	84.49	0.0	0.	21.6	2.58E-07
1600.0	1834.0	1834.0	0.00	0.	144.2	212.1	118817.	211.6	.00	13.59	.30	84.90	0.0	0.	17.6	2.09E-07
1632.0	1840.3	1840.3	0.00	0.	144.7	212.1	118993.	212.0	.00	13.25	.34	85.05	0.0	0.	19.6	2.33E-07

CASE 659 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, RELF 10PSIG
CASE 659 12 NOV 76 2347 HRS

HCDA TIME (HRS)	REACTOR VESSEL: UPPER TEMP. (DEG.F)	REACTOR VESSEL: LOWER TEMP. (DEG.F)	REACTOR VESSEL: PRESS. (PSIG)	REACTOR VESSEL: SODIUM MASS (LBS)	REACTOR CAVITY TEMP. (DEG.F)	H&V ROOMS: ATM. TEMP. (DEG.F)	H&V ROOMS: WATER MASS (LBS)	REACTOR CONTAINMENT BUILDING: ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM: SODIUM INRATE (LB/HR)	SODIUM: INRATE FRACTION (1/SEC)	SODIUM: MIXED-ATM LEAKRATE (TRUE CFM)	MIXED-ATM LEAKRATE FRACTION (1/SEC)
0.0	1050.0	980.0	0.00	620007.	120.0	N/A	N/A	80.0	0.00	0.00	20.71	1.38	0.0	0.	0.0	0.
.2	1084.8	984.4	.49	620000.	145.2	N/A	N/A	124.7	1.17	0.00	20.67	1.20	0.0	0.	6.1	7.24E-08
3.0	1275.8	1023.7	.48	619998.	153.2	N/A	N/A	97.8	.45	0.00	20.66	1.20	1.0	4.52E-10	.3	3.22E-09
60.0	1699.4	1539.7	7.04	592547.	204.2	N/A	N/A	425.0	5.94	0.00	13.49	0.00	1014.3	4.54E-07	3.9	4.65E-08
72.0	1718.4	1606.9	9.03	580116.	211.4	N/A	N/A	554.7	9.01	0.00	9.65	0.00	1066.9	4.78E-07	4.6	5.48E-08
120.0	1726.2	1729.0	10.08	509986.	234.3	N/A	N/A	822.8	10.02	32.81	.00	.06	1722.9	7.72E-07	281.0	3.35E-06
144.0	1728.1	1728.6	10.07	469644.	242.8	N/A	N/A	818.9	10.01	47.41	0.00	0.00	1606.5	7.20E-07	239.3	2.85E-06
180.0	1725.7	1725.7	9.80	412624.	253.2	106.7	11101.	798.4	9.77	60.99	0.00	0.00	1468.8	6.58E-07	111.0	1.32E-06
213.9	1714.6	1714.6	8.59	364437.	261.5	110.9	15151.	793.5	8.37	66.79	0.00	0.00	1650.8	7.40E-07	2.6	3.08E-08
240.0	1692.1	1692.1	6.28	325956.	266.4	117.8	18754.	784.3	6.28	63.18	0.00	0.00	1448.7	6.49E-07	2.2	2.57E-08
295.5	1697.4	1697.4	6.81	263237.	277.0	122.8	25930.	751.1	5.74	64.90	0.00	0.00	1030.1	4.62E-07	2.2	2.65E-08
300.0	1697.9	1697.9	6.86	258559.	277.9	123.3	26544.	747.7	6.79	65.08	0.00	0.00	1059.2	4.75E-07	2.1	2.54E-08
360.0	1681.1	1681.1	5.23	195933.	288.9	128.6	34058.	711.3	5.22	63.26	0.00	0.00	1016.1	4.55E-07	1.9	2.23E-08
384.0	1671.2	1671.2	4.31	171973.	293.0	129.3	36920.	698.3	4.30	61.73	0.00	0.00	1002.2	4.49E-07	1.7	2.03E-08
420.0	1654.8	1654.8	2.87	137241.	299.1	132.6	41105.	681.3	2.84	58.82	0.00	0.00	905.1	4.05E-07	1.4	1.65E-08
468.0	1651.1	1651.1	2.55	97429.	308.1	135.5	46345.	657.0	2.52	58.81	0.00	0.00	827.8	3.71E-07	1.3	1.55E-08
480.0	1648.2	1648.2	2.32	87702.	310.2	136.9	47683.	651.0	2.22	58.23	0.00	0.00	820.9	3.68E-07	1.2	1.45E-08
516.0	1626.9	1626.9	.62	56989.	316.0	140.7	51789.	637.3	.59	53.94	0.00	0.00	815.7	3.65E-07	.7	7.83E-09
540.0	1621.2	1621.2	.19	37458.	319.6	143.8	54649.	632.5	.17	52.64	0.00	0.00	776.6	3.48E-07	.3	4.15E-09
564.0	1616.9	1616.9	0.00	19280.	323.1	146.3	57364.	624.1	0.00	51.82	0.00	0.00	751.0	3.36E-07	.0	6.11E-11
590.2	1616.5	1616.5	0.00	405.	327.0	148.9	60724.	623.1	0.00	48.39	0.00	0.00	714.2	3.20E-07	2.4	2.90E-08

HCDA TIME (HRS)	R.CAVITY FOLLOWING VESSEL MELT-THRU: CAVITY TEMP. (DEG.F)	VESSEL TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	SUB-CAVITY TEMP. (DEG.F)	H&V ROOMS: ATM. TEMP. (DEG.F)	H&V ROOMS: WATER MASS (LBS)	REACTOR CONTAINMENT BUILDING: ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
591.2	1220.8	1220.8	2.36	0.	142.3	157.0	61430.	621.0	.22	48.45	0.00	0.00	0.0	0.	66.7	7.94E-07
600.0	1237.3	1237.3	2.73	0.	150.9	196.1	67574.	613.6	2.78	54.75	0.00	0.00	0.0	0.	3.0	3.59E-08
660.0	1203.0	1203.0	9.81	0.	199.9	237.3	97819.	510.7	9.80	73.59	0.00	0.00	0.0	0.	124.5	1.48E-06
720.0	1402.3	1402.3	9.88	0.	307.9	238.4	114214.	497.7	9.87	84.89	0.00	0.00	0.0	0.	216.7	2.58E-06
756.0	1396.0	1396.0	9.89	0.	393.1	239.4	120582.	490.4	9.89	88.66	0.00	0.00	0.0	0.	234.9	2.80E-06
780.0	1421.9	1421.9	9.88	0.	438.7	239.2	122933.	501.9	9.88	91.18	0.00	0.00	0.0	0.	246.5	2.93E-06
840.0	1483.9	1483.9	9.87	0.	524.9	239.3	127181.	512.5	9.87	95.11	0.00	0.00	0.0	0.	270.2	3.22E-06
852.0	1489.6	1489.6	9.83	0.	542.3	239.1	127563.	513.8	9.82	95.70	0.00	0.00	0.0	0.	237.0	2.82E-06
900.0	1524.6	1524.6	9.79	0.	519.1	239.1	128780.	509.6	9.77	97.27	0.00	0.00	0.0	0.	227.9	2.71E-06
948.0	1561.9	1561.9	9.77	0.	555.7	239.0	129444.	455.4	9.76	84.13	0.00	14.06	0.0	0.	134.3	1.60E-06
960.0	1663.2	1663.2	9.84	0.	264.4	238.7	132358.	434.8	9.77	80.91	.00	17.47	0.0	0.	141.7	1.69E-06
1020.0	1641.7	1641.7	9.75	0.	265.3	238.4	141264.	362.7	9.74	68.37	.00	30.52	0.0	0.	108.0	1.29E-06
1080.0	1666.0	1666.0	9.74	0.	265.6	238.6	147420.	324.1	9.72	59.20	.00	39.96	0.0	0.	79.8	9.50E-07
1120.0	1691.2	1691.2	9.66	0.	265.6	238.7	150486.	307.2	9.66	54.26	.00	45.01	0.0	0.	60.7	7.23E-07
1140.1	1704.6	1704.6	9.67	0.	265.8	238.8	151824.	300.5	9.67	51.56	.00	47.75	0.0	0.	48.0	5.71E-07
1200.1	1735.3	1735.3	9.67	0.	266.1	238.9	154819.	286.1	9.67	44.13	.00	55.28	0.0	0.	48.9	5.82E-07
1260.1	1750.8	1750.8	9.67	0.	266.3	238.9	156961.	276.7	9.67	38.53	.00	60.95	0.0	0.	44.3	5.28E-07
1320.1	1769.9	1769.9	9.65	0.	266.5	238.8	158959.	270.9	9.65	34.79	.00	64.74	0.0	0.	35.3	4.21E-07
1344.1	1776.2	1776.2	9.65	0.	266.5	238.8	159690.	269.1	9.65	33.55	.00	66.00	0.0	0.	34.3	4.08E-07
1380.0	1789.8	1789.8	9.63	0.	266.6	238.7	160589.	266.5	9.63	31.95	.00	67.62	0.0	0.	27.8	3.31E-07
1440.0	1804.0	1804.0	9.62	0.	266.9	238.7	162142.	263.8	9.62	29.75	.00	69.85	0.0	0.	24.2	2.88E-07
1500.0	1819.2	1819.2	9.61	0.	267.4	238.6	163384.	261.3	9.61	28.06	.00	71.57	0.0	0.	18.9	2.25E-07
1560.0	1832.7	1832.7	9.61	0.	267.9	238.6	164453.	259.9	9.61	26.72	.00	72.92	0.0	0.	17.9	2.14E-07
1620.0	1845.5	1845.5	9.60	0.	268.3	238.6	165307.	258.5	9.60	25.59	.00	74.07	0.0	0.	15.7	1.87E-07
1632.0	1846.2	1848.2	9.60	0.	268.4	238.6	165455.	258.6	9.61	25.38	.00	74.28	0.0	0.	16.5	1.97E-07

CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+O2 R, PURGE
CASE 675   10 NOV 76   0233 HRS

HCDA TIME (HRS)	REACTOR VESSEL---- UPPER TEMP. (DEG.F)	LOWER TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	REACTOR CAVITY TEMP. (DEG.F)	H&V ROOMS---- ATM. TEMP. (DEG.F)	WATER MASS (LBS)	REACTOR CONTAINMENT BUILDING---- ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	--SODIUM---- SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	MIXED-ATM LEAKRATE FRACTION (1/SEC)
0.0	1050.0	980.0	0.00	620007.	120.0	N/A	N/A	80.0	0.00	0.00	20.71	1.38	0.0	0.	0.0	0.
.2	1084.7	984.4	.49	620000.	145.3	N/A	N/A	124.9	1.18	0.00	20.67	1.20	0.0	0.	.6	6.99E-09
3.0	1275.7	1023.4	.48	619998.	153.2	N/A	N/A	97.8	.45	0.00	20.67	1.20	1.0	4.52E-10	.3	3.21E-09
HCDA TIME (HRS)	**R.CAVITY FOLLOWING VESSEL MELT-THRU CAVITY TEMP. (DEG.F)**	**VESSEL TEMP. (DEG.F)**	**PRESS. (PSIG)**	**SODIUM MASS (LBS)**	**SUB-CAVITY TEMP. (DEG.F)**	**H&V ROOMS---- ATM. TEMP. (DEG.F)**	**WATER MASS (LBS)**	**REACTOR CONTAINMENT BUILDING---- ATM. TEMP. (DEG.F)**	**ATM. PRESS. (PSIG)**	**H2 CONC. (V%)**	**O2 CONC. (V%)**	**H2O CONC. (V%)**	**SODIUM INRATE (LB/HR)**	**INRATE FRACTION (1/SEC)**	**MIXED-ATM LEAKRATE (TRUE CFM)**	**LEAKRATE FRACTION (1/SEC)**
4.0	1112.0	1112.0	.71	619928.	109.2	139.7	867.	99.8	.72	0.00	20.47	1.23	10.6	4.73E-09	2.0*	2.39E-08
7.0	1082.9	1082.9	.47	619922.	109.9	193.1	6449.	102.7	1.07	0.00	20.32	1.95	0.0	0.	1.4*	1.63E-08
50.0	1184.8	1184.8	4.34	619842.	203.2	225.5	42060.	136.2	4.41	0.00	17.88	13.77	0.0	0.	1.0*	1.13E-08
72.0	1215.0	1215.0	5.25	619829.	213.1	227.7	52613.	144.5	5.25	0.00	17.35	16.33	0.0	0.	.9*	1.10E-08
100.0	1243.6	1243.6	6.18	619808.	221.4	230.4	63627.	152.6	6.18	0.00	16.77	19.08	.0	6.25E-12	.9*	1.12E-08
150.0	1283.3	1283.3	7.61	619780.	228.0	234.1	79212.	163.5	7.63	0.00	15.93	23.18	0.0	0.	1.1*	1.32E-08
168.0	1291.4	1291.4	8.08	619763.	230.4	235.2	83772.	166.7	8.11	0.00	15.66	24.47	0.0	0.	1.2*	1.39E-08
200.0	1306.0	1306.0	8.98	619729.	232.7	237.5	90697.	172.3	9.08	0.00	15.13	26.99	0.0	0.	1.3*	1.56E-08
229.0	1320.0	1320.0	9.99	619684.	234.8	239.5	95623.	178.0	10.00	0.00	14.66	29.26	0.0	0.	1.2*	1.43E-08
230.0	1320.1	1320.1	.71	619647.	213.9	214.9	92269.	164.4	.70	0.00	13.55	34.36	39.3	1.75E-08	16536.8	1.97E-04
250.0	1329.8	1329.8	0.00	619638.	212.1	212.1	89788.	176.1	.00	.00	10.93	47.03	.1	3.82E-11	103.7	1.24E-06
300.0	1351.7	1351.7	.00	619632.	212.2	212.1	87654.	186.3	.00	.00	8.48	58.85	.1	3.71E-11	112.4	1.34E-06
312.0	1356.4	1356.4	.00	619631.	212.3	212.1	87081.	188.2	.00	.00	7.96	61.38	.1	4.13E-11	113.3	1.35E-06
350.0	1369.7	1369.7	.00	619628.	212.6	212.2	86381.	191.7	.00	.00	6.99	66.09	.1	3.74E-11	101.1	1.20E-06
384.0	1380.4	1380.4	.00	619625.	212.5	212.2	84933.	195.1	.00	.01	5.96	71.04	.1	3.86E-11	126.6	1.51E-06
400.0	1384.9	1384.9	.00	619623.	212.1	212.1	84510.	196.1	.00	.01	5.67	72.44	.1	3.77E-11	68.0	8.09E-07
450.0	1397.7	1397.7	.00	619619.	212.2	212.1	83661.	198.4	.00	.01	4.94	75.97	.1	3.68E-11	72.6	8.64E-07
500.0	1408.5	1408.5	.00	619614.	212.2	212.1	82757.	200.3	.00	.01	4.30	79.08	.1	3.57E-11	68.1	8.10E-07
504.0	1409.3	1409.3	.00	619613.	212.3	212.1	82709.	200.5	.00	.01	4.25	79.35	.1	3.59E-11	75.9	9.04E-07
552.0	1418.1	1418.1	.00	619609.	212.4	212.1	82009.	202.0	.00	.01	3.74	81.79	.1	3.54E-11	80.1	9.53E-07
604.1	1426.4	1426.4	.00	619605.	212.4	212.1	81286.	203.3	.00	.01	3.27	84.08	.1	3.43E-11	72.6	8.64E-07
656.0	1433.5	1433.5	.00	619602.	212.4	212.1	80370.	204.6	.00	.01	2.83	86.22	.1	3.24E-11	60.5	7.20E-07
672.0	1435.5	1435.5	.00	619600.	212.4	212.1	80163.	204.9	.00	.01	2.72	86.75	.1	3.00E-11	74.3	8.84E-07
708.0	1439.4	1439.4	.00	619598.	212.5	212.2	79588.	205.6	.00	.01	2.46	88.00	.1	2.86E-11	55.7	6.64E-07
760.0	1444.6	1444.6	.00	619595.	212.4	212.1	78913.	206.4	.00	.01	2.15	89.49	.1	2.52E-11	52.0	6.19E-07
812.1	1448.9	1448.9	.00	619592.	212.4	212.1	78261.	207.2	.00	.01	1.87	90.84	.1	2.25E-11	69.9	8.32E-07
864.0	1452.7	1452.7	.00	619589.	212.4	212.1	77486.	207.9	.00	.01	1.61	92.11	.0	2.16E-11	84.6	1.01E-06
916.1	1458.9	1458.9	.00	619585.	212.5	212.2	76888.	208.5	.00	.02	1.40	93.16	.1	2.71E-11	74.7	8.90E-07
968.1	1462.2	1462.2	.00	619582.	212.5	212.1	76405.	208.9	.00	.02	1.22	94.02	.1	2.29E-11	55.4	6.60E-07
1020.1	1464.9	1464.9	.00	619580.	318.8	212.1	75926.	209.3	.00	.02	1.07	94.76	.0	1.83E-11	53.1	6.32E-07
1070.1	1466.9	1466.9	.00	619578.	325.0	212.1	75414.	209.7	.00	.01	.94	95.40	.0	1.29E-11	49.5	5.89E-07
1120.1	1468.5	1468.5	.00	619577.	331.7	212.1	74888.	210.0	.00	.01	.82	95.97	.0	1.31E-11	53.6	6.39E-07
1170.0	1469.8	1469.8	.00	619575.	336.7	212.2	74359.	210.2	.00	.01	.72	96.48	.0	7.02E-12	67.4	8.03E-07
1220.0	1470.8	1470.8	.00	619574.	340.9	212.2	73827.	210.5	.00	.01	.62	96.93	.0	4.44E-12	72.2	8.60E-07
1270.0	1471.4	1471.4	.00	619574.	347.7	212.1	73304.	210.7	.00	.01	.54	97.33	.0	2.10E-12	74.1	8.82E-07
1320.0	1471.6	1471.6	.00	619573.	351.6	212.1	72849.	210.9	.00	.01	.47	97.67	.0	4.65E-13	75.1	8.94E-07
1370.0	1471.7	1471.7	.00	619568.	355.6	212.1	72405.	211.0	.00	.01	.41	97.97	0.0	0.	76.5	9.11E-07
1376.0	1471.6	1471.6	.00	619568.	356.1	212.1	72349.	211.0	.00	.01	.41	98.00	.0	7.55E-13	58.2	6.92E-07
1420.1	1471.5	1471.5	.00	619551.	361.2	212.2	71977.	211.2	.00	.01	.36	98.23	0.0	0.	77.2	9.19E-07
1470.1	1471.2	1471.2	.00	619526.	366.1	212.2	71560.	211.3	.00	.01	.31	98.45	0.0	0.	74.0	8.82E-07
1520.1	1470.7	1470.7	0.00	619492.	370.2	212.2	71144.	211.4	.00	.01	.27	98.65	0.0	0.	69.1	8.22E-07
1570.1	1470.1	1470.1	0.00	619451.	373.2	212.2	70722.	211.5	.00	.00	.24	98.82	0.0	0.	49.5	5.90E-07
1620.1	1469.3	1469.3	0.00	619406.	378.0	212.2	70302.	211.5	.00	.00	.21	98.97	0.0	0.	49.3	5.86E-07
1632.1	1469.1	1469.1	0.00	619395.	379.0	212.2	70204.	211.6	.00	.00	.20	99.01	0.0	0.	82.0	9.76E-07

* See note on Page A-27.

CASE 677 3HR MELTHRU, C.LNER FAIL, NO B.CLR, NO H2+O2, PURGE
CASE 677 10 NOV 76 0908 HRS

HCDA TIME (HRS)	REACTOR VESSEL UPPER TEMP. (DEG.F)	REACTOR VESSEL LOWER TEMP. (DEG.F)	REACTOR VESSEL PRESS. (PSIG)	REACTOR VESSEL SODIUM MASS (LBS)	REACTOR CAVITY TEMP. (DEG.F)	H&V ROOMS ATM. TEMP. (DEG.F)	H&V ROOMS WATER MASS (LBS)	REACTOR CONTAINMENT BUILDING ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM SODIUM INRATE (LB/HR)	SODIUM INRATE FRACTION (1/SEC)	SODIUM MIXED-ATM LEAKRATE (TRUE CFM)	MIXED-ATM LEAKRATE FRACTION (1/SEC)
0.0	1050.0	380.0	0.00	620007.	120.0	N/A	N/A	80.0	0.00	0.00	20.71	1.38	0.0	0.	0.0	0.
.2	1084.7	984.4	.49	620000.	145.3	N/A	N/A	124.7	1.18	.01	20.68	1.20	0.0	0.	.6	6.97E-09
3.0	1275.9	1023.5	.48	619998.	153.2	N/A	N/A	97.8	.45	.01	20.67	1.20	1.0	4.53E-10	.3	3.20E-09
HCDA TIME (HRS)	R.CAVITY FOLLOWING VESSEL MELT-THRU CAVITY TEMP. (DEG.F)	VESSEL TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	SUB-CAVITY TEMP. (DEG.F)	H&V ROOMS ATM. TEMP. (DEG.F)	H&V ROOMS WATER MASS (LBS)	REACTOR CONTAINMENT BUILDING ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
4.0	1122.0	1122.0	.97	617300.	109.3	140.4	872.	100.4	.78	.12	20.41	1.22	18.2	8.14E-09	.4	4.27E-09
7.0	1114.0	1114.0	1.24	615208.	110.2	195.2	6610.	103.3	1.24	.45	20.14	1.98	1.2	5.33E-10	.4	5.33E-09
42.2	1201.5	1201.5	5.14	607263.	140.8	227.5	38054.	134.7	5.09	3.75	17.18	12.81	5.5	2.48E-09	.9	1.03E-08
43.0	1201.9	1201.9	.39	607352.	128.9	212.7	37344.	130.2	.37	4.04	16.68	14.92	29.4	1.32E-08	10037.2	1.19E-04
50.0	1213.7	1213.7	.04	606627.	123.4	212.3	39802.	137.6	.01	4.00	15.97	18.56	4.3	1.92E-09	423.0	5.04E-06
72.0	1245.2	1245.2	.03	603818.	126.0	212.1	47378.	144.3	.01	4.00	15.34	22.02	4.5	2.02E-09	337.2	4.01E-06
100.0	1274.5	1274.5	.03	600934.	134.1	212.3	55025.	151.8	.00	4.00	14.44	26.58	4.5	1.99E-09	278.6	3.32E-06
150.0	1308.3	1308.3	.03	597266.	150.9	212.2	65103.	161.9	.00	4.00	12.94	33.91	5.6	2.51E-09	258.9	3.08E-06
166.0	1317.2	1317.2	.04	596038.	157.8	212.1	67758.	164.5	.01	4.00	12.50	36.07	7.2	3.23E-09	308.7	3.68E-06
200.0	1332.4	1332.4	.02	594444.	169.9	212.3	71227.	171.4	.00	4.00	11.21	42.27	4.1	1.82E-09	161.3	1.92E-06
250.0	1356.4	1356.4	.03	592567.	190.0	212.1	74266.	179.0	.00	4.00	9.57	50.13	5.1	2.29E-09	167.3	1.99E-06
300.0	1374.8	1374.8	.01	591523.	206.8	212.2	75042.	187.3	.00	3.77	7.53	60.13	2.3	1.02E-09	112.2	1.34E-06
312.0	1378.8	1378.8	.01	591368.	209.1	212.0	75156.	188.7	.00	3.71	7.16	61.96	2.2	9.66E-10	85.4	1.02E-06
350.0	1391.3	1391.3	.01	590541.	211.7	212.4	75672.	192.2	.00	3.77	6.14	66.79	2.7	1.20E-09	112.7	1.34E-06
400.0	1404.7	1404.7	.01	590076.	212.2	212.1	75321.	196.1	.00	3.43	5.01	72.53	1.7	7.40E-10	75.0	8.93E-07
450.0	1416.1	1416.1	.00	589733.	262.9	212.1	75615.	198.5	.00	3.23	4.31	76.09	1.3	5.72E-10	83.0	9.88E-07
480.0	1422.0	1422.0	.00	589593.	270.3	212.1	75555.	199.8	.00	3.06	3.91	78.18	1.2	5.23E-10	87.2	1.04E-06
500.0	1425.6	1425.6	.01	589511.	272.1	212.2	75672.	200.4	.00	2.98	3.72	79.17	1.1	4.92E-10	86.2	1.03E-06
552.0	1434.0	1434.0	.01	589329.	281.7	212.1	75614.	202.1	.00	2.73	3.20	81.92	1.0	4.35E-10	81.2	9.67E-07
604.0	1441.0	1441.0	.00	589176.	288.7	212.1	75460.	203.4	.00	2.49	2.76	84.25	.9	3.94E-10	76.3	9.08E-07
656.0	1446.9	1446.9	.00	589067.	295.7	212.1	75006.	204.7	.00	2.24	2.37	86.38	.7	3.16E-10	56.3	6.70E-07
672.0	1448.5	1448.5	.00	589036.	298.0	212.1	74925.	205.0	.00	2.18	2.27	86.93	.7	3.03E-10	82.6	9.83E-07
708.0	1451.9	1451.9	.00	588970.	303.0	212.1	74533.	205.7	.00	2.02	2.04	88.19	.7	2.94E-10	48.8	5.81E-07
760.1	1456.3	1456.3	.00	588883.	309.0	212.1	74126.	206.6	.00	1.83	1.76	89.69	.6	2.65E-10	60.1	7.15E-07
812.0	1460.0	1460.0	.00	588798.	316.1	212.1	73674.	207.3	.00	1.66	1.52	91.02	.6	2.73E-10	77.1	9.18E-07
864.0	1463.2	1463.2	.00	588714.	320.9	212.1	73038.	208.0	.00	1.49	1.30	92.28	.6	2.59E-10	84.9	1.01E-06
916.0	1466.7	1466.7	.01	588632.	327.2	212.1	72586.	208.5	.00	1.37	1.11	93.27	.6	2.84E-10	75.1	8.95E-07
968.0	1471.6	1471.6	.00	588554.	332.3	212.1	72224.	209.0	.00	1.26	.97	94.09	.6	2.62E-10	59.5	7.09E-07
1020.0	1473.8	1473.8	.00	588481.	338.7	212.1	71812.	209.4	.00	1.15	.84	94.82	.5	2.33E-10	59.0	7.02E-07
1070.0	1475.4	1475.4	.00	588415.	343.5	212.1	71366.	209.7	.00	1.06	.73	95.45	.4	1.88E-10	55.4	6.60E-07
1120.0	1476.6	1476.6	.00	588361.	349.2	212.1	70893.	210.0	.00	.96	.63	96.02	.4	1.71E-10	59.4	7.08E-07
1170.1	1477.5	1477.5	.01	588311.	354.6	212.2	70424.	210.3	.00	.87	.54	96.52	.3	1.51E-10	72.1	8.58E-07
1220.1	1478.2	1478.2	.00	588264.	357.6	212.2	69948.	211.7	.00	.79	.47	96.95	.4	1.75E-10	137.0	1.63E-06
1270.1	1478.5	1478.5	.00	588220.	363.2	212.2	69467.	215.6	.00	.78	.44	97.08	.3	1.29E-10	28.7	3.42E-07
1320.1	1478.6	1478.6	.00	588179.	369.5	212.2	69041.	217.4	.00	.77	.42	97.19	.3	1.17E-10	25.9	3.09E-07
1370.1	1478.5	1478.5	.00	588140.	373.1	212.2	68609.	218.5	.00	.77	.40	97.29	.2	1.04E-10	26.0	3.09E-07
1376.1	1478.4	1478.4	.00	588136.	373.7	212.2	68556.	218.2	.00	.77	.40	97.31	.2	1.04E-10	21.2	2.53E-07
1420.0	1478.2	1478.2	.00	588104.	378.3	212.2	68179.	219.3	.00	.76	.38	97.39	.2	9.47E-11	23.6	2.81E-07
1470.0	1477.7	1477.7	.00	588069.	382.2	212.2	67757.	219.7	.00	.75	.37	97.49	.2	8.51E-11	22.1	2.63E-07
1520.0	1477.1	1477.1	.00	588037.	387.0	212.2	67347.	220.1	.00	.73	.35	97.58	.2	7.58E-11	20.6	2.45E-07
1570.0	1476.3	1476.3	.00	588005.	390.5	212.2	66922.	220.4	.00	.72	.33	97.67	.1	6.63E-11	18.8	2.24E-07
1620.0	1475.4	1475.4	.00	587976.	394.9	212.2	66502.	220.7	.00	.70	.32	97.75	.1	6.09E-11	18.9	2.25E-07
1632.0	1475.2	1475.2	.00	587968.	396.4	212.2	66402.	221.5	.00	.70	.32	97.77	.1	6.12E-11	22.1	2.63E-07

CASE 678 3HR MELTHRU, C.LINER FAIL, NO 3.COOLER, FAIL 20PSIG
CASE 678 10 NOV 76 0223 HRS

	REACTOR VESSEL---------------				REACTOR	H&V ROOMS----		REACTOR CONTAINMENT BUILDING--------------					SODIUM-------------			MIXED-ATM
HCDA TIME (HRS)	UPPER TEMP. (DEG.F)	LOWER TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
0.0	1050.0	980.0	0.00	620007.	120.0	N/A	N/A	80.0	0.00	0.00	20.71	1.38	0.0	0.	0.0	0.
.2	1084.7	984.4	.49	620000.	145.3	N/A	N/A	124.9	1.18	0.00	20.67	1.20	0.0	0.	.6	6.99E-09
3.0	1275.7	1023.4	.48	619998.	153.2	N/A	N/A	97.8	.45	0.00	20.67	1.20	1.0	4.52E-10	.3	3.21E-09
	R.CAVITY FOLLOWING VESSEL MELT-THRU				SUB-	H&V ROOMS----		REACTOR CONTAINMENT BUILDING--								
HCDA TIME (HRS)	CAVITY TEMP. (DEG.F)	VESSEL TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
4.0	1122.1	1122.1	1.01	617295.	109.3	140.3	869.	101.8	.81	0.00	20.37	1.34	18.1	8.09E-09	.4	4.48E-09
7.0	1114.0	1114.0	1.25	615208.	110.0	195.1	6616.	105.6	1.26	0.00	19.96	2.44	1.2	5.43E-10	.5	5.41E-09
50.0	1214.8	1214.8	5.75	606332.	145.8	229.4	42745.	151.6	5.74	0.00	15.02	19.04	2.8	1.25E-09	.9	1.08E-08
72.0	1246.4	1246.4	6.85	603472.	155.1	232.0	53627.	161.1	6.84	0.00	13.79	22.74	3.0	1.35E-09	1.0	1.17E-08
100.0	1276.2	1276.2	8.09	600480.	164.3	235.2	64928.	170.3	8.07	0.00	12.54	26.64	2.6	1.17E-09	1.1	1.26E-08
150.0	1311.3	1311.3	9.73	596412.	176.0	239.0	80796.	180.7	9.70	0.00	11.00	31.47	3.6	1.62E-09	1.1	1.36E-08
168.0	1320.0	1320.0	10.03	595157.	178.4	239.6	85272.	181.7	10.01	.53	10.87	31.76	3.8	1.69E-09	1.2	1.38E-08
200.0	1335.1	1335.1	10.85	593801.	184.3	241.5	91924.	185.3	10.85	1.05	10.55	33.22	1.9	8.60E-10	1.2	1.42E-08
250.0	1358.8	1358.8	12.11	592067.	201.0	244.0	99869.	190.4	12.10	1.66	10.10	35.35	1.3	5.97E-10	1.2	1.49E-08
300.0	1377.6	1377.6	13.61	591201.	220.1	247.1	105417.	196.5	13.61	1.86	9.63	38.11	1.2	5.31E-10	1.3	1.55E-08
312.0	1381.7	1381.7	13.86	591029.	224.1	247.4	106617.	197.5	13.86	1.91	9.55	38.53	.9	3.99E-10	1.3	1.56E-08
350.0	1393.7	1393.7	14.57	590602.	236.9	249.0	110195.	200.2	14.57	2.01	9.34	39.75	.7	3.02E-10	1.3	1.59E-08
400.0	1407.6	1407.6	15.54	590132.	247.7	250.7	113853.	203.7	15.54	2.09	9.07	41.38	.6	2.90E-10	1.4	1.63E-08
450.0	1418.9	1418.9	16.07	589875.	251.8	251.8	117452.	205.6	16.07	2.14	8.91	42.30	.3	1.40E-10	1.4	1.65E-08
480.0	1424.8	1424.8	16.49	589755.	252.8	252.6	119269.	207.1	16.49	2.15	8.80	43.03	.2	9.33E-11	1.4	1.66E-08
500.0	1428.4	1428.4	16.62	589692.	253.1	252.9	120488.	207.6	16.62	2.16	8.76	43.26	.1	6.69E-11	1.4	1.67E-08
552.0	1436.8	1436.8	17.19	589555.	254.1	254.0	123185.	209.6	17.19	2.16	8.60	44.26	.1	2.31E-11	1.4	1.69E-08
604.0	1443.7	1443.7	17.69	589446.	273.3	254.8	125455.	211.4	17.69	2.15	8.46	45.14	.3	1.21E-10	1.4	1.71E-08
656.0	1449.6	1449.6	18.14	589307.	285.8	255.6	127175.	212.9	18.13	2.15	8.33	45.90	.3	1.29E-10	1.4	1.72E-08
672.0	1451.2	1451.2	18.25	589269.	289.0	255.8	127686.	213.4	18.25	2.16	8.30	46.11	.1	4.93E-11	1.4	1.72E-08
708.0	1454.8	1454.8	18.54	589121.	298.7	256.4	128616.	214.3	18.54	2.18	8.22	46.58	.4	1.63E-10	1.5	1.74E-08
760.0	1459.2	1459.2	18.85	588998.	304.9	256.9	129901.	215.4	18.86	2.19	8.13	47.15	.2	9.80E-11	1.5	1.75E-08
812.0	1462.9	1462.9	19.21	588899.	312.8	257.5	130972.	216.6	19.20	2.19	8.03	47.76	.1	3.33E-11	1.5	1.76E-08
864.0	1466.2	1466.2	19.61	588805.	318.2	258.2	131771.	217.9	19.61	2.18	7.92	48.43	.1	2.64E-11	1.5	1.77E-08
916.0	1471.8	1471.8	19.89	588721.	325.3	258.7	132557.	218.8	19.88	2.18	7.84	48.92	.1	5.75E-11	1.5	1.78E-08
960.0	1474.4	1474.4	20.04	588659.	330.0	258.9	133163.	219.4	20.04	2.19	7.79	49.24	.0	1.93E-11	1.5	1.78E-08
961.0	1466.7	1466.7	.06	589263.	263.5	213.0	124885.	186.7	.06	2.74	6.10	59.18	473.2	2.12E-07	40019.3	4.76E-04
966.0	1470.6	1470.6	.55	589224.	329.0	214.4	122318.	194.8	.66	2.18	4.86	67.51	0.0	0.	949.2	1.13E-05
1020.1	1474.8	1474.8	.02	589158.	336.9	212.1	108566.	202.2	.02	1.30	2.66	82.11	.6	2.75E-10	179.5	2.14E-06
1070.1	1476.5	1476.5	.02	589086.	341.7	212.1	100860.	205.2	.01	.98	1.89	87.20	.5	2.17E-10	137.3	1.63E-06
1120.1	1477.6	1477.6	.01	589030.	347.9	212.1	94808.	207.0	.01	.77	1.42	90.37	.4	1.65E-10	121.6	1.45E-06
1170.1	1478.5	1478.5	.01	588978.	353.8	212.3	89973.	208.1	.01	.64	1.10	92.52	.3	1.42E-10	118.4	1.41E-06
1220.1	1479.1	1479.1	.01	588931.	356.9	212.2	85976.	209.0	.01	.54	.86	94.07	.3	1.25E-10	114.3	1.36E-06
1270.1	1479.3	1479.3	.01	588886.	362.2	212.1	82679.	209.5	.01	.46	.69	95.21	.3	1.15E-10	108.4	1.29E-06
1320.1	1479.2	1479.2	.01	588844.	369.2	212.1	80003.	210.0	.01	.40	.57	96.06	.2	1.05E-10	103.5	1.23E-06
1370.0	1478.9	1478.9	.01	588805.	372.7	212.2	77817.	210.4	.01	.36	.47	96.72	.2	1.05E-10	102.6	1.22E-06
1420.0	1478.5	1478.5	.01	588768.	377.9	212.1	75941.	210.7	.01	.32	.39	97.25	.2	9.74E-11	95.3	1.13E-06
1470.0	1477.8	1477.8	.01	588734.	381.8	212.1	74364.	210.9	.00	.29	.33	97.68	.2	8.82E-11	89.7	1.07E-06
1520.0	1477.0	1477.0	.00	588701.	386.6	212.1	73004.	211.0	.00	.26	.27	98.03	.2	7.97E-11	83.5	9.94E-07
1570.0	1476.1	1476.1	.00	588670.	390.9	212.1	71822.	211.2	.00	.23	.23	98.32	.2	7.06E-11	77.9	9.28E-07
1620.0	1475.1	1475.1	.00	588636.	394.6	212.1	70812.	215.7	0.00	.24	.21	98.42	.2	6.87E-11	27.1	3.22E-07
1632.0	1474.8	1474.8	.00	588629.	395.6	212.1	70586.	217.1	.00	.24	.21	98.44	.1	5.53E-11	29.9	3.56E-07

CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+O2 REAC, PURGE
CASE 681 01 DEC 76 1809 HRS

	REACTOR VESSEL				REACTOR	H&V ROOMS		REACTOR CONTAINMENT BUILDING					SODIUM			MIXED-ATM
HCDA TIME (HRS)	UPPER TEMP. (DEG.F)	LOWER TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
0.0	1050.0	980.0	0.00	620007.	120.0	N/A	N/A	80.0	0.00	0.00	20.71	1.38	0.0	0.	0.0	0.
.2	1084.9	984.4	.50	620000.	143.8	N/A	N/A	124.7	1.17	0.00	20.67	1.20	0.0	0.	.6	6.98E-09
3.0	1276.1	1023.5	.43	619998.	151.2	N/A	N/A	97.8	.45	0.00	20.67	1.20	1.0	4.54E-10	.3	3.21E-09

	R.CAVITY FOLLOWING VESSEL MELT-THRU				SUB-	H&V ROOMS		REACTOR CONTAINMENT BUILDING								
HCDA TIME (HRS)	CAVITY TEMP. (DEG.F)	VESSEL TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
4.0	1122.5	1122.5	1.00	617300.	109.3	137.0	885.	101.8	.80	0.00	20.37	1.33	18.4	8.23E-09	.4	4.47E-09
7.0	1112.7	1112.7	1.19	615211.	109.3	186.9	6954.	105.5	1.19	0.00	20.01	2.18	1.3	5.55E-10	.4	5.29E-09
50.0	1205.0	1205.0	4.62	606430.	132.0	226.2	52755.	144.8	4.61	0.00	15.72	15.19	2.7	1.22E-09	.8	9.83E-09
72.0	1234.4	1234.4	5.75	603620.	143.0	229.2	67440.	153.0	5.75	0.00	14.34	19.68	2.9	1.28E-09	.9	1.09E-08
100.0	1261.6	1261.6	6.85	600683.	153.0	232.0	82825.	152.2	6.83	0.00	13.12	23.35	2.8	1.24E-09	1.0	1.18E-08
150.0	1295.3	1295.3	8.24	596872.	165.3	235.4	104765.	172.5	8.22	0.00	11.64	27.85	3.1	1.37E-09	1.1	1.27E-08
168.0	1302.5	1302.5	8.85	595643.	169.9	236.9	111282.	176.4	8.83	0.00	11.13	29.65	3.2	1.43E-09	1.1	1.31E-08
200.0	1313.1	1313.1	9.45	594200.	177.7	238.3	121115.	179.4	9.43	.42	10.79	30.87	2.0	8.95E-10	1.1	1.35E-08
201.0	1310.7	1310.7	.53	594576.	168.9	213.7	117196.	166.1	.53	.92	9.88	36.16	73.9	3.31E-08	15868.6	1.89E-04
240.0	1327.6	1327.6	.01	593203.	190.4	212.0	115683.	182.6	.00	1.60	6.92	54.29	3.9	1.74E-09	158.6	1.89E-06
250.0	1331.6	1331.6	.02	592852.	194.1	212.0	115847.	184.3	.00	1.77	6.58	56.31	3.8	1.72E-09	104.3	1.24E-06
300.0	1347.5	1347.5	.00	591986.	208.7	212.0	116311.	190.9	.00	1.99	5.19	64.95	1.6	7.32E-10	101.2	1.21E-06
350.0	1360.6	1360.6	.00	591488.	212.3	212.1	116096.	195.4	.00	1.96	4.17	71.47	1.0	4.55E-10	84.2	1.00E-06
380.2	1367.4	1367.4	.00	591314.	212.4	212.1	115454.	197.8	.00	1.85	3.62	75.08	.9	3.84E-10	137.1	1.63E-06
384.0	1368.2	1368.2	.01	591294.	212.4	212.1	115333.	198.1	.00	1.82	3.54	75.59	.9	3.85E-10	126.1	1.50E-06
400.0	1372.5	1372.5	.01	590836.	212.2	212.1	115141.	198.8	.00	2.06	3.34	76.67	2.3	1.04E-09	71.9	8.56E-07
450.0	1381.2	1381.2	.01	590485.	235.0	212.1	114753.	200.5	.00	2.07	2.91	79.34	1.1	4.74E-10	61.6	7.34E-07
500.0	1388.6	1388.6	.00	590229.	269.6	212.1	114064.	201.7	.00	2.05	2.60	81.39	.8	3.42E-10	66.3	7.89E-07
504.0	1389.1	1389.1	.00	590213.	268.8	212.1	113994.	201.9	.00	2.05	2.57	81.58	.8	3.37E-10	65.7	7.82E-07
552.0	1394.9	1394.9	.00	590050.	278.2	212.1	112982.	202.8	.00	1.99	2.33	83.17	.6	2.84E-10	57.9	6.89E-07
604.0	1400.2	1400.2	.00	589910.	284.9	212.1	111378.	203.8	.00	1.90	2.09	84.78	.5	2.41E-10	62.2	7.40E-07
656.0	1404.8	1404.8	.00	589794.	291.6	212.1	109090.	204.7	.00	1.79	1.85	86.38	.5	2.12E-10	49.0	5.83E-07
672.0	1406.1	1406.1	.00	589762.	294.3	212.1	108275.	205.0	.00	1.75	1.78	86.86	.5	2.04E-10	72.8	8.67E-07
708.1	1408.7	1408.7	.00	589694.	299.5	212.1	106254.	205.6	.00	1.66	1.63	87.92	.4	1.92E-10	46.3	5.51E-07
760.0	1411.9	1411.9	.00	589614.	305.1	212.2	102866.	206.4	.00	1.52	1.42	89.43	.3	1.49E-10	59.3	7.06E-07
812.0	1414.7	1414.7	.00	589547.	312.3	212.2	98923.	207.2	.00	1.35	1.21	90.90	.3	1.35E-10	79.1	9.42E-07
864.1	1417.0	1417.0	.00	589486.	316.5	212.2	94500.	208.0	.00	1.19	1.02	92.29	.3	1.27E-10	95.5	1.14E-06
916.0	1422.0	1422.0	.01	589426.	322.3	212.4	89799.	208.7	.00	1.06	.85	93.50	.3	1.39E-10	95.5	1.14E-06
968.0	1424.2	1424.2	.01	589367.	329.2	212.4	84657.	209.2	.00	.92	.71	94.57	.3	1.43E-10	78.4	9.33E-07
1020.0	1425.6	1425.6	.00	589306.	333.1	212.4	79319.	209.7	.00	.81	.59	95.45	.3	1.27E-10	76.7	9.13E-07
1070.0	1426.5	1426.5	.00	589251.	338.9	212.4	74107.	210.1	.00	.72	.49	96.14	.3	1.18E-10	72.8	8.66E-07
1120.0	1427.0	1427.0	.00	589200.	344.0	212.4	68692.	210.4	.00	.64	.41	96.75	.2	8.78E-11	74.8	8.91E-07
1170.1	1427.2	1427.2	.01	589160.	349.8	212.4	63109.	210.7	.01	.56	.34	97.28	.2	7.46E-11	91.2	1.09E-06
1220.1	1427.2	1427.2	.01	589122.	354.1	212.4	57351.	210.9	.01	.49	.28	97.73	.2	6.74E-11	98.9	1.18E-06
1270.1	1426.8	1426.8	.01	589085.	358.2	212.4	51412.	211.1	.01	.42	.23	98.11	.1	5.95E-11	103.0	1.23E-06
1320.1	1426.1	1426.1	.01	589051.	363.3	212.4	45375.	211.3	.01	.37	.19	98.43	.1	5.23E-11	105.0	1.25E-06
1370.1	1425.2	1425.2	.01	589019.	367.8	212.4	39242.	211.4	.01	.32	.15	98.70	.1	4.82E-11	105.5	1.26E-06
1400.1	1424.5	1424.5	.01	589000.	370.7	212.4	35527.	211.5	.00	.29	.14	98.83	.1	4.97E-11	97.6	1.16E-06
1420.0	1424.0	1424.0	.01	588988.	374.3	212.4	33061.	211.5	.01	.28	.13	98.91	.1	4.85E-11	96.8	1.15E-06
1470.0	1422.7	1422.7	.01	588958.	376.5	212.4	26816.	211.6	.01	.24	.10	99.09	.1	3.97E-11	103.7	1.23E-06
1520.0	1421.3	1421.3	.01	588931.	381.3	212.4	20487.	211.7	.00	.21	.09	99.24	.1	3.67E-11	98.7	1.17E-06
1570.0	1419.7	1419.7	.01	588904.	386.5	212.4	14087.	211.7	.00	.19	.07	99.37	.1	3.18E-11	77.6	9.24E-07
1620.0	1417.9	1417.9	.01	588878.	388.7	212.4	7624.	211.8	.00	.16	.06	99.47	.1	2.60E-11	78.8	9.39E-07
1632.0	1417.5	1417.5	.01	588872.	389.7	212.4	6064.	211.8	.01	.16	.05	99.49	.1	2.52E-11	111.7	1.33E-06

CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
CASE 682   03 DEC 76   0845 HRS

	REACTOR VESSEL---------------				REACTOR	H&V ROOMS----		REACTOR CONTAINMENT BUILDING-------------					--SODIUM------------			-MIXED-ATM
HCDA TIME (HRS)	UPPER TEMP. (DEG.F)	LOWER TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
0.0	1050.0	980.0	0.00	620007.	120.0	N/A	N/A	80.0	0.00	0.00	20.71	1.38	0.0	0.	0.0	0.
.2	1084.9	984.4	.50	620000.	143.8	N/A	N/A	124.7	1.17	0.00	20.67	1.20	0.0	0.	.6	6.98E-09
3.0	1276.1	1023.5	.48	619998.	151.2	N/A	N/A	97.8	.45	0.00	20.67	1.20	1.0	4.54E-10	.3	3.21E-09

R.CAVITY FOLLOWING VESSEL MELT-THRU					SUB-	H&V ROOMS----		REACTOR CONTAINMENT BUILDING---								
HCDA TIME (HRS)	CAVITY TEMP. (DEG.F)	VESSEL TEMP. (DEG.F,	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
4.0	1139.7	1139.7	1.06	617311.	109.2	137.2	877.	102.0	.81	0.00	20.36	1.33	17.5	7.85E-09	.4	4.46E-09
7.0	1237.5	1237.5	1.85	613683.	111.3	193.2	7366.	123.7	1.79	0.00	19.57	2.88	40.7	1.82E-08	.5	6.29E-09
55.1	1312.8	1312.8	6.47	580864.	134.4	229.4	56985.	182.5	6.40	3.43	10.46	19.03	33.9	1.52E-08	1.0	1.18E-08
56.0	1312.4	1312.4	.08	580647.	123.6	211.2	55725.	184.9	.08	4.04	10.06	21.29	111.7	5.00E-08	12762.9	1.52E-04
60.0	1318.3	1318.3	0.00	578570.	123.7	210.1	57062.	195.4	0.00	1.15	8.88	25.42	45.4	2.04E-08	0.0	0.
72.0	1328.9	1328.9	.25	573819.	129.4	212.9	62686.	192.0	.17	4.01	9.16	25.25	43.3	1.94E-08	1542.3	1.84E-05
120.0	1364.8	1364.8	.10	553363.	144.2	212.3	79706.	219.2	.00	3.29	8.39	31.11	58.9	2.64E-08	147.6	1.76E-06
168.0	1390.4	1390.4	.21	537048.	160.8	212.4	91676.	225.3	.12	4.01	9.05	32.20	56.5	2.53E-08	1128.2	1.34E-05
180.0	1401.0	1401.0	.11	532022.	165.7	212.1	94024.	237.8	.00	2.90	8.51	33.00	80.2	3.59E-08	35.2	4.19E-07
240.0	1431.0	1431.0	0.00	512346.	189.6	210.1	101682.	256.1	0.00	.76	8.85	35.72	84.5	3.78E-08	.0	1.22E-12
300.0	1452.3	1452.3	.03	494394.	209.9	212.2	106098.	259.1	.00	2.52	7.76	42.26	57.7	2.59E-08	191.7	2.28E-06
322.3	1459.0	1459.0	0.00	488700.	221.3	210.7	106977.	267.1	0.00	.92	8.71	39.06	78.0	3.49E-08	0.0	0.
360.0	1465.5	1465.5	0.00	480658.	237.7	210.1	107579.	266.5	0.00	.30	8.81	40.81	61.4	2.75E-08	942.2	1.12E-05
384.0	1469.5	1469.5	.03	476679.	245.7	212.2	108216.	259.3	.00	3.02	7.44	46.62	45.1	2.02E-08	146.1	1.74E-06
420.0	1471.8	1471.8	.02	473023.	263.7	212.1	109115.	246.2	.01	4.00	9.86	39.14	25.1	1.12E-08	334.2	3.98E-06
480.0	1475.2	1475.2	.00	468617.	273.8	212.1	109478.	244.3	.00	2.20	7.77	46.74	16.6	7.43E-09	65.7	7.82E-07
504.0	1476.0	1476.0	.00	467414.	279.9	212.1	109350.	240.7	.00	2.91	7.19	49.65	15.4	6.90E-09	55.4	6.59E-07
540.1	1477.1	1477.1	.03	465820.	284.0	212.1	109173.	236.5	.00	3.82	6.60	52.40	12.8	5.72E-09	43.0	5.11E-07
600.1	1478.2	1478.2	.02	463665.	294.9	212.2	107839.	233.3	.01	4.00	8.43	46.96	10.5	4.70E-09	137.2	1.63E-06
660.1	1478.8	1478.8	.01	461864.	302.5	212.2	105413.	231.0	.00	4.00	9.34	44.88	9.1	4.08E-09	114.4	1.36E-06
672.1	1478.8	1478.8	.01	461540.	304.2	212.2	104839.	231.4	.00	4.00	9.43	44.77	8.7	3.88E-09	111.8	1.33E-06
720.0	1478.8	1478.8	.01	460381.	310.3	212.2	102052.	230.7	.00	4.00	9.23	46.79	6.2	2.78E-09	80.8	9.62E-07
780.0	1478.4	1478.4	.01	459323.	316.9	212.3	97776.	229.2	.00	4.00	8.08	53.05	5.3	2.37E-09	68.3	8.13E-07
840.0	1477.9	1477.9	.01	458337.	324.7	212.3	92734.	229.6	.00	4.00	6.72	60.16	5.6	2.49E-09	77.3	9.21E-07
864.0	1477.7	1477.7	.01	457936.	327.3	212.3	90491.	229.6	.00	3.98	6.21	62.88	5.2	2.34E-09	78.3	9.32E-07
900.0	1479.2	1479.2	.03	457367.	330.9	212.4	87065.	228.9	.00	3.95	5.52	66.52	5.1	2.28E-09	72.0	8.57E-07
960.0	1479.1	1479.1	.02	456505.	336.6	212.3	81084.	229.4	.00	3.87	4.57	71.65	4.3	1.94E-09	71.9	8.56E-07
1000.0	1478.6	1478.6	.02	456001.	341.5	212.3	76377.	228.7	.00	3.78	4.04	74.56	3.8	1.71E-09	72.0	8.57E-07
1020.1	1478.2	1478.2	.02	455773.	343.5	212.4	74374.	228.5	.00	3.72	3.79	75.91	3.5	1.57E-09	71.0	8.45E-07
1080.1	1477.0	1477.0	.02	455163.	350.6	212.4	68279.	228.8	.00	3.50	3.14	79.65	3.0	1.34E-09	75.5	8.98E-07
1140.1	1475.4	1475.4	.01	454643.	356.4	212.4	61389.	227.9	.00	3.24	2.58	82.87	2.5	1.12E-09	74.1	8.83E-07
1200.1	1473.6	1473.6	.01	454200.	364.2	212.4	54183.	228.2	.00	2.95	2.11	85.67	2.1	9.30E-10	79.2	9.43E-07
1260.1	1471.3	1471.3	.01	453912.	367.1	212.4	46794.	227.1	.00	2.60	1.73	88.09	1.3	5.63E-10	76.4	9.10E-07
1320.1	1468.8	1468.8	.01	453673.	374.3	212.4	39260.	227.4	.00	2.29	1.41	90.10	1.0	4.55E-10	79.5	9.46E-07
1380.1	1466.0	1466.0	.01	453475.	380.5	212.4	31650.	226.5	.00	2.01	1.16	91.73	.8	3.60E-10	74.1	8.82E-07
1440.1	1463.0	1463.0	.01	453312.	384.1	212.4	23888.	226.9	.00	1.74	.95	93.13	.6	2.80E-10	79.9	9.52E-07
1500.1	1460.0	1460.0	.01	453143.	391.3	212.4	16008.	226.0	.00	1.53	.78	94.27	.6	2.85E-10	75.5	8.99E-07
1560.1	1456.8	1456.8	.01	453005.	394.1	212.4	8030.	226.4	.01	1.33	.64	95.24	.5	2.16E-10	80.8	9.62E-07
1620.0	1453.5	1453.5	.00	452894.	398.7	212.1	1190.	225.6	0.00	1.18	.53	95.96	.4	1.73E-10	21.6	2.58E-07
1625.0	1453.2	1453.2	.00	452886.	399.2	212.1	1189.	225.7	.00	1.18	.53	95.97	.3	1.55E-10	18.0	2.14E-07
1632.0	1452.8	1452.8	.00	452874.	397.5	226.4	1152.	226.2	.00	1.18	.53	95.99	.3	1.48E-10	19.5	2.32E-07

CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
CASE 683   15 DEC 76   0204 HRS

	REACTOR VESSEL				REACTOR	H&V ROOMS		REACTOR CONTAINMENT BUILDING					SODIUM		MIXED-ATM	
HCDA TIME (HRS)	UPPER TEMP. (DEG.F)	LOWER TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
0.0	1050.0	980.0	0.00	620007.	120.0	N/A	N/A	80.0	0.00	0.00	20.71	1.38	0.0	0.	0.0	0.
.2	1084.9	984.4	.50	620000.	143.8	N/A	N/A	124.7	1.17	0.00	20.67	1.20	0.0	0.	.6	6.98E-09
3.0	1276.1	1023.5	.48	619998.	151.2	N/A	N/A	97.8	.45	0.00	20.67	1.20	1.0	4.54E-10	.3	3.21E-09
R.CAVITY FOLLOWING VESSEL MELT-THRU					SUB-	H&V ROOMS		REACTOR CONTAINMENT BUILDING								
HCDA TIME (HRS)	CAVITY TEMP. (DEG.F)	VESSEL TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
4.0	1139.7	1139.7	1.06	617311.	109.2	137.2	877.	102.0	.81	0.00	20.36	1.33	17.5	7.85E-09	.4	4.46E-09
7.0	1237.5	1237.5	1.85	613683.	111.3	193.2	7366.	123.7	1.79	0.00	19.57	2.88	40.7	1.82E-08	.5	6.29E-09
55.1	1312.8	1312.8	6.47	580664.	134.4	229.4	56985.	182.5	6.40	3.43	10.46	19.03	33.9	1.52E-08	1.0	1.18E-08
56.0	1312.4	1312.4	.08	580647.	123.6	211.2	55725.	184.9	.08	4.04	10.06	21.29	111.7	5.00E-08	12762.9	1.52E-04
72.0	1328.9	1328.9	.25	573819.	129.4	212.9	62686.	192.0	.17	4.01	9.16	25.25	43.3	1.94E-08	1542.3	1.84E-05
80.0	1339.0	1339.0	.01	570262.	131.1	211.7	65634.	204.2	0.00	1.70	8.67	28.65	54.4	2.44E-08	0.0	0.
160.0	1384.5	1384.5	.11	539871.	158.0	212.1	89851.	228.0	.00	2.48	8.28	34.28	52.1	2.33E-08	163.1	1.94E-[illegible]
168.0	1390.4	1390.4	.21	537048.	160.8	212.4	91676.	225.3	.12	4.01	9.05	32.20	56.5	2.53E-08	1128.2	1.[illegible]
240.0	1431.0	1431.0	0.00	512345.	189.6	210.1	101652.	256.3	0.00	.79	8.82	35.80	82.6	3.70E-08	0.0	0.
320.0	1458.2	1458.2	0.00	489325.	210.0	210.1	105825.	267.6	0.00	.50	8.86	38.60	92.9	4.15E-08	936.4	1.11E-[illegible]
372.1	1467.7	1467.7	.03	478689.	241.7	212.1	107926.	262.2	.00	1.72	7.98	44.52	72.8	3.26E-08	423.6	5.04E-06
384.0	1469.6	1469.6	.05	476665.	244.2	212.3	108219.	259.2	.01	3.09	7.39	46.78	46.6	2.09E-08	144.4	1.72E-06
384.0	1474.8	1474.8	5.95	475183.	244.8	212.2	108213.	290.9	.68	3.52	7.36	46.50	13002.8	5.83E-06	4290.5	5.11E-05
R.CAVITY FOLLOWING FLOOR FAILURE					SUB-	H&V ROOMS		REACTOR CONTAINMENT BUILDING								
HCDA TIME (HRS)	CAVITY TEMP. (DEG.F)	VESSEL TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	CAVITY TEMP. (DEG.F)	ATM. TEMP. (DEG.F)	WATER MASS (LBS)	ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
391.5	1617.8	1617.8	1.05	427138.	1617.8	213.7	108696.	941.3	.68	4.03	10.15	8.93	7677.8	3.44E-06	12696.6	1.51E-04
400.0	1602.9	1602.9	.32	386773.	1602.9	212.2	108715.	1035.0	.01	3.47	7.91	17.83	3613.0	1.62E-06	7556.0	9.00E-05
428.7	1612.1	1612.1	.19	253054.*	1612.1	212.5	108633.	1460.8	.08	4.04	6.07	2.96	4272.9	1.91E-06	4753.1	5.66E-05
429.7	1604.9	1604.9	3.01	0.	1604.9	212.1	108610.	1303.8	.08	4.01	5.93	14.78	0.0	0.	2792.5	3.32E-05
450.0	1546.8	1546.8	.12	0.	1546.8	209.8	108985.	830.7	.12	4.01	16.29	18.35	0.0	0.	4926.7	5.87E-05
480.0	1517.2	1517.2	.13	0.	1517.2	208.6	109212.	604.0	.09	4.01	17.65	11.93	0.0	0.	3854.5	4.59E-05
504.0	1500.5	1500.5	.07	0.	1500.5	208.8	109290.	491.7	.05	4.01	17.95	10.50	0.0	0.	2638.6	3.14E-05
560.0	1472.8	1472.8	.04	0.	1472.8	211.1	109315.	365.5	.04	4.01	18.89	6.02	0.0	0.	1414.9	1.68E-05
594.4	1462.3	1462.3	.12	0.	1462.3	212.0	108863.	326.9	.02	4.01	19.28	4.16	0.0	0.	1679.3	2.00E-05
640.1	1450.0	1450.0	.10	0.	1450.0	212.4	107223.	296.2	.06	4.01	19.28	4.19	0.0	0.	1048.1	1.25E-05
672.1	1446.4	1446.4	.21	0.	1446.4	212.6	105497.	281.4	.11	4.02	19.50	3.14	0.0	0.	1368.9	1.63E-05
720.0	1438.1	1438.1	.18	0.	1438.1	212.4	101946.	267.0	.01	4.02	19.21	4.49	0.0	0.	849.9	1.01E-05
800.0	1445.3	1445.3	.00	0.	1445.3	212.3	94362.	252.9	.00	3.75	18.07	10.23	0.0	0.	46.6	5.55E-07
864.0	1457.9	1457.9	.00	0.	1457.9	212.4	87081.	247.7	.00	3.23	15.52	22.86	0.0	0.	59.6	7.09E-07
880.1	1459.6	1459.6	.00	0.	1459.6	212.4	85112.	246.1	.00	3.10	14.88	26.06	0.0	0.	60.7	7.22E-07
960.1	1468.6	1468.6	.00	0.	1468.6	212.4	74579.	242.3	.00	2.48	11.90	40.88	0.0	0.	67.8	8.07E-07
1040.1	1475.2	1475.2	.00	0.	1475.2	212.4	62977.	239.4	.00	1.95	9.33	53.61	0.0	0.	72.4	8.61E-07
1120.1	1482.3	1482.3	.00	0.	1482.3	212.4	50473.	237.5	.00	1.50	7.14	64.51	0.0	0.	78.2	9.32E-07
1200.1	1490.3	1490.3	.00	0.	1490.3	212.4	37211.	237.1	.00	1.13	5.35	73.41	0.0	0.	89.4	1.06E-06
1280.1	1494.3	1494.3	.00	0.	1494.3	212.4	23304.	236.3	.00	.83	3.93	80.47	0.0	0.	90.8	1.08E-06
1344.1	1498.6	1498.6	.00	0.	1498.6	212.4	11767.	236.4	.01	.65	3.05	84.84	0.0	0.	95.1	1.13E-06
1360.1	1500.3	1500.3	.00	0.	1500.3	212.4	8802.	235.8	.00	.61	2.86	85.78	0.0	0.	96.8	1.15E-06
1400.1	1504.9	1504.9	.00	0.	1504.9	212.4	1319.	236.0	.00	.52	2.43	87.92	0.0	0.	94.5	1.13E-06
1440.0	1513.5	1513.5	0.00	0.	1513.5	240.1	1127.	236.4	0.00	.51	2.39	88.10	0.0	0.	9.0	1.07E-07
1493.1	1522.1	1522.1	0.00	0.	1522.1	249.0	1113.	236.7	.00	.51	2.35	88.28	0.0	0.	6.1	7.30E-08
1520.0	1528.7	1528.7	0.00	0.	1528.7	286.3	1057.	236.7	.00	.51	2.33	88.38	0.0	0.	4.7	5.55E-08
1600.0	1538.3	1538.3	0.00	0.	1538.3	305.2	1031.	237.3	.00	.50	2.28	88.63	0.0	0.	5.6	6.69E-08
1632.0	1541.9	1541.9	0.00	0.	1541.9	310.7	1024.	238.1	0.00	.50	2.26	88.73	0.0	0.	8.1	9.60E-08

* See note on Page A-27.

CASE 588 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG
CASE 588   03 FEB 77   1245 HRS

HCDA TIME (HRS)	REACTOR VESSEL UPPER TEMP. (DEG.F)	LOWER TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	REACTOR CAVITY TEMP. (DEG.F)	H&V ROOMS ATM. TEMP. (DEG.F)	WATER MASS (LBS)	REACTOR CONTAINMENT BUILDING ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	SODIUM INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	MIXED-ATM LEAKRATE FRACTION (1/SEC)
0.0	1050.0	980.0	0.00	620007.	120.0	N/A	N/A	80.0	0.00	0.00	20.71	1.38	0.0	0.	0.0	0.
.2	1084.9	984.4	.50	620000.	143.8	N/A	N/A	124.7	1.17	0.00	20.67	1.20	0.0	0.	.6	6.98E-09
3.0	1275.7	1023.4	.48	619998.	153.2	N/A	N/A	97.8	.45	0.00	20.67	1.20	1.0	4.52E-10	.3	3.21E-09
R.CAVITY FOLLOWING VESSEL MELT-THRU																
HCDA TIME (HRS)	CAVITY TEMP. (DEG.F)	VESSEL TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	SUB-CAVITY TEMP. (DEG.F)	H&V ROOMS ATM. TEMP. (DEG.F)	WATER MASS (LBS)	REACTOR CONTAINMENT BUILDING ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
4.0	1122.1	1122.1	1.01	617295.	109.3	140.3	869.	101.8	.81	0.00	20.37	1.34	18.1	8.09E-09	.4	4.48E-09
7.0	1114.0	1114.0	1.26	615208.	110.0	195.1	6616.	105.6	1.26	0.00	19.96	2.44	1.2	5.43E-10	.5	5.41E-09
72.0	1246.4	1246.4	6.85	603472.	155.1	232.0	53627.	161.1	6.84	0.00	13.79	22.74	3.0	1.35E-09	1.0	1.17E-08
80.0	1254.7	1254.7	7.42	602746.	159.5	233.6	56986.	165.1	7.38	0.00	13.37	24.34	3.9	1.76E-09	1.0	1.21E-08
160.0	1316.1	1316.1	9.86	595705.	177.1	239.2	83286.	181.1	9.83	.30	10.94	31.53	3.9	1.74E-09	1.2	1.37E-08
168.0	1320.0	1320.0	10.03	595157.	178.4	239.6	85272.	181.7	10.01	.53	10.87	31.76	3.8	1.69E-09	1.2	1.38E-08
240.0	1355.0	1355.0	11.97	592275.	197.3	243.6	98395.	189.8	11.95	1.59	10.15	35.10	2.3	1.04E-09	1.2	1.48E-08
312.0	1381.7	1381.7	13.86	591029.	224.1	247.4	106617.	197.5	13.86	1.91	9.55	38.53	.9	3.99E-10	1.3	1.56E-08
320.0	1384.3	1384.3	13.92	590939.	226.6	247.6	107515.	197.7	13.91	1.94	9.53	38.62	1.0	4.31E-10	1.3	1.57E-08
400.0	1407.6	1407.6	15.54	590132.	247.7	250.7	113853.	203.7	15.54	2.09	9.07	41.38	.6	2.90E-10	1.4	1.63E-08
480.0	1424.8	1424.8	16.49	589755.	252.8	252.6	119269.	207.1	16.49	2.15	8.80	43.03	.2	9.33E-11	1.4	1.66E-08
560.0	1437.9	1437.9	17.27	589539.	254.3	254.1	123553.	209.9	17.26	2.15	8.58	44.39	.2	8.03E-11	1.4	1.69E-08
640.0	1447.9	1447.9	17.98	589348.	282.6	255.4	126640.	212.4	17.98	2.15	8.37	45.64	.2	1.01E-10	1.4	1.72E-08
672.0	1451.2	1451.2	18.25	589269.	289.0	255.8	127686.	213.4	18.25	2.16	8.30	46.11	.1	4.93E-11	1.4	1.72E-08
720.0	1455.9	1455.9	18.67	589088.	300.3	256.6	128931.	214.7	18.66	2.18	8.19	46.79	.2	6.90E-11	1.5	1.74E-08
800.0	1462.1	1462.1	19.14	588920.	311.2	257.4	130776.	216.4	19.14	2.19	8.05	47.64	.2	8.72E-11	1.5	1.76E-08
864.0	1466.2	1466.2	19.61	588805.	318.2	258.2	131771.	217.9	19.61	2.18	7.92	48.43	.1	2.64E-11	1.5	1.77E-08
880.0	1468.9	1468.9	19.64	588781.	325.2	258.3	132015.	218.0	19.64	2.19	7.91	48.51	.2	8.70E-11	1.5	1.77E-08
960.0	1474.4	1474.4	20.04	588659.	330.0	258.9	133163.	219.4	20.04	2.19	7.79	49.24	.0	1.93E-11	1.5	1.78E-08
961.0	1466.7	1466.7	.06	589263.	263.5	213.0	124885.	186.7	.06	2.74	6.10	59.18	473.2	2.12E-07	40019.3	4.76E-04
1008.1	1474.3	1474.3	.03	589175.	335.4	212.2	110807.	201.3	.03	1.40	2.91	80.41	.6	2.56E-10	209.2	2.49E-06
R.CAVITY FOLLOWING FLOOR FAILURE																
HCDA TIME (HRS)	CAVITY TEMP. (DEG.F)	VESSEL TEMP. (DEG.F)	PRESS. (PSIG)	SODIUM MASS (LBS)	SUB-CAVITY TEMP. (DEG.F)	H&V ROOMS ATM. TEMP. (DEG.F)	WATER MASS (LBS)	REACTOR CONTAINMENT BUILDING ATM. TEMP. (DEG.F)	ATM. PRESS. (PSIG)	H2 CONC. (V%)	O2 CONC. (V%)	H2O CONC. (V%)	SODIUM INRATE (LB/HR)	INRATE FRACTION (1/SEC)	MIXED-ATM LEAKRATE (TRUE CFM)	LEAKRATE FRACTION (1/SEC)
1012.0	1644.1	1644.1	2.46	560739.	1644.1	212.1	108477.	848.8	.01	25.75	.67	69.04	12958.6	5.81E-06	17407.5	2.07E-04
1015.5	1607.5	1607.5	.17	523491.	1607.5	211.5	106455.	937.9	0.00	85.43	.12	9.63	7272.8	3.26E-06	0.0	0.
1040.0	1610.0	1610.0	.20	417319.	1610.0	212.4	97327.	1122.9	.00	98.92	0.00	0.00	3969.5	1.78E-06	1385.5	1.65E-05
1062.4	1613.5	1613.5	.23	309906.*	1613.5	212.4	89988.	1203.5	0.00	99.68	0.00	0.00	4489.3	2.01E-06	1075.2	1.28E-05
1063.4	1609.1	1609.1	2.01	0.	1609.1	212.1	89667.	1103.6	.02	90.19	.00	8.79	0.0	0.	1054.8	1.26E-05
1074.0	1586.4	1586.4	.03	0.	1586.4	212.1	86548.	881.9	.01	42.88	.00	56.15	0.0	0.	1266.9	1.51E-05
1120.0	1564.6	1564.6	.04	0.	1564.6	212.1	74146.	560.8	.01	15.49	.00	84.39	0.0	0.	588.1	7.00E-06
1201.0	1544.8	1544.8	.24	0.	1544.8	212.6	54828.	366.5	.01	16.44	.00	83.53	0.0	0.	224.1	2.67E-06
1230.0	1529.1	1529.1	.01	0.	1529.1	212.4	35285.	301.5	.01	18.73	.00	81.25	0.0	0.	168.0	2.00E-06
1296.0	1527.6	1527.6	.01	0.	1527.6	212.4	34005.	299.2	.01	18.65	.00	81.33	0.0	0.	156.4	1.86E-06
1370.1	1520.0	1520.0	.09	0.	1520.0	212.4	18490.	277.2	.01	19.91	.00	80.08	0.0	0.	148.2	1.76E-06
1400.1	1515.9	1515.9	.05	0.	1515.9	212.4	12301.	270.9	.01	19.76	.00	80.23	0.0	0.	125.7	1.50E-06
1450.1	1514.0	1514.0	.10	0.	1514.0	212.1	10322.	263.5	.00	23.53	.00	76.47	0.0	0.	64.0	7.62E-07
1530.1	1510.9	1510.9	.04	0.	1510.9	212.2	5842.	255.6	.00	27.75	.00	72.25	0.0	0.	60.7	7.22E-07
1610.1	1511.4	1511.4	.06	0.	1511.4	260.0	1096.	251.0	.00	31.17	.00	68.83	0.0	0.	48.6	5.79E-07
1632.1	1516.7	1516.7	0.00	0.	1516.7	263.9	1090.	249.6	0.00	32.02	.00	67.97	0.0	0.	13.1	1.56E-07

* See note on Page A-27.

XI. Case Figures

Figures provided for each case are as follows:

Building Atmosphere Conditions

Building Roof Temperature

Building Average Vent Rate

Sodium Temperature

Sodium Inventory

Cavity Atmosphere Temperatures

Structural Temperatures - Reactor Containment Building Floor

Structural Temperatures - Cavity Roof

Structural Temperatures - Upper 16 feet of Reactor Cavity Wall

Structural Temperatures - Middle 16 feet of Reactor Cavity Wall

Structural Temperatures - Lower 10 feet of Reactor Cavity Wall

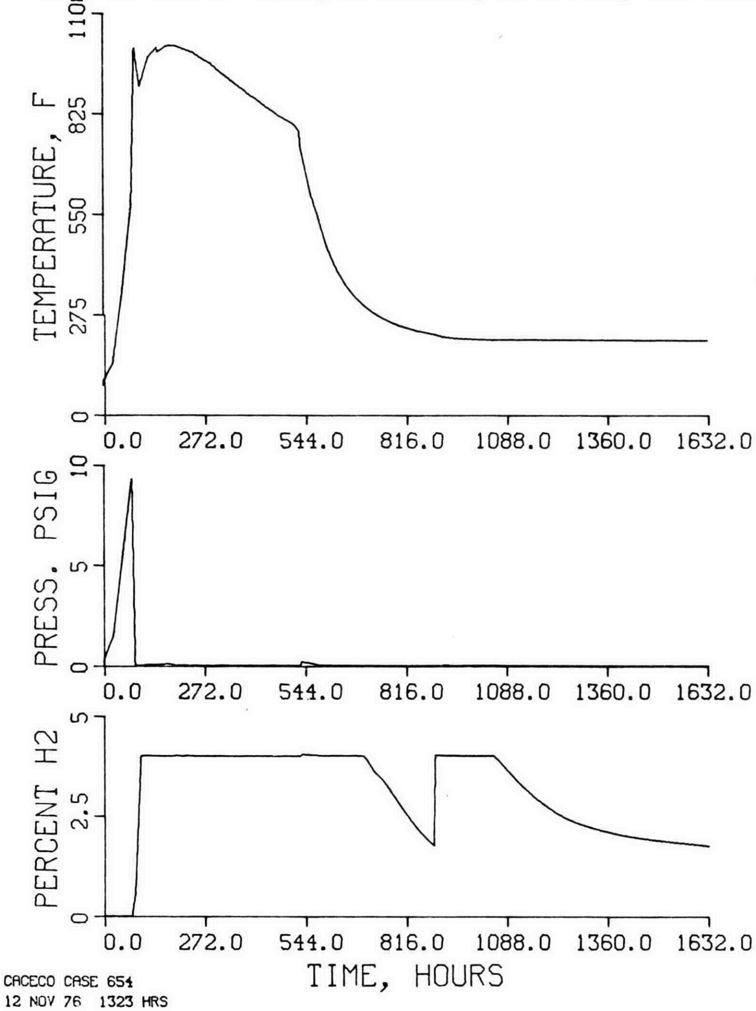
Structural Temperatures - Reactor Cavity Floor Center

Structural Temperatures - Subcavity Walls

Structural Temperatures - Subcavity Floor

BUILDING ATMOSPHERE CONDITIONS

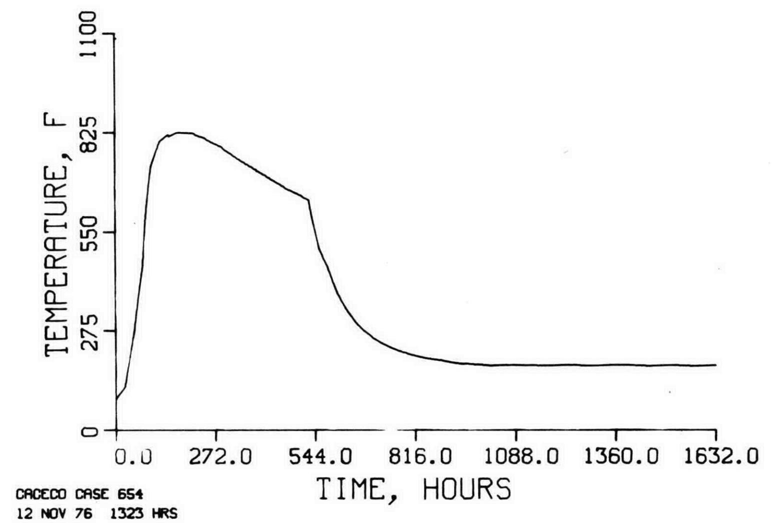
CASE 654 CORE IN VESSEL, NO B.COOLER, H2+02 REAC, VENT-PURGE

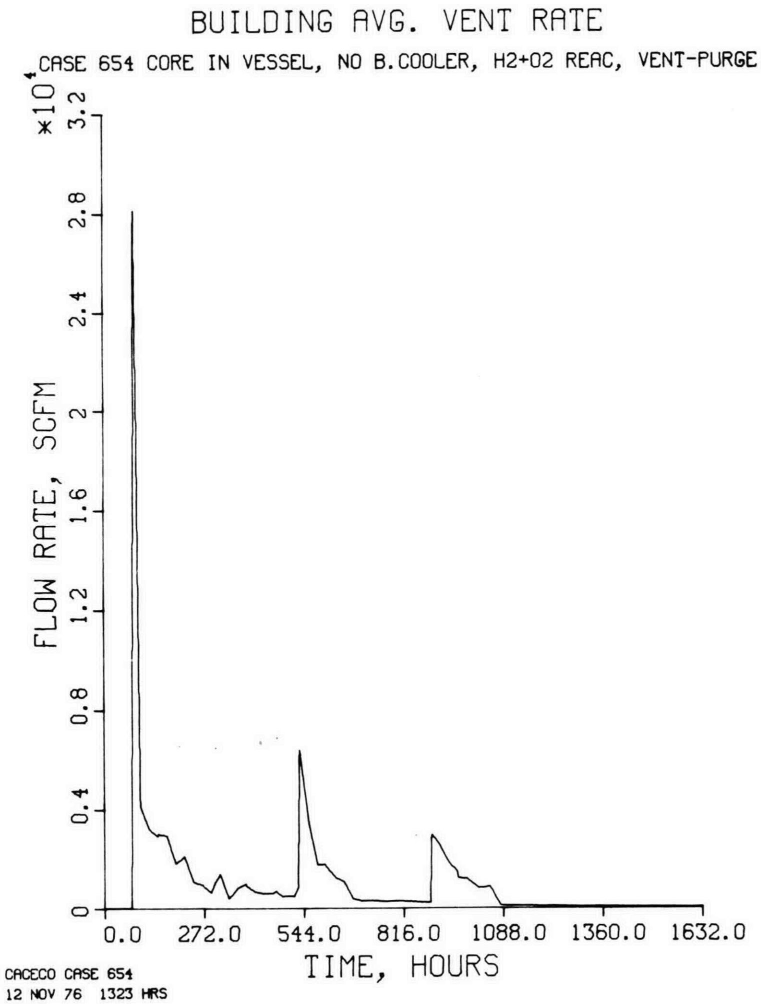


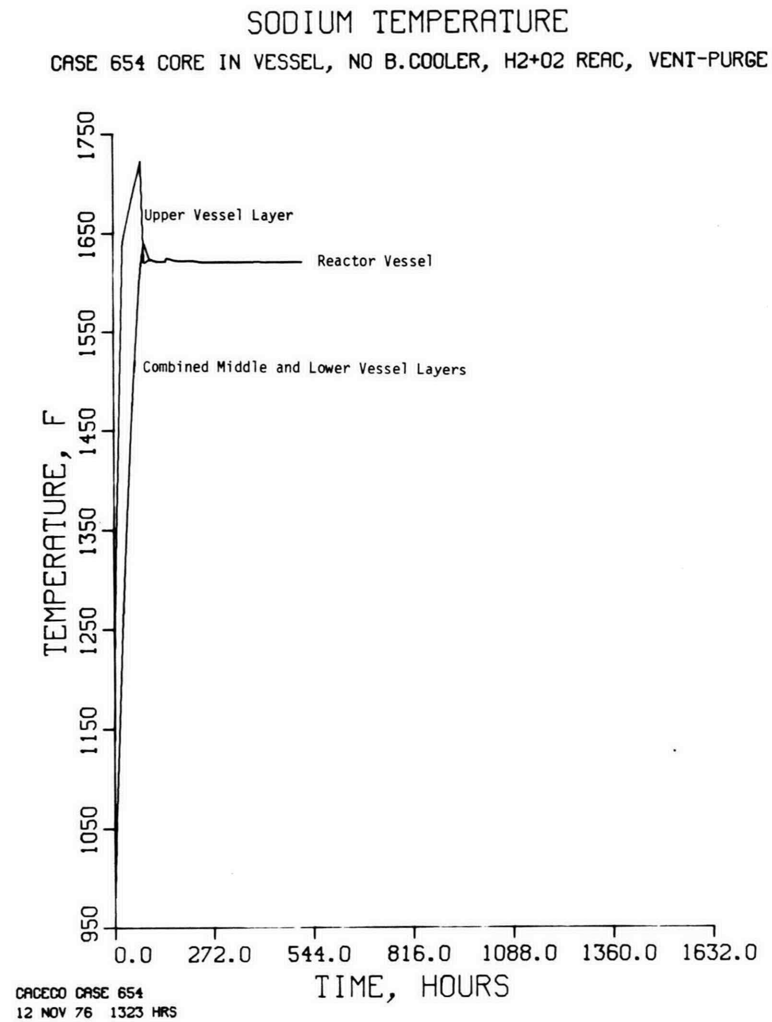
BUILDING ROOF TEMPERATURE

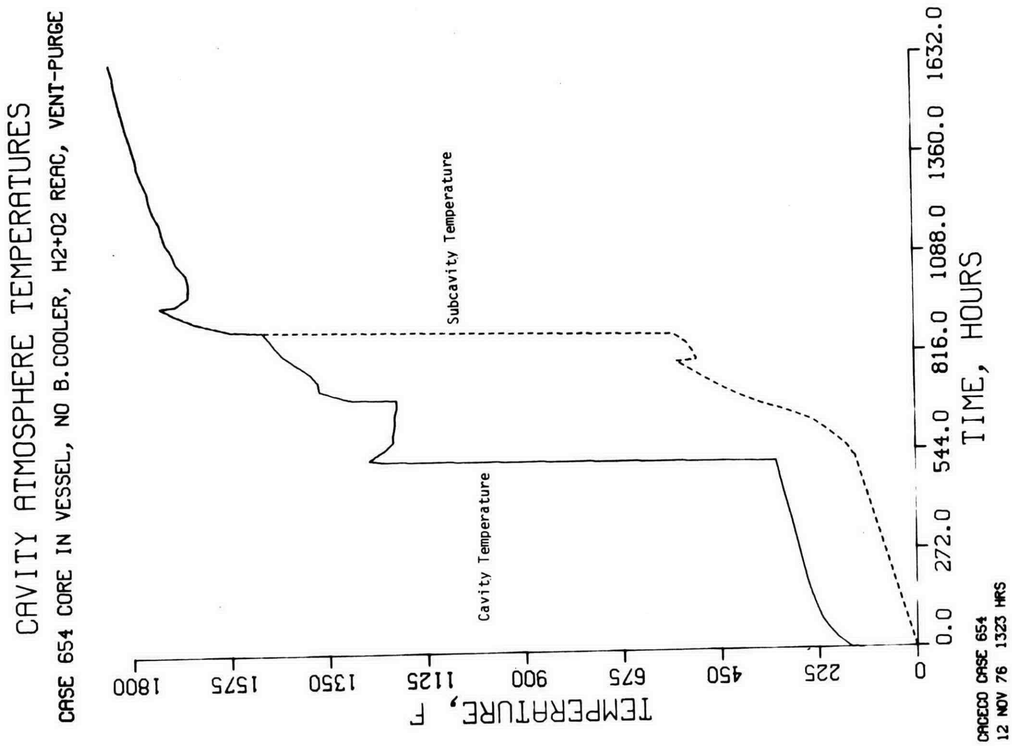
CASE 654 CORE IN VESSEL, NO B.COOLER, H2+02 REAC, VENT-PURGE

R.C.BLDG ROOF, 34,200-FT2, 1.1-IN.C.STEEL. INSIDE LEFT, OUTSIDE(

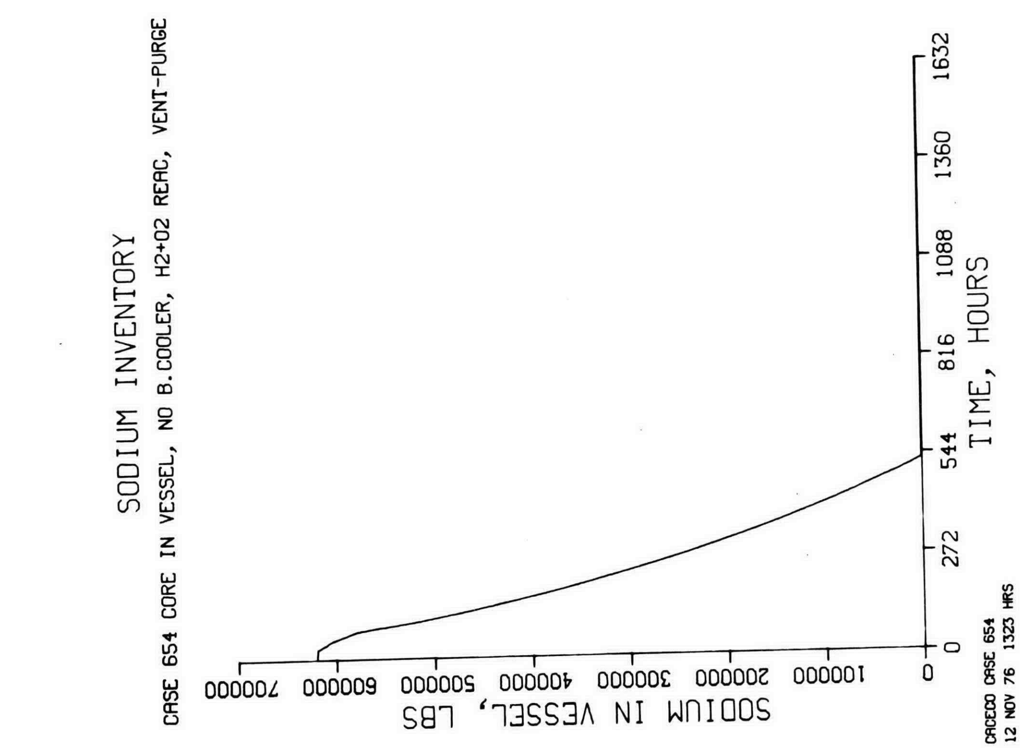



BUILDING AVG. VENT RATE
CASE 654 CORE IN VESSEL, NO B.COOLER, H2+02 REAC, VENT-PURGE
*10^4
FLOW RATE, SCFM
0
0.4
0.8
1.2
1.6
2
2.4
2.8
3.2
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 654
12 NOV 76 1323 HRS

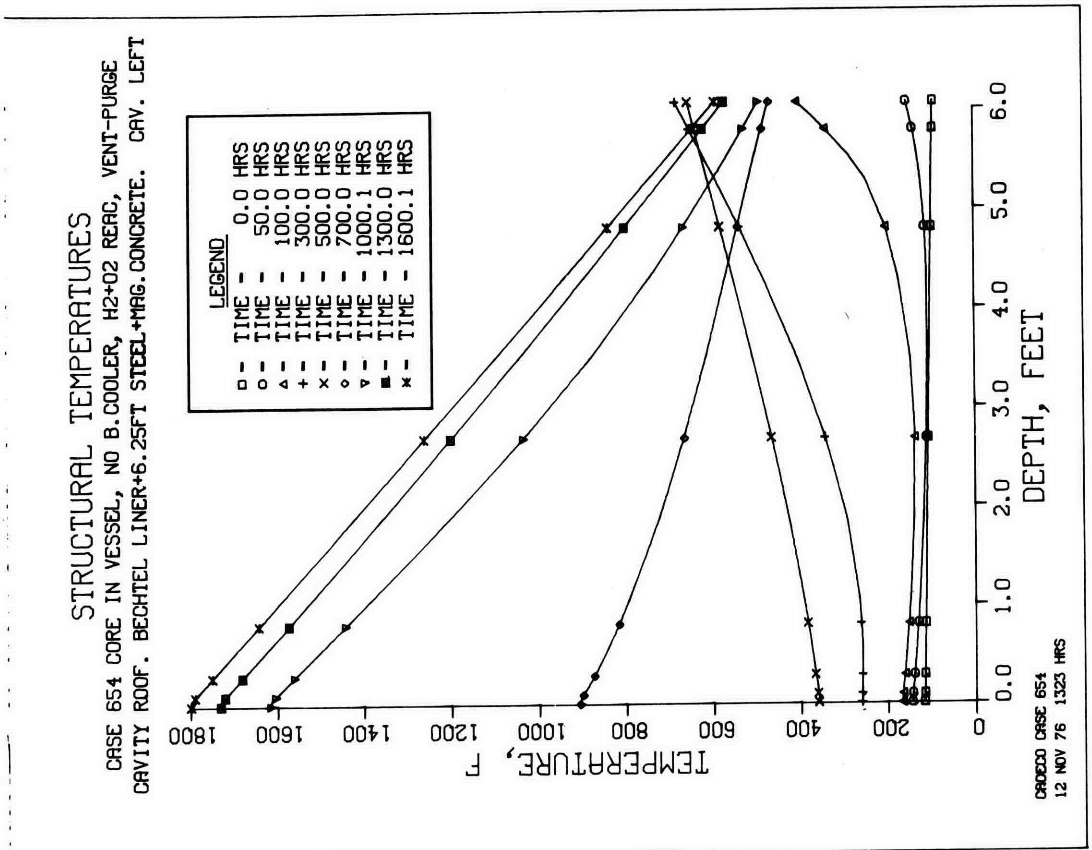

SODIUM TEMPERATURE
CASE 654 CORE IN VESSEL, NO B.COOLER, H2+02 REAC, VENT-PURGE
TEMPERATURE, F
950
1050
1150
1250
1350
1450
1550
1650
1750
Upper Vessel Layer
Reactor Vessel
Combined Middle and Lower Vessel Layers
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 654
12 NOV 76 1323 HRS

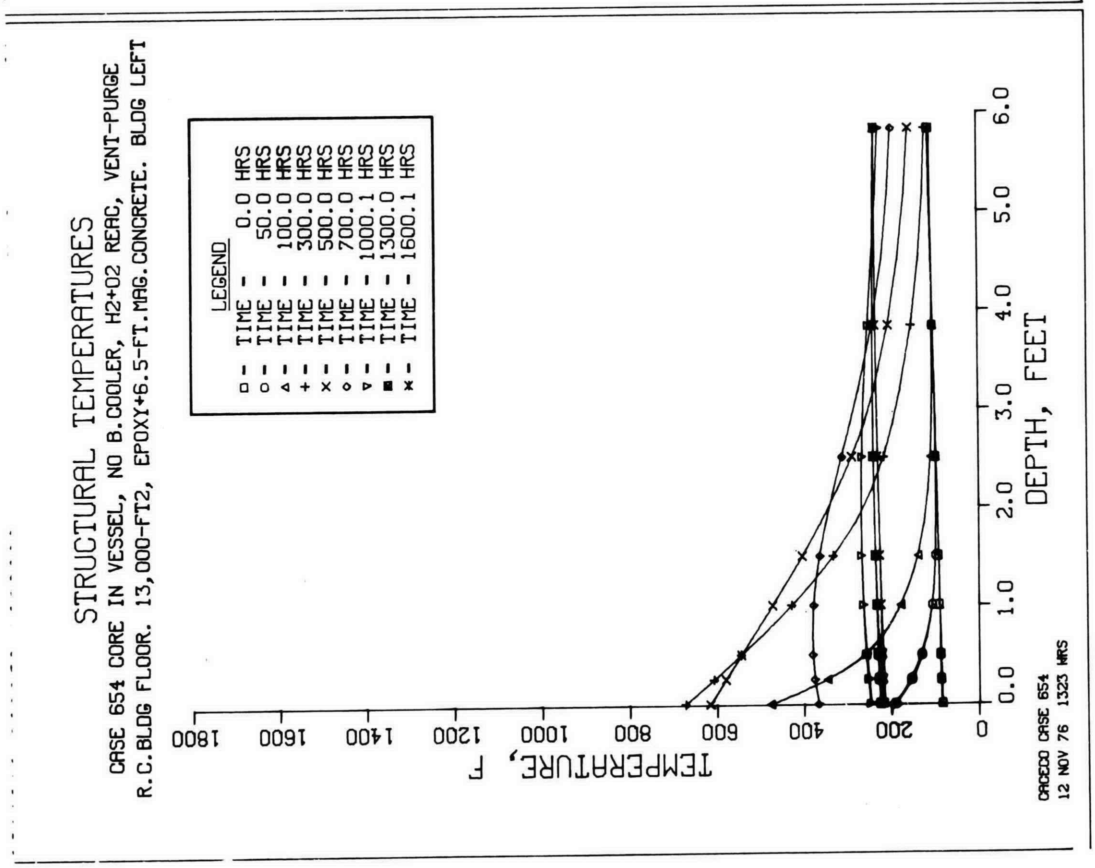


CAVITY ATMOSPHERE TEMPERATURES
CASE 654 CORE IN VESSEL, NO B.COOLER, H2+O2 REAC, VENT-PURGE
TEMPERATURE, F
0
225
450
675
900
1125
1350
1575
1800
TIME, HOURS
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
Cavity Temperature
Subcavity Temperature
CACECO CASE 654
12 NOV 76 1323 HRS



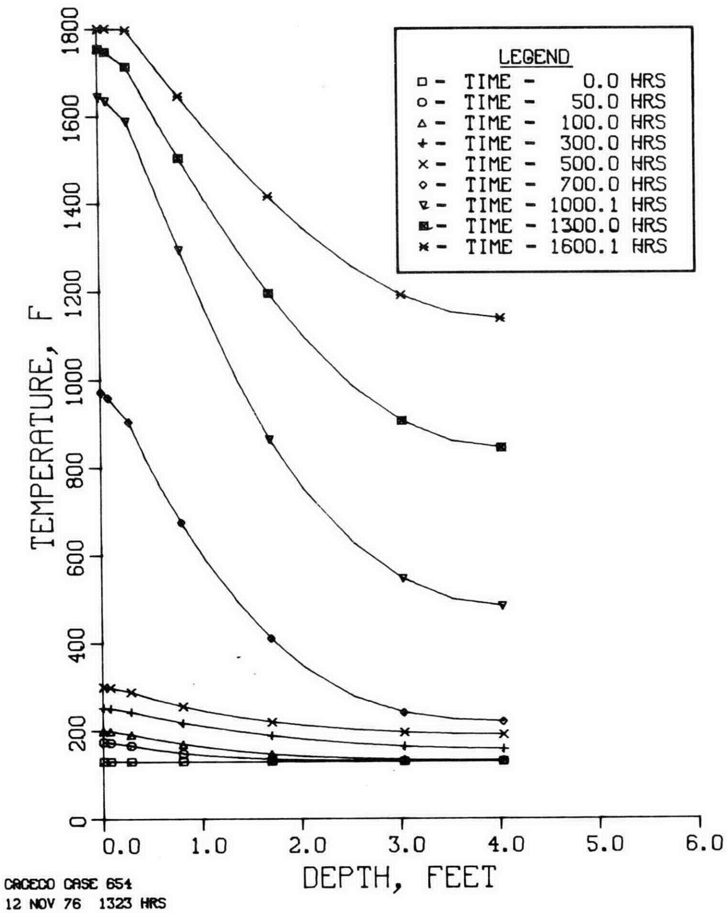
SODIUM INVENTORY
CASE 654 CORE IN VESSEL, NO B.COOLER, H2+O2 REAC, VENT-PURGE
SODIUM IN VESSEL, LBS
0
100000
200000
300000
400000
500000
600000
700000
TIME, HOURS
0
272
544
816
1088
1360
1632
CACECO CASE 654
12 NOV 76 1323 HRS


STRUCTURAL TEMPERATURES
CASE 654 CORE IN VESSEL, NO B.COOLER, H2+O2 REAC, VENT-PURGE
CAVITY ROOF. BECHTEL LINER+6.25FT STEEL+MAG.CONCRETE. CAV. LEFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.1 HRS
■ - TIME - 1300.0 HRS
✱ - TIME - 1600.1 HRS
TEMPERATURE, F
1800
1600
1400
1200
1000
800
600
400
200
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CRDECO CASE 654
12 NOV 76 1323 HRS


STRUCTURAL TEMPERATURES
CASE 654 CORE IN VESSEL, NO B.COOLER, H2+O2 REAC, VENT-PURGE
R.C.BLDG FLOOR. 13,000-FT2, EPOXY+6.5-FT.MAG.CONCRETE. BLDG LEFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.1 HRS
■ - TIME - 1300.0 HRS
✱ - TIME - 1600.1 HRS
TEMPERATURE, F
1800
1600
1400
1200
1000
800
600
400
200
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CRDECO CASE 654
12 NOV 76 1323 HRS

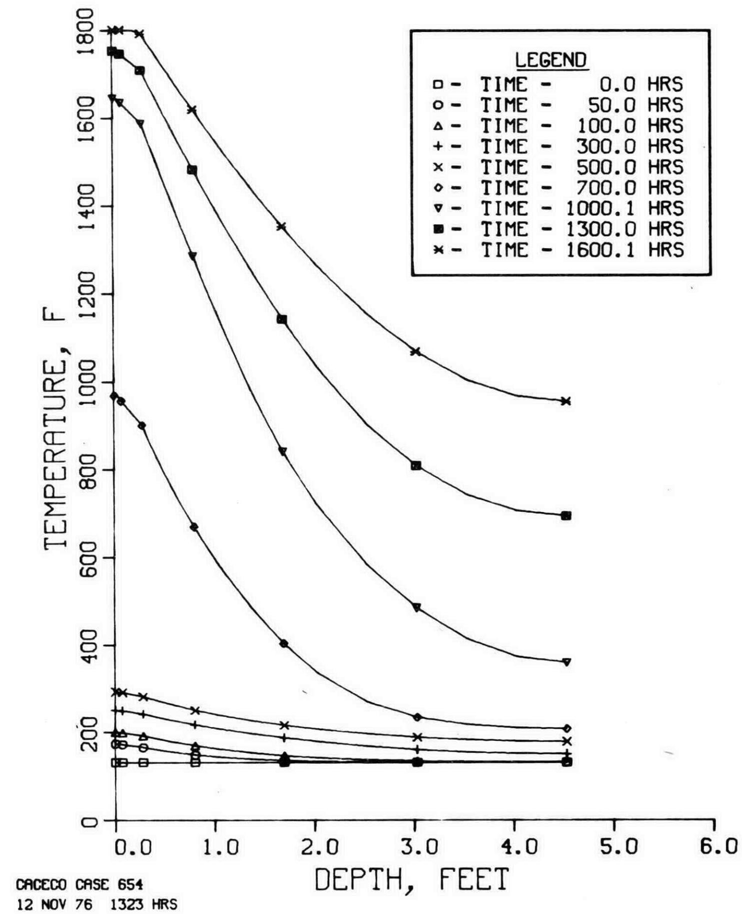
STRUCTURAL TEMPERATURES

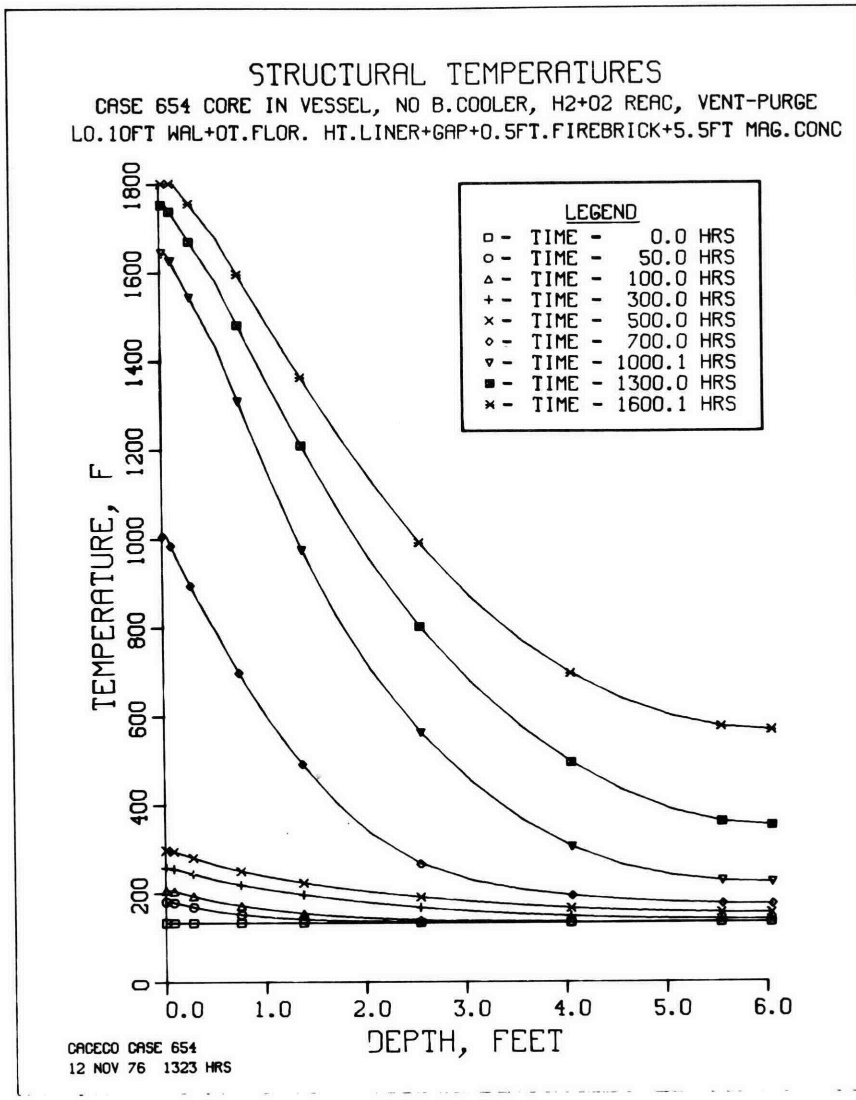
CASE 654 CORE IN VESSEL, NO B.COOLER, H2+02 REAC, VENT-PURGE
UP.16FT CAV.WALL. EFCO LINER+GAP+4FT MAG.CONCRETE. CAV. AT LEFT

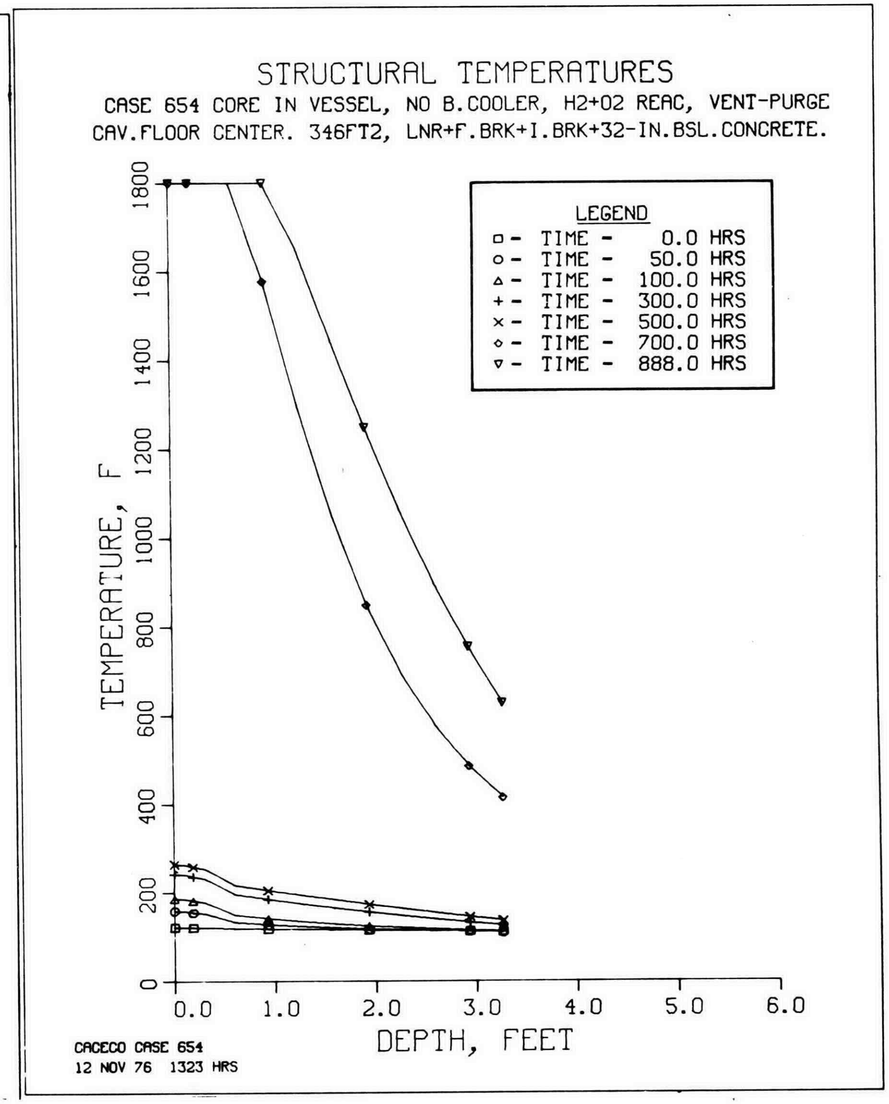


STRUCTURAL TEMPERATURES

CASE 654 CORE IN VESSEL, NO B.COOLER, H2+02 REAC, VENT-PURGE
MID.16FT CAV.WALL. BECHTEL LINER+GAP+4.5FT MAG.CONCRETE. CAV.LFT

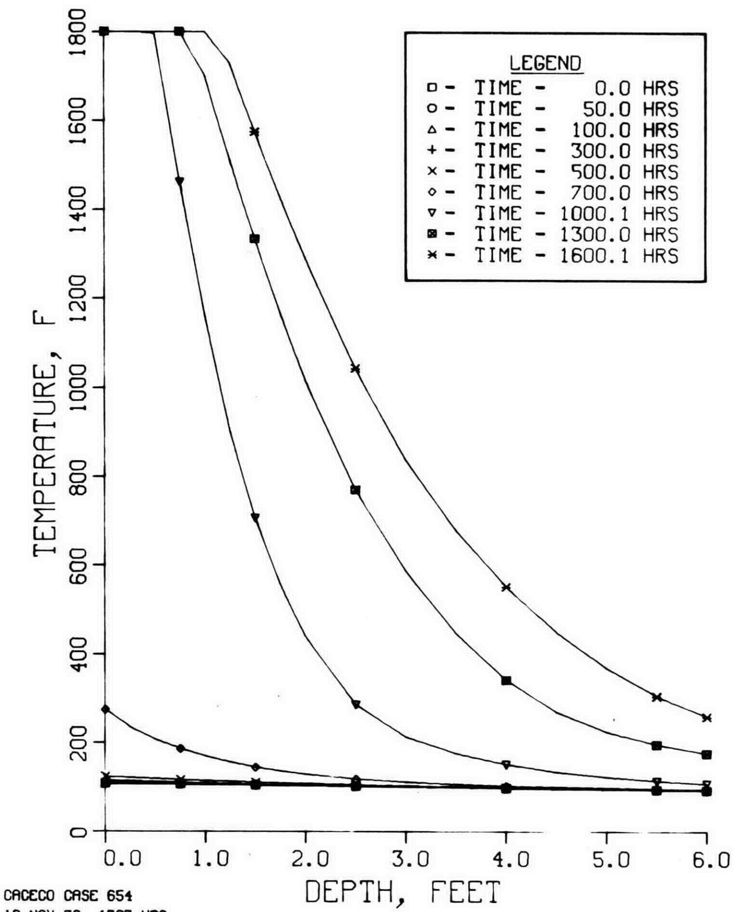



STRUCTURAL TEMPERATURES
CASE 654 CORE IN VESSEL, NO B.COOLER, H2+O2 REAC, VENT-PURGE
LO.10FT WAL+OT.FLOR. HT.LINER+GAP+0.5FT.FIREBRICK+5.5FT MAG.CONC
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 654
12 NOV 76 1323 HRS


STRUCTURAL TEMPERATURES
CASE 654 CORE IN VESSEL, NO B.COOLER, H2+O2 REAC, VENT-PURGE
CAV.FLOOR CENTER. 346FT2, LNR+F.BRK+I.BRK+32-IN.BSL.CONCRETE.
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 888.0 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 654
12 NOV 76 1323 HRS

STRUCTURAL TEMPERATURES

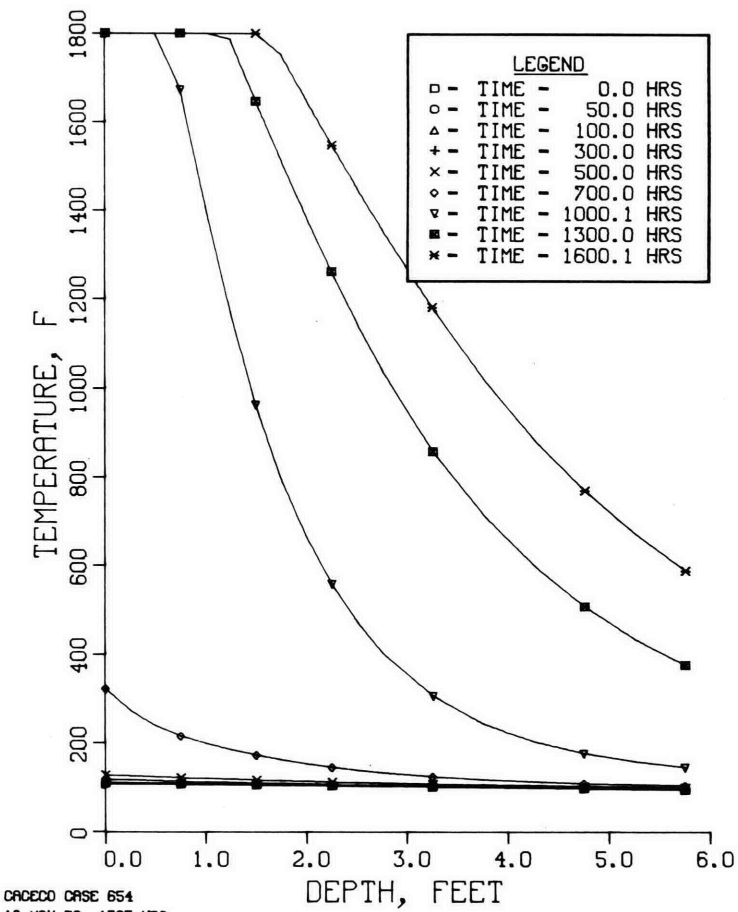
CASE 654 CORE IN VESSEL, NO B.COOLER, H2+O2 REAC, VENT-PURGE
SUB.CAVITY WALLS. 700 FT2 OF 12-FT THICK MAG.CONCRETE. S.CAV.LF



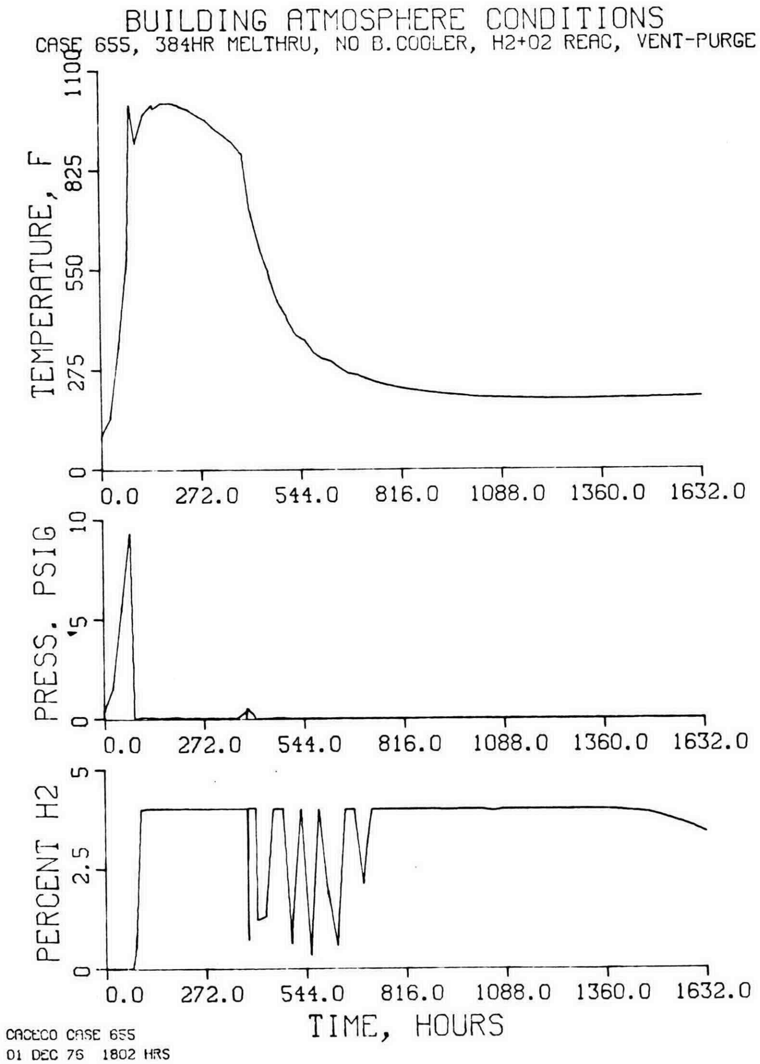
CACECO CASE 654
12 NOV 76 1323 HRS

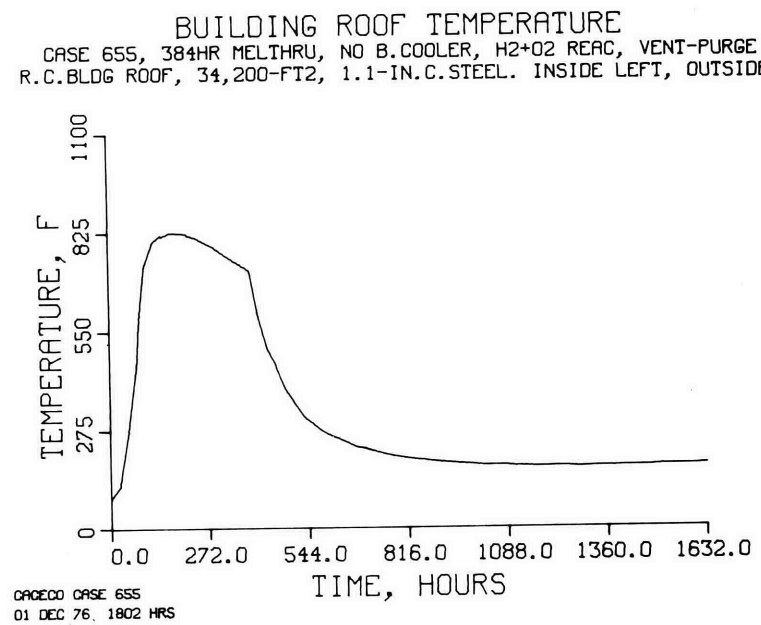
STRUCTURAL TEMPERATURES

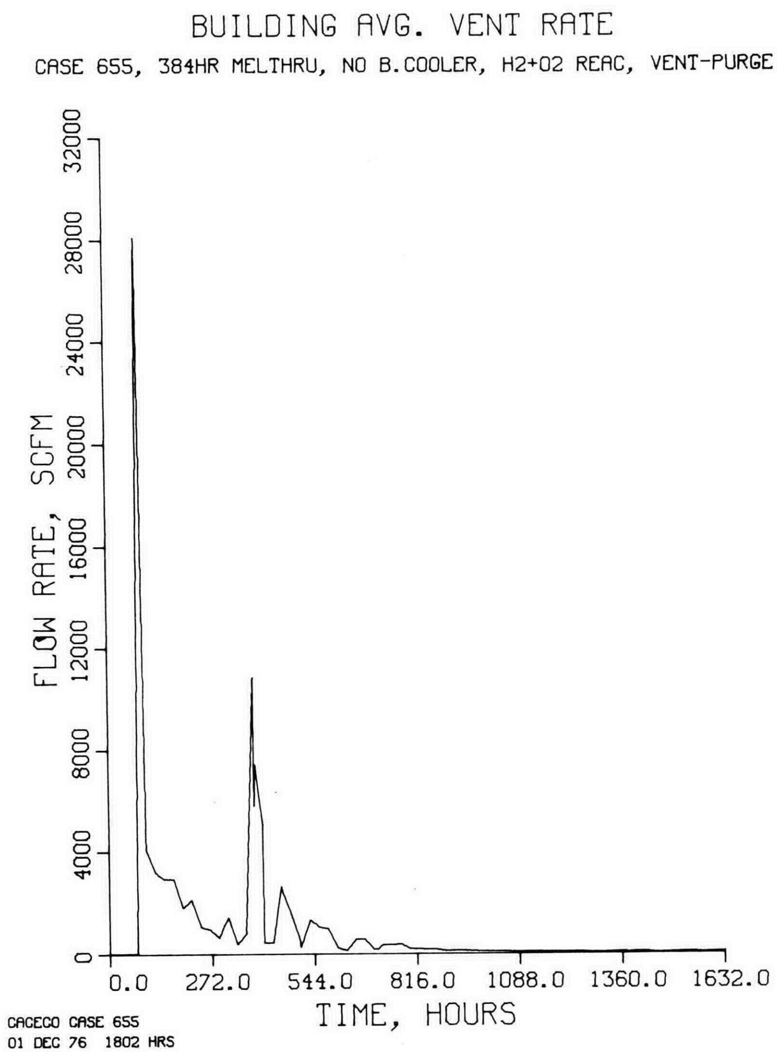
CASE 654 CORE IN VESSEL, NO B.COOLER, H2+O2 REAC, VENT-PURGE
SUB.CAVITY FLOOR. 346 FT2 OF 6.8-FT BSL.CONCRETE. SUB.CAV. LEFT

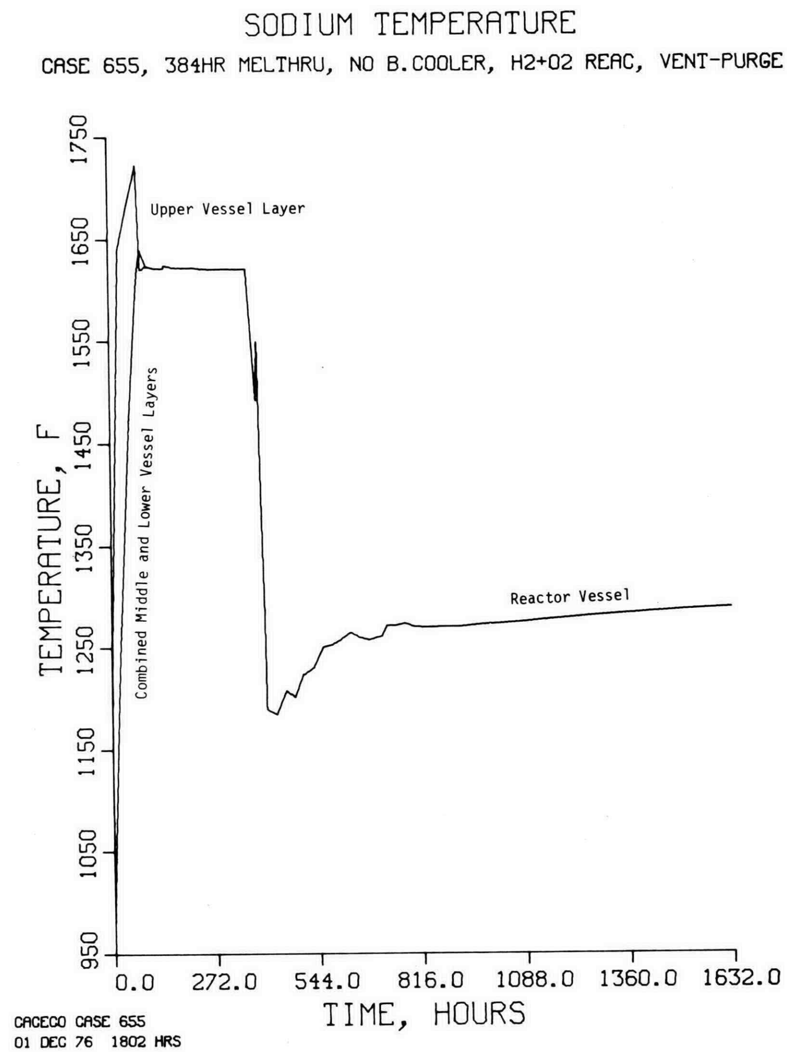


CACECO CASE 654
12 NOV 76 1323 HRS


BUILDING ATMOSPHERE CONDITIONS
CASE 655, 384HR MELTHRU, NO B.COOLER, H2+O2 REAC, VENT-PURGE
TEMPERATURE, F
0
275
550
825
1100
PRESS. PSIG
0
5
10
PERCENT H2
0
2.5
5
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 655
01 DEC 76 1802 HRS

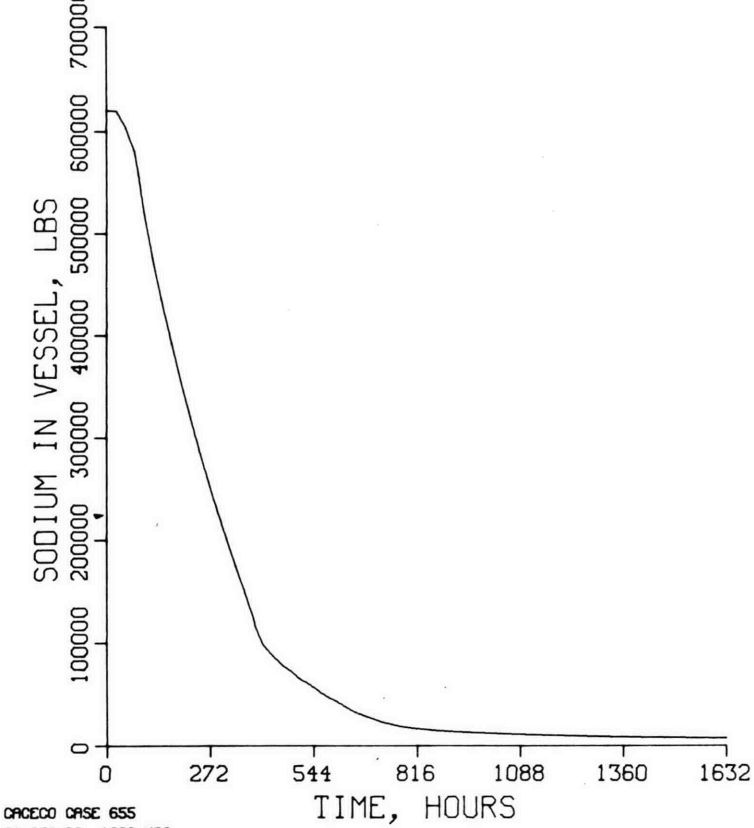

BUILDING ROOF TEMPERATURE
CASE 655, 384HR MELTHRU, NO B.COOLER, H2+O2 REAC, VENT-PURGE
R.C.BLDG ROOF, 34,200-FT2, 1.1-IN.C.STEEL. INSIDE LEFT, OUTSIDE(
TEMPERATURE, F
0
275
550
825
1100
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 655
01 DEC 76. 1802 HRS


BUILDING AVG. VENT RATE
CASE 655, 384HR MELTHRU, NO B.COOLER, H2+O2 REAC, VENT-PURGE
FLOW RATE, SCFM
0
4000
8000
12000
16000
20000
24000
28000
32000
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 655
01 DEC 76 1802 HRS


SODIUM TEMPERATURE
CASE 655, 384HR MELTHRU, NO B.COOLER, H2+O2 REAC, VENT-PURGE
TEMPERATURE, F
950
1050
1150
1250
1350
1450
1550
1650
1750
Upper Vessel Layer
Combined Middle and Lower Vessel Layers
Reactor Vessel
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 655
01 DEC 76 1802 HRS

SODIUM INVENTORY

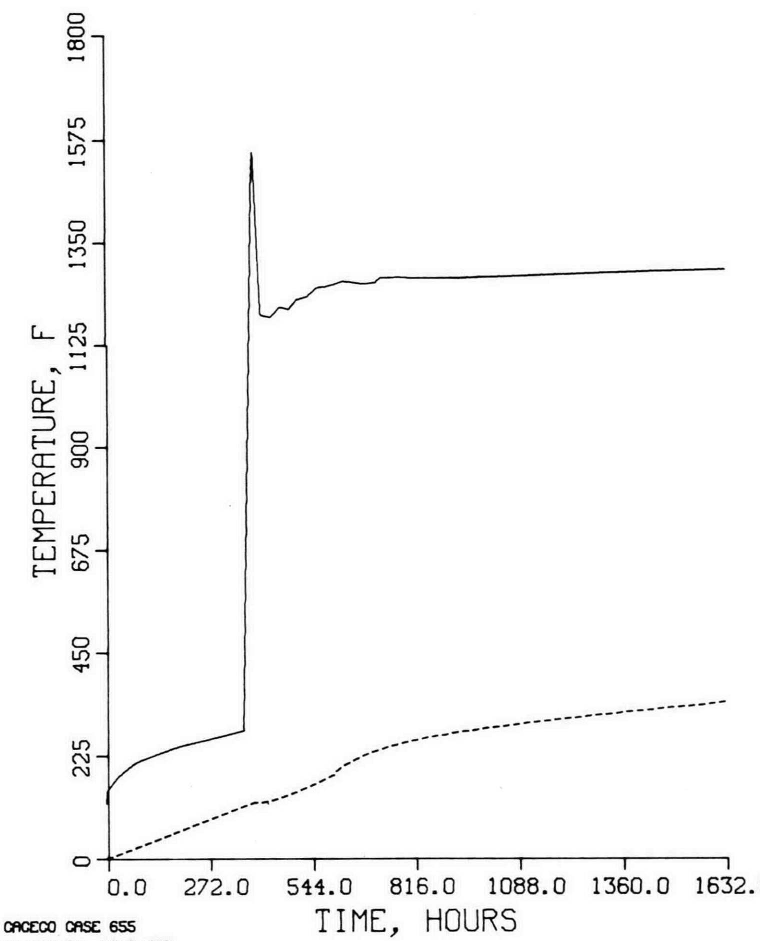
CASE 655, 384HR MELTHRU, NO B.COOLER, H2+02 REAC, VENT-PURGE



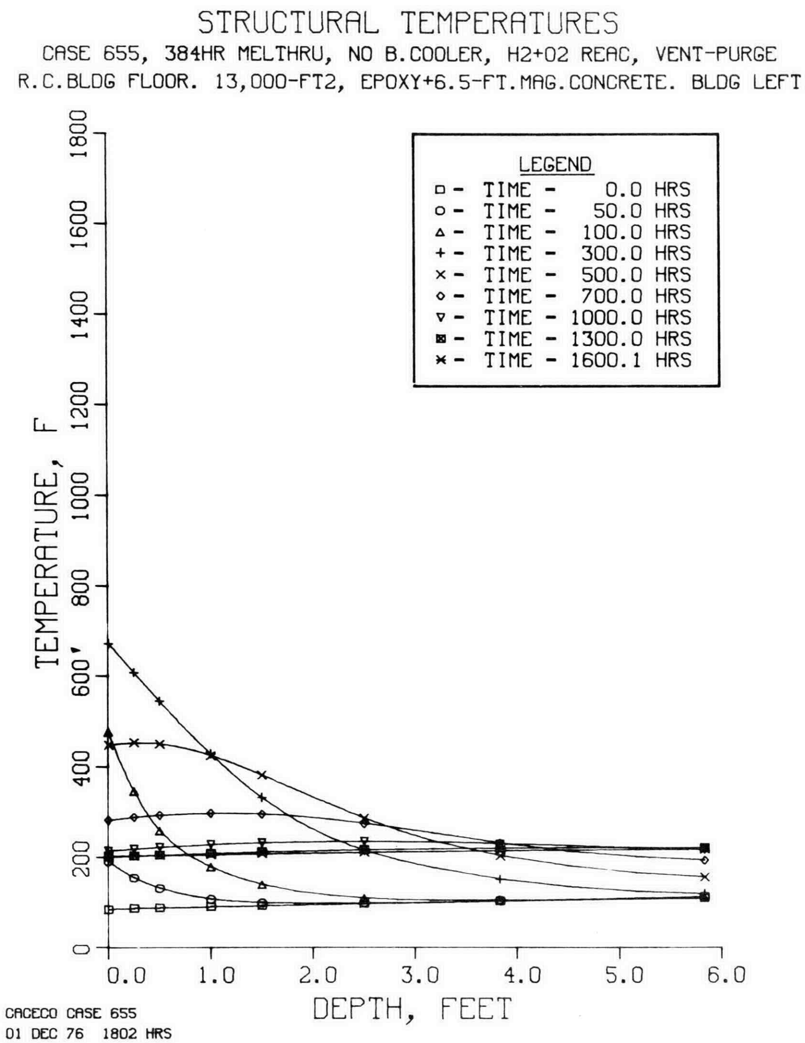
CACECO CASE 655
01 DEC 76 1802 HRS

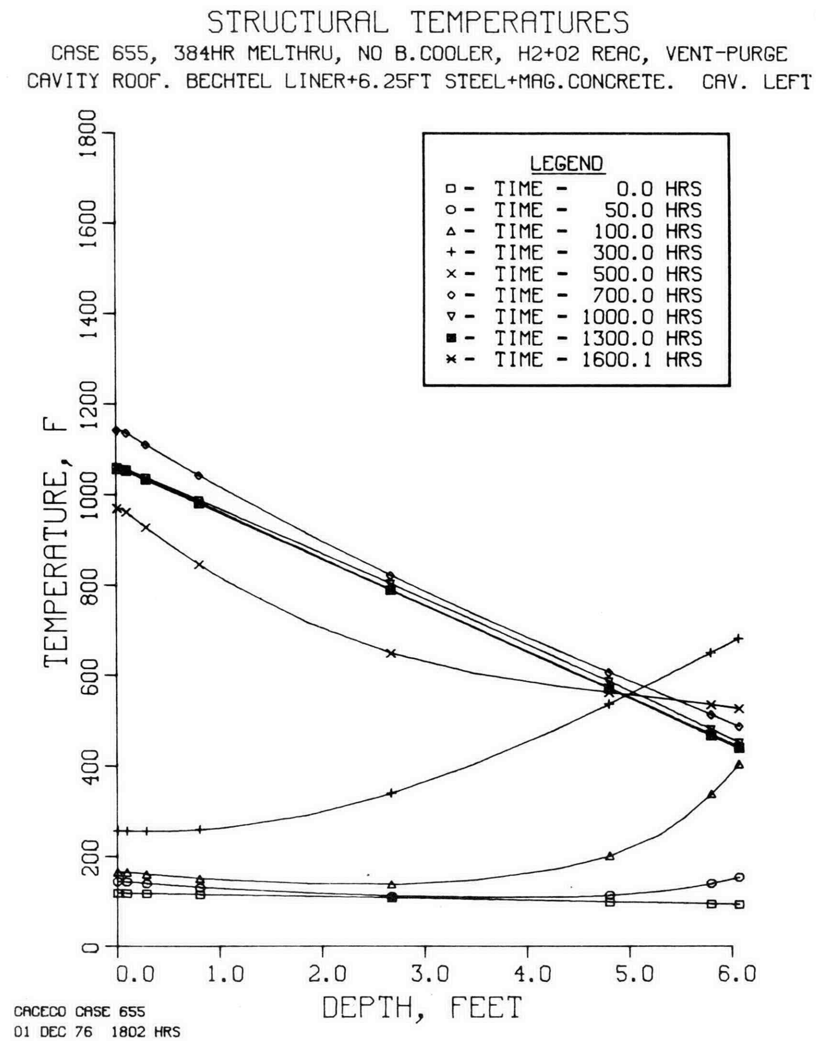
CAVITY ATMOSPHERE TEMPERATURES

CASE 655, 384HR MELTHRU, NO B.COOLER, H2+02 REAC, VENT-PURGE



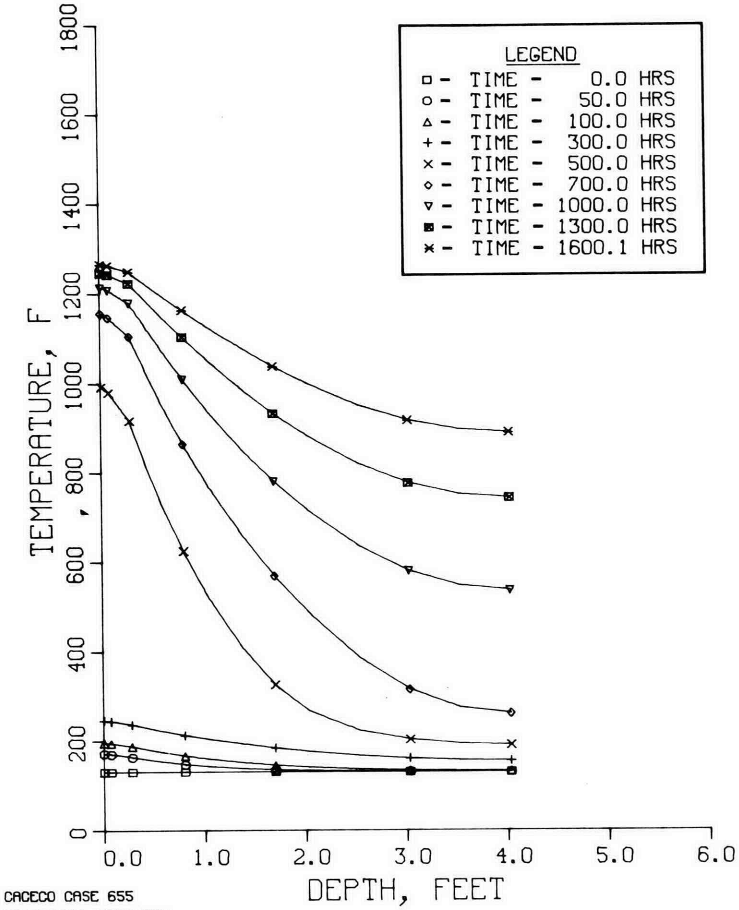
CACECO CASE 655
01 DEC 76 1802 HRS


STRUCTURAL TEMPERATURES
CASE 655, 384HR MELTHRU, NO B.COOLER, H2+O2 REAC, VENT-PURGE
R.C.BLDG FLOOR. 13,000-FT2, EPOXY+6.5-FT.MAG.CONCRETE. BLDG LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 655
01 DEC 76 1802 HRS


STRUCTURAL TEMPERATURES
CASE 655, 384HR MELTHRU, NO B.COOLER, H2+O2 REAC, VENT-PURGE
CAVITY ROOF. BECHTEL LINER+6.25FT STEEL+MAG.CONCRETE. CAV. LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 655
01 DEC 76 1802 HRS

STRUCTURAL TEMPERATURES

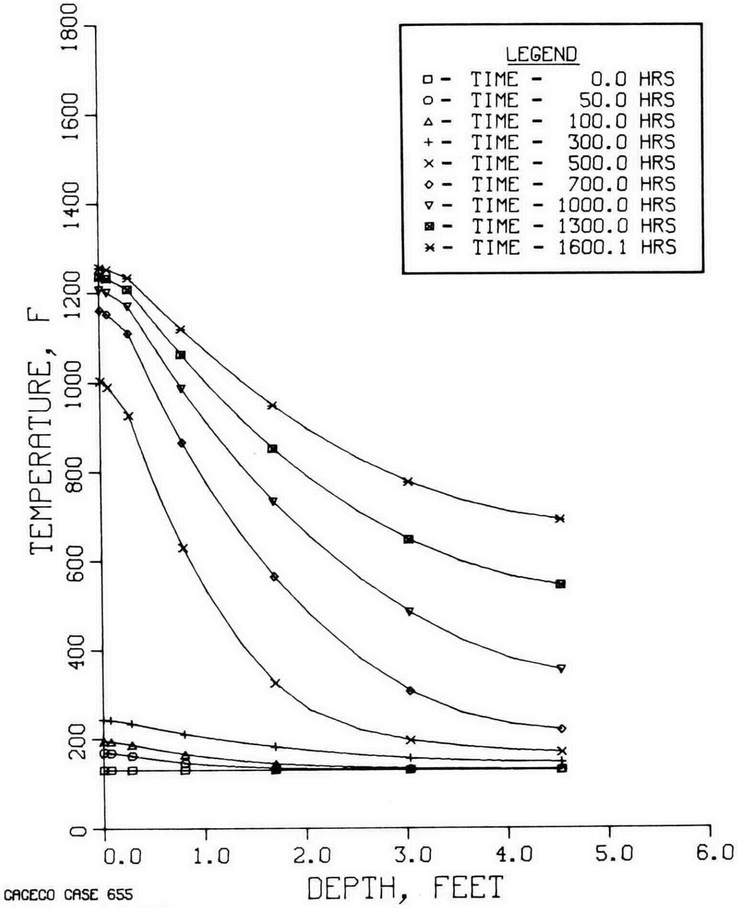
CASE 655, 384HR MELTHRU, NO B.COOLER, H2+O2 REAC, VENT-PURGE
UPP 16.1FT CAV.WALL. IA-1820FT2, EFCO LINER+GAP+4FT MAG.CONCRETE



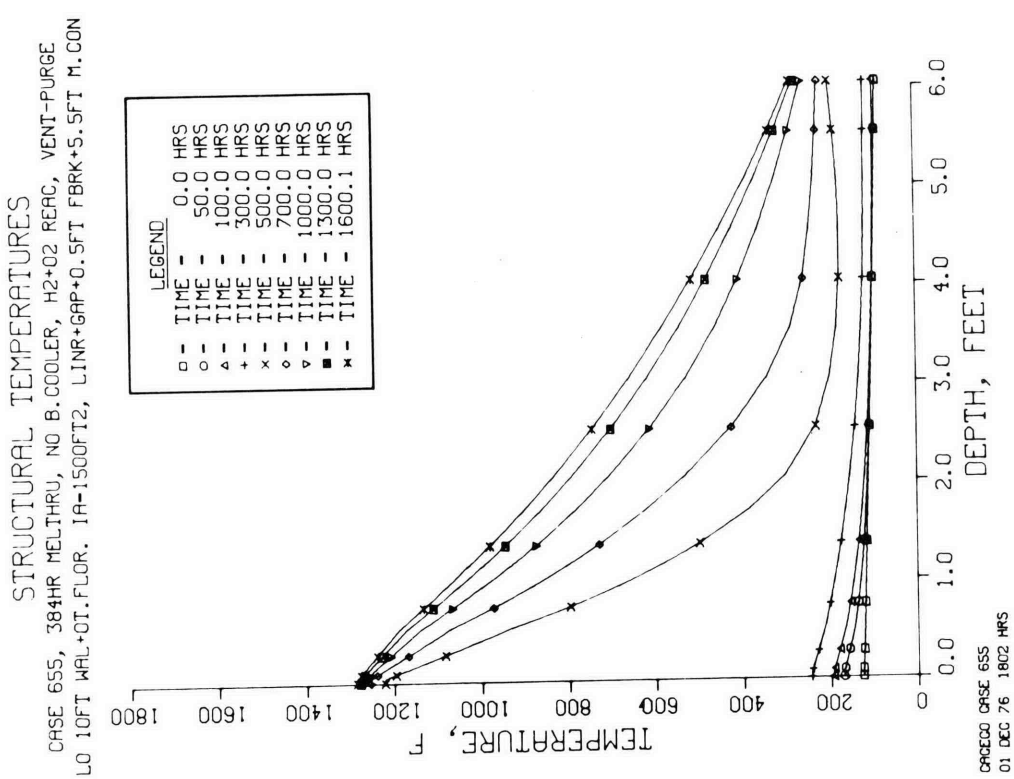
CACECO CASE 655
01 DEC 76 1802 HRS

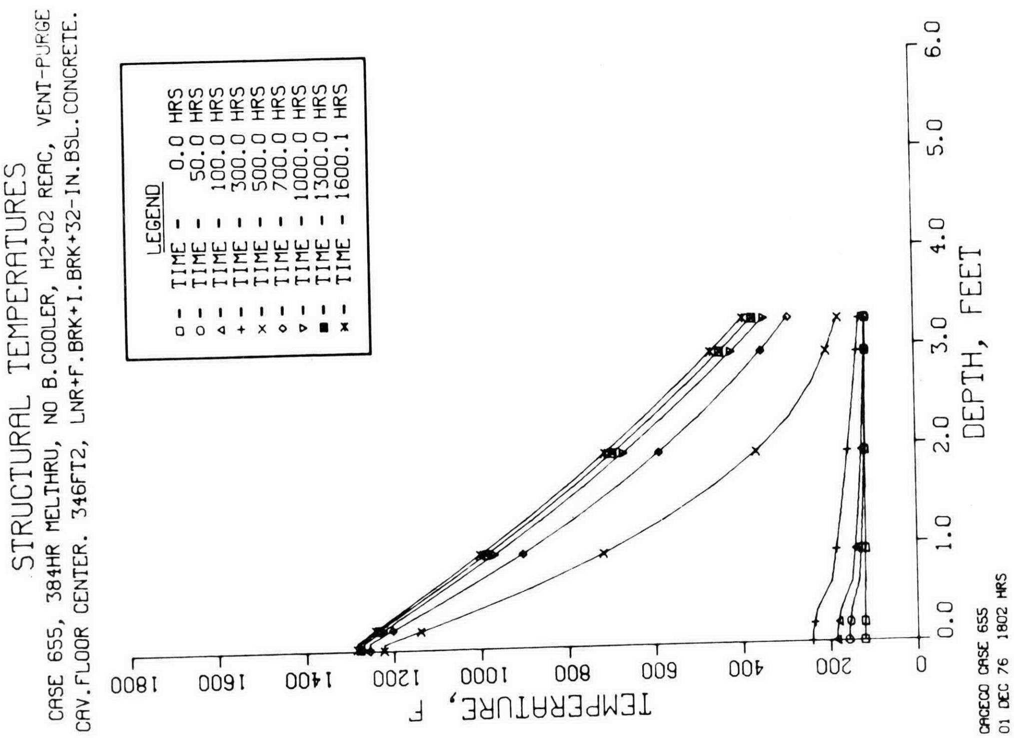
STRUCTURAL TEMPERATURES

CASE 655, 384HR MELTHRU, NO B.COOLER, H2+O2 REAC, VENT-PURGE
MID 16.1FT CAV.WALL. IA-1820FT2, BECHTEL LINER+GAP+4.5FT MAG.CON



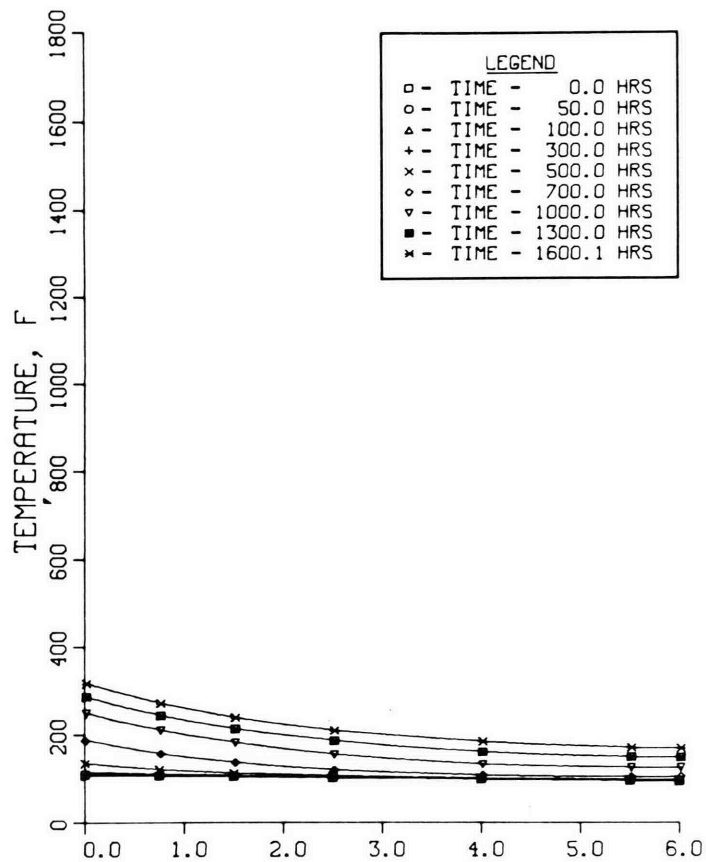
CACECO CASE 655
01 DEC 76 1802 HRS


STRUCTURAL TEMPERATURES
CASE 655, 384HR MELTHRU, NO B.COOLER, H2+O2 REAC, VENT-PURGE
LO 10FT WAL+CT.FLOR. IA-1500FT2, LINR+GAP+0.5FT FBRK+5.5FT M.CON
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.0 HRS
✖ - TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 655
01 DEC 76 1802 HRS


STRUCTURAL TEMPERATURES
CASE 655, 384HR MELTHRU, NO B.COOLER, H2+O2 REAC, VENT-PURGE
CAV.FLOOR CENTER. 346FT2, LNR+F.BRK+I.BRK+32-IN.BSL.CONCRETE.
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.0 HRS
✖ - TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 655
01 DEC 76 1802 HRS

STRUCTURAL TEMPERATURES

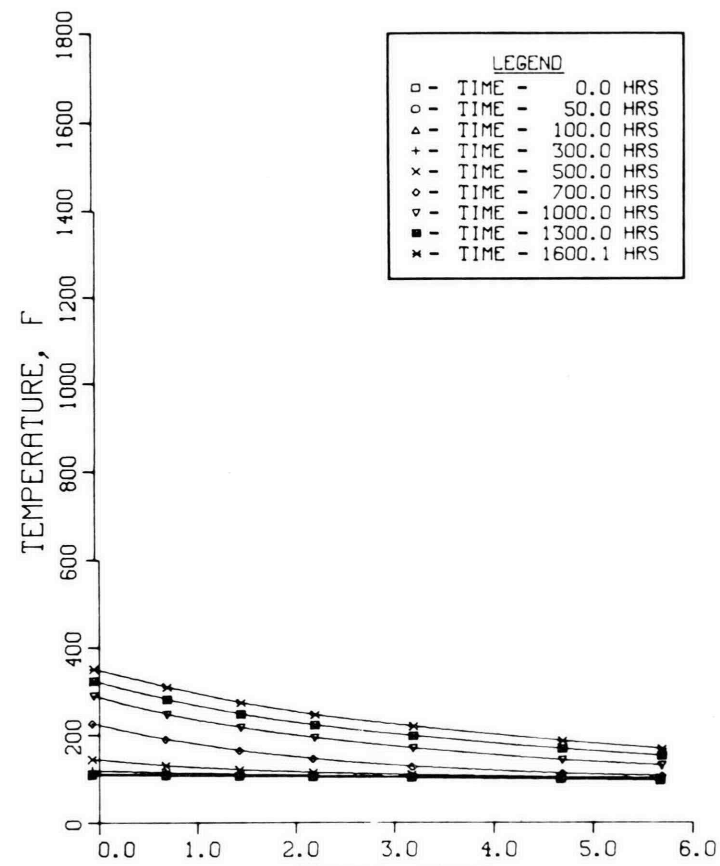
CASE 655, 384HR MELTHRU, NO B.COOLER, H2+O2 REAC, VENT-PURGE
SUB.CAVITY WALLS. 700 FT2 OF 12-FT THICK MAG.CONCRETE. S.CAV.LF



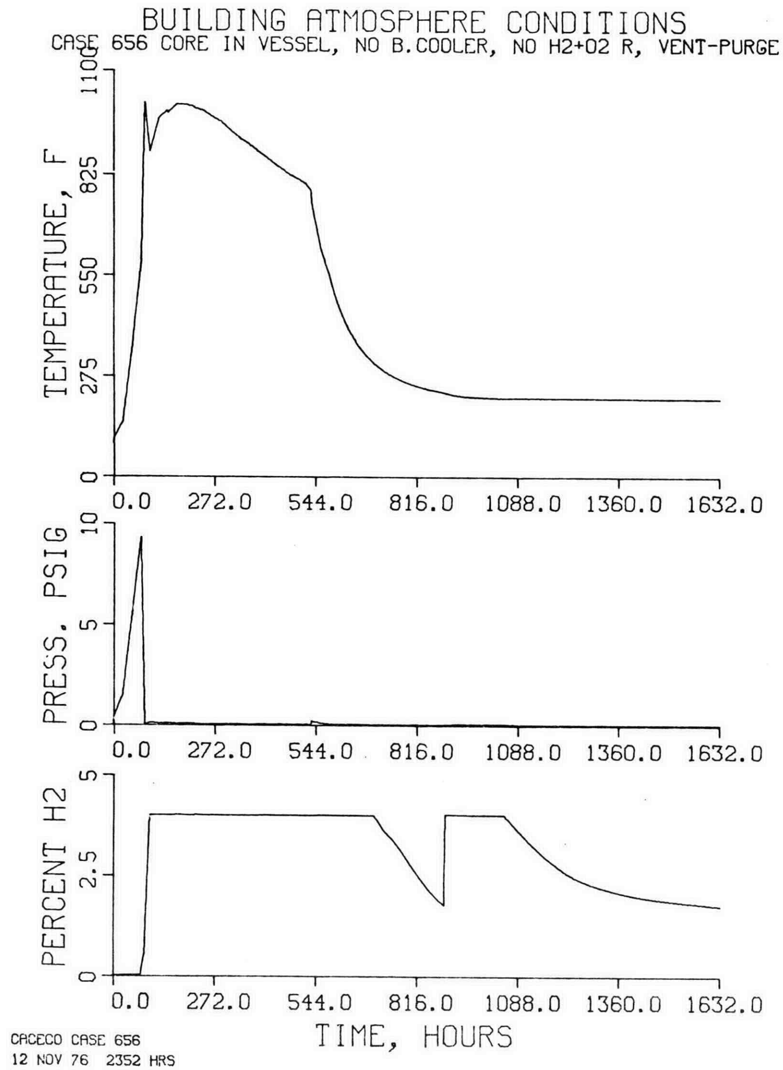
CACECO CASE 655
01 DEC 76 1802 HRS

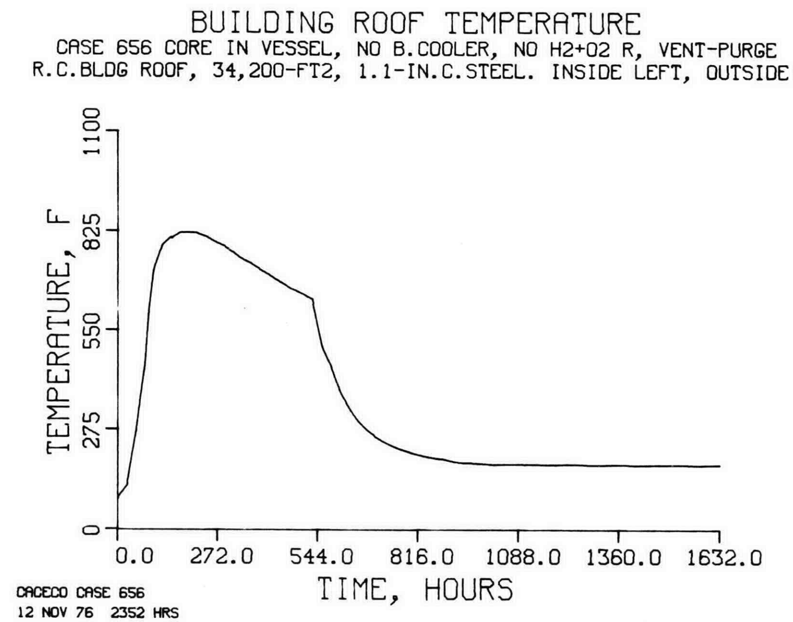
STRUCTURAL TEMPERATURES

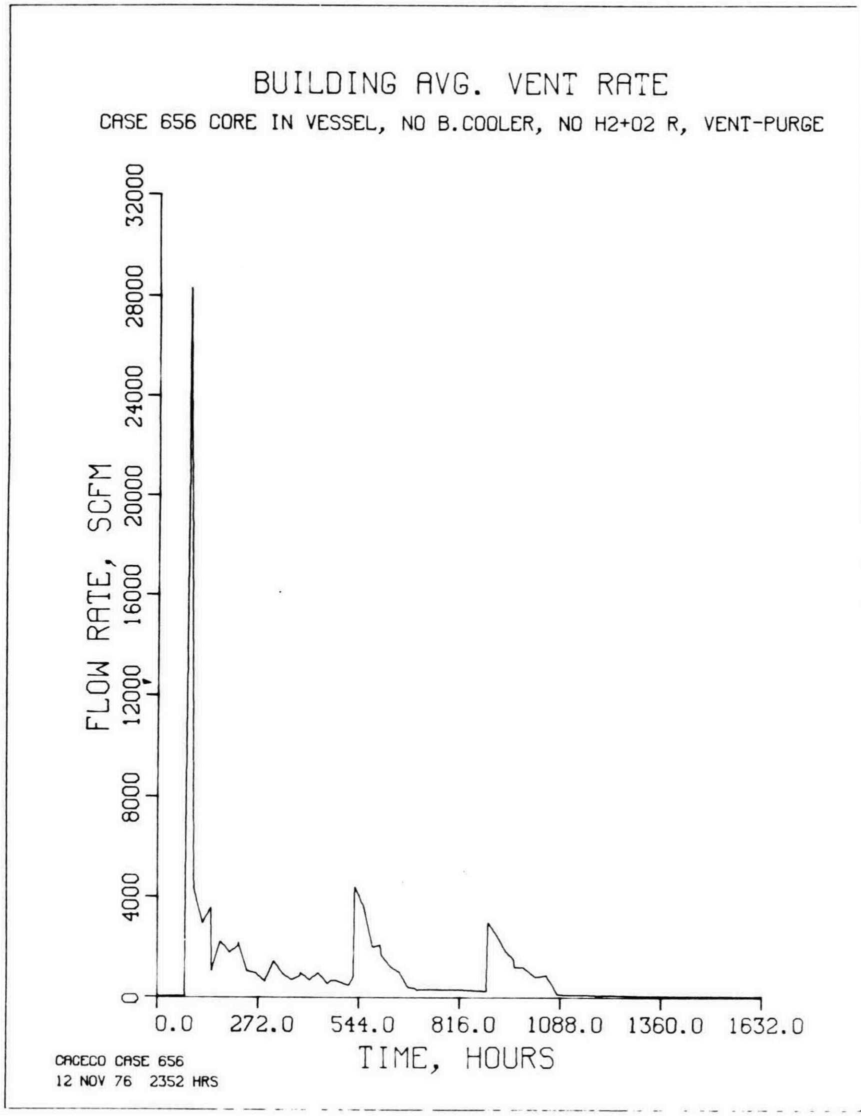
CASE 655, 384HR MELTHRU, NO B.COOLER, H2+O2 REAC, VENT-PURGE
SUB.CAVITY FLOOR. 346 FT2 OF 6.8-FT BSL.CONCRETE. SUB.CAV. LEFT

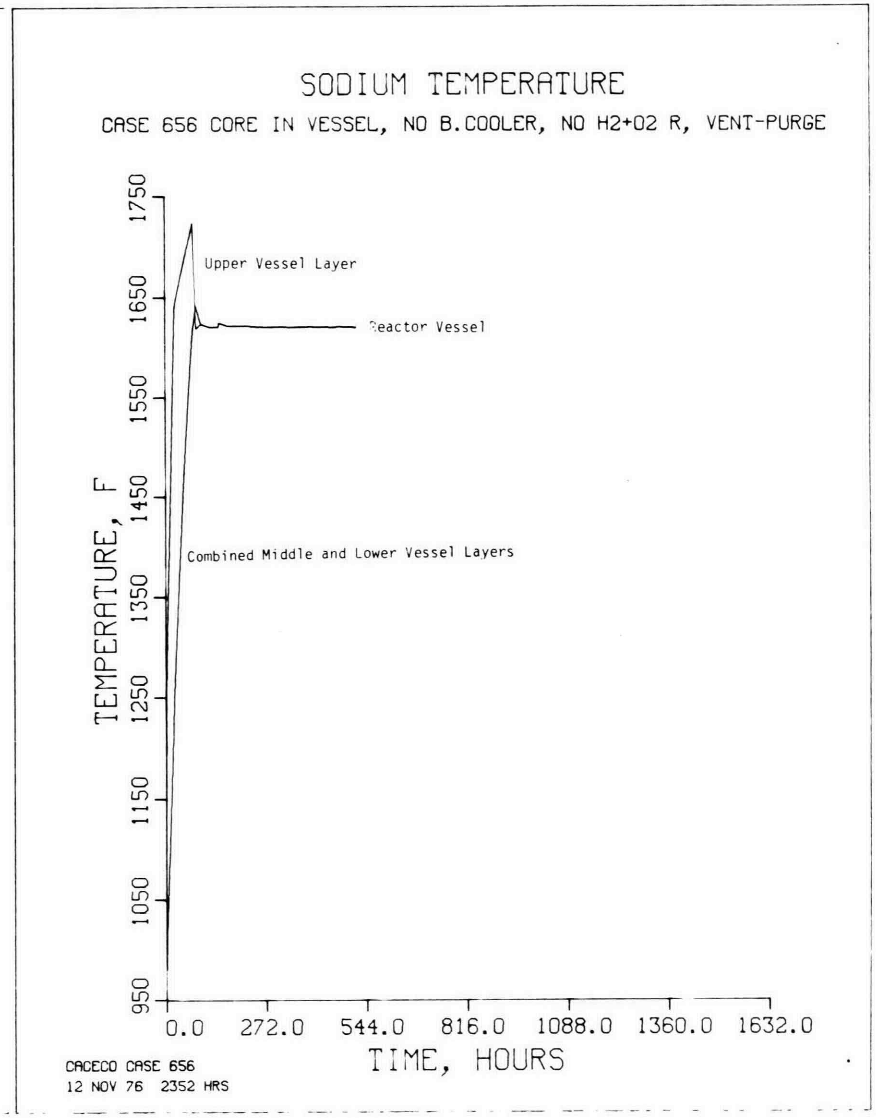


CACECO CASE 655
01 DEC 76 1802 HRS


BUILDING ATMOSPHERE CONDITIONS
CASE 656 CORE IN VESSEL, NO B.COOLER, NO H2+02 R, VENT-PURGE
TEMPERATURE, F
0
275
550
825
1100
PRESS. PSIG
0
5
10
PERCENT H2
0
2.5
5
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 656
12 NOV 76 2352 HRS

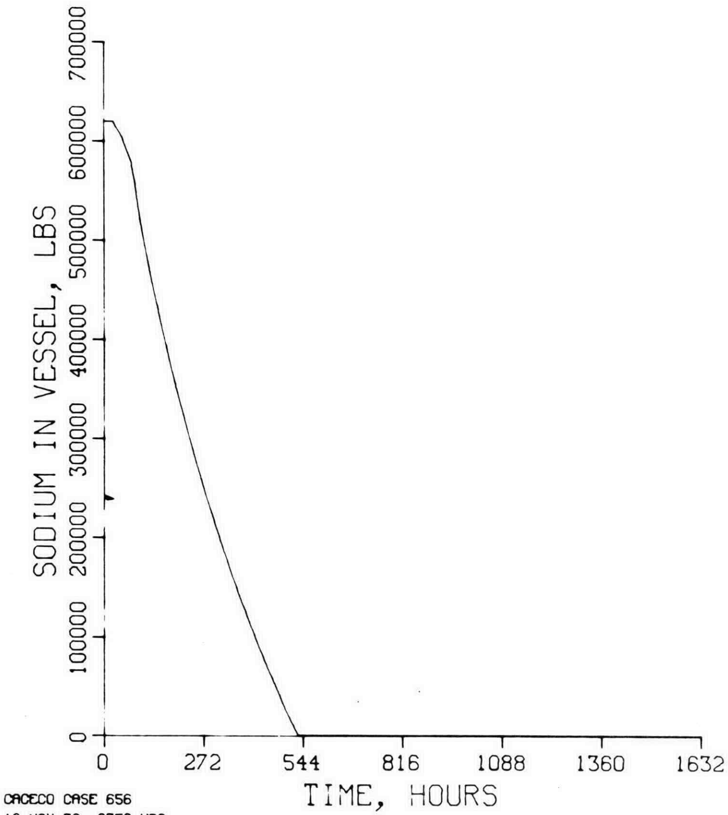

BUILDING ROOF TEMPERATURE
CASE 656 CORE IN VESSEL, NO B.COOLER, NO H2+02 R, VENT-PURGE
R.C.BLDG ROOF, 34,200-FT2, 1.1-IN.C.STEEL. INSIDE LEFT, OUTSIDE(
TEMPERATURE, F
0
275
550
825
1100
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 656
12 NOV 76 2352 HRS


BUILDING AVG. VENT RATE
CASE 656 CORE IN VESSEL, NO B.COOLER, NO H2+02 R, VENT-PURGE
FLOW RATE, SCFM
0
4000
8000
12000
16000
20000
24000
28000
32000
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 656
12 NOV 76 2352 HRS


SODIUM TEMPERATURE
CASE 656 CORE IN VESSEL, NO B.COOLER, NO H2+02 R, VENT-PURGE
TEMPERATURE, F
950
1050
1150
1250
1350
1450
1550
1650
1750
Upper Vessel Layer
Reactor Vessel
Combined Middle and Lower Vessel Layers
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 656
12 NOV 76 2352 HRS

SODIUM INVENTORY

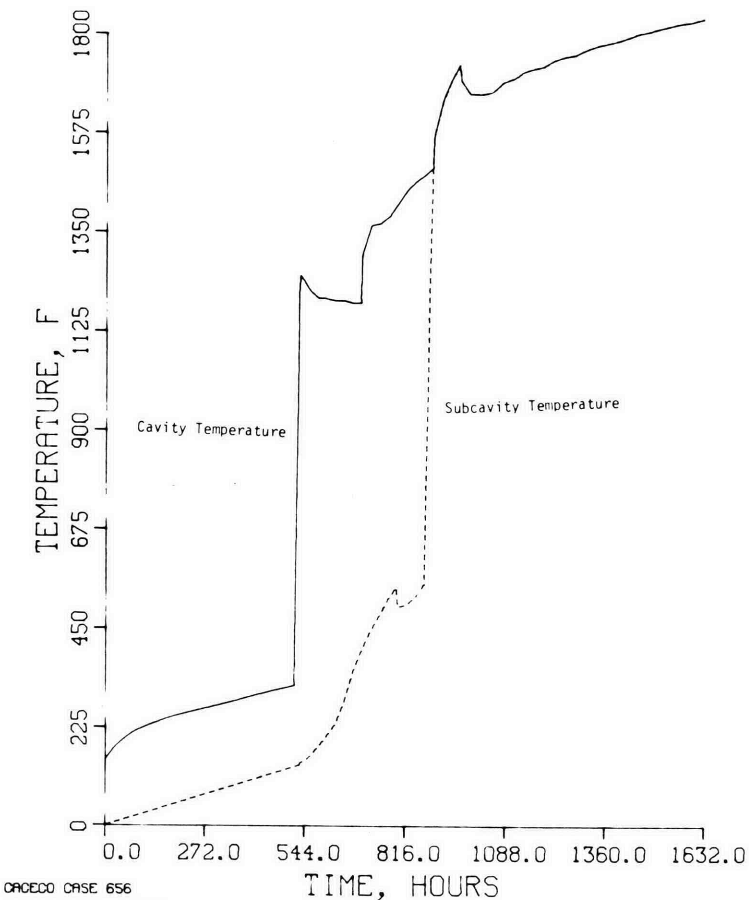
CASE 656 CORE IN VESSEL, NO B.COOLER, NO H2+02 R, VENT-PURGE



CACECO CASE 656
12 NOV 76 2352 HRS

CAVITY ATMOSPHERE TEMPERATURES

CASE 656 CORE IN VESSEL, NO B.COOLER, NO H2+02 R, VENT-PURGE

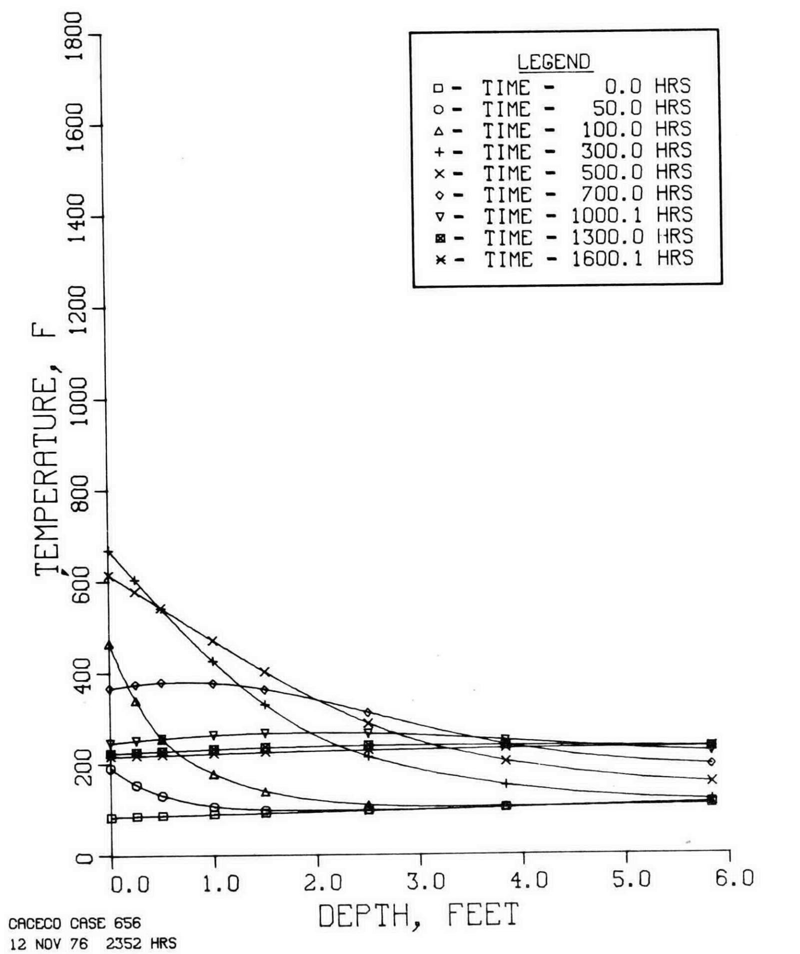


CACECO CASE 656
12 NOV 76 2352 HRS

STRUCTURAL TEMPERATURES

CASE 656 CORE IN VESSEL, NO B.COOLER, NO H2+02 R, VENT-PURGE

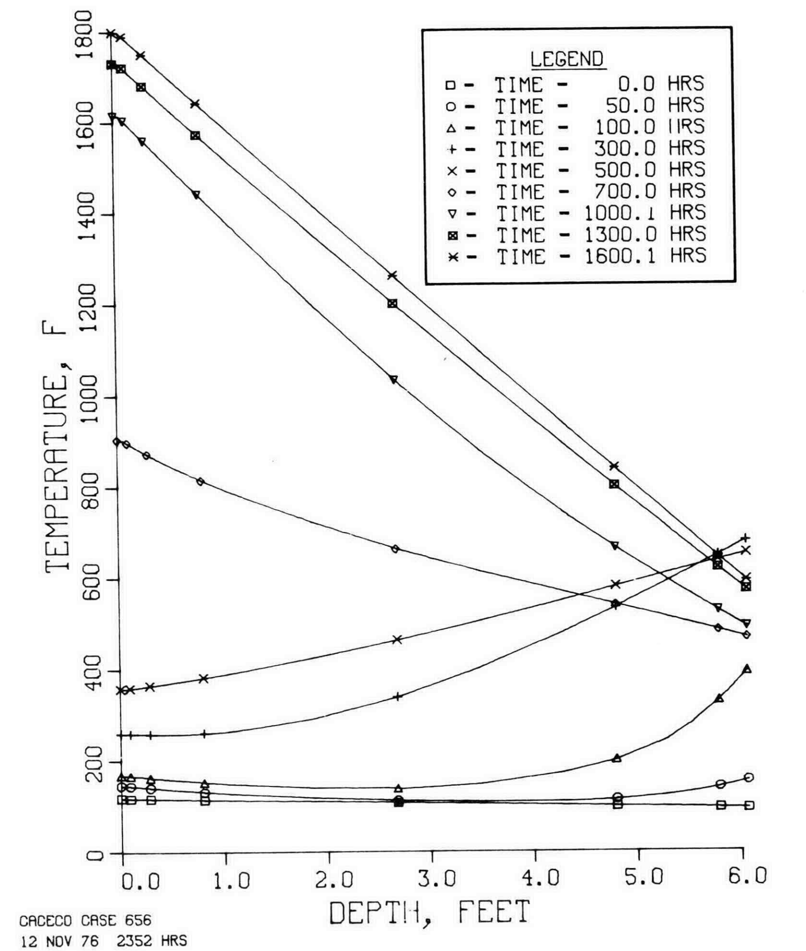
R.C.BLDG FLOOR. 13,000-FT2, EPOXY+6.5-FT.MAG.CONCRETE. BLDG LEFT

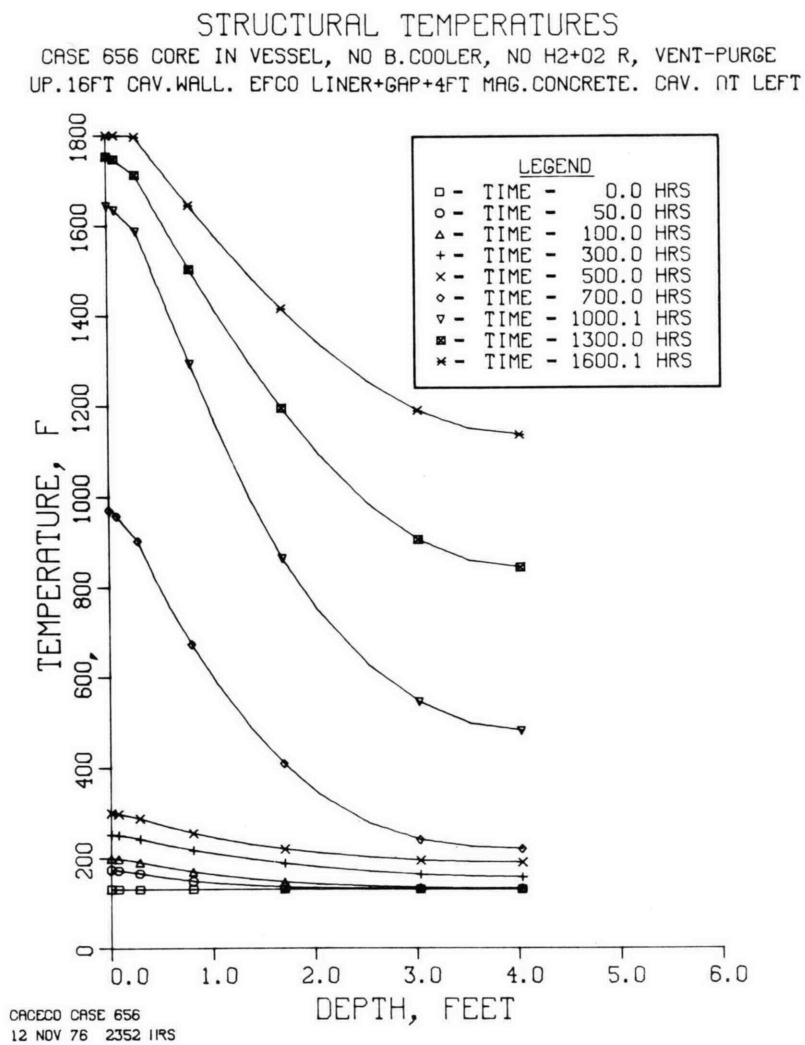


STRUCTURAL TEMPERATURES

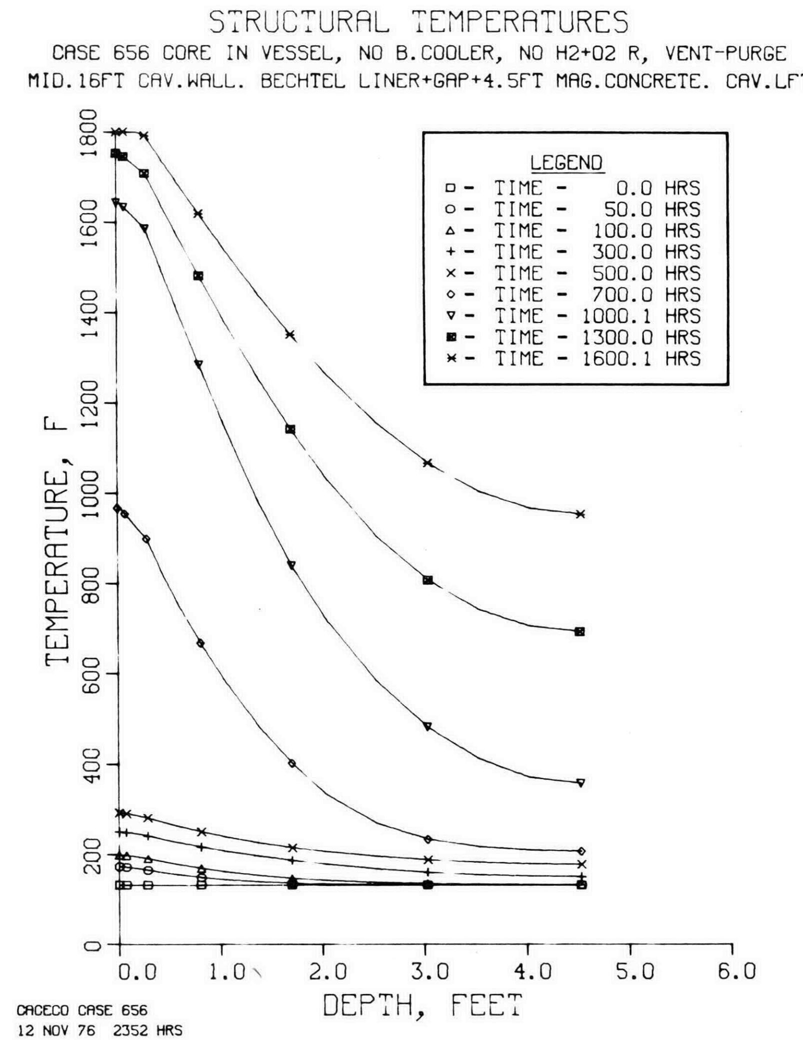
CASE 656 CORE IN VESSEL, NO B.COOLER, NO H2+02 R, VENT-PURGE

CAVITY ROOF. BECHTEL LINER-6.25FT STEEL+MAG.CONCRETE. CAV. LEFT



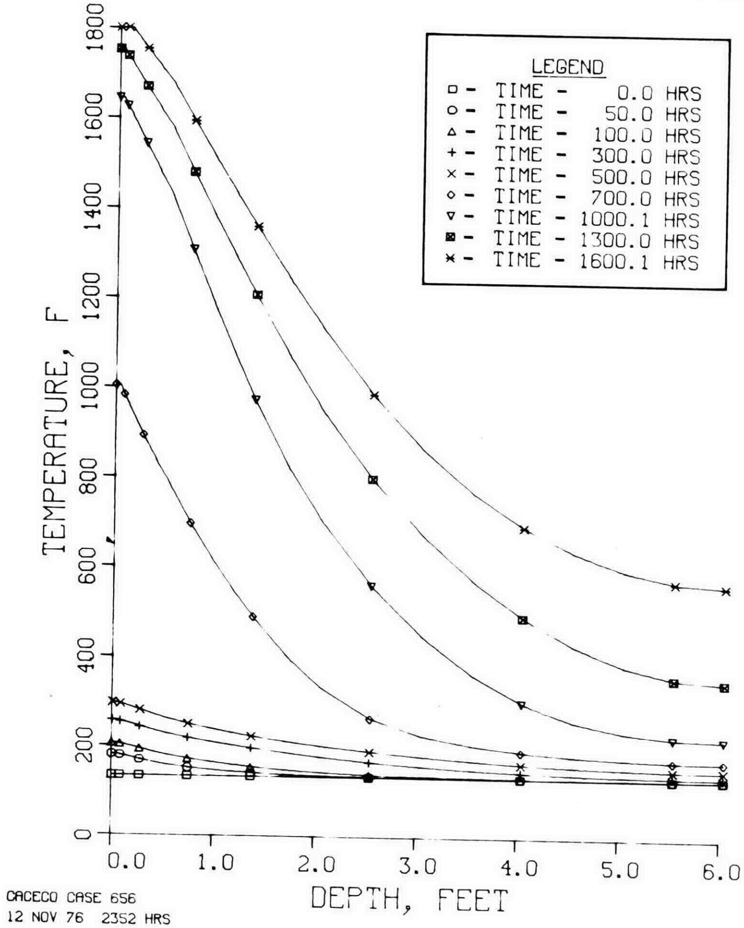


STRUCTURAL TEMPERATURES
CASE 656 CORE IN VESSEL, NO B.COOLER, NO H2+O2 R, VENT-PURGE
UP.16FT CAV.WALL. EFCO LINER+GAP+4FT MAG.CONCRETE. CAV. NT LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 656
12 NOV 76 2352 HRS

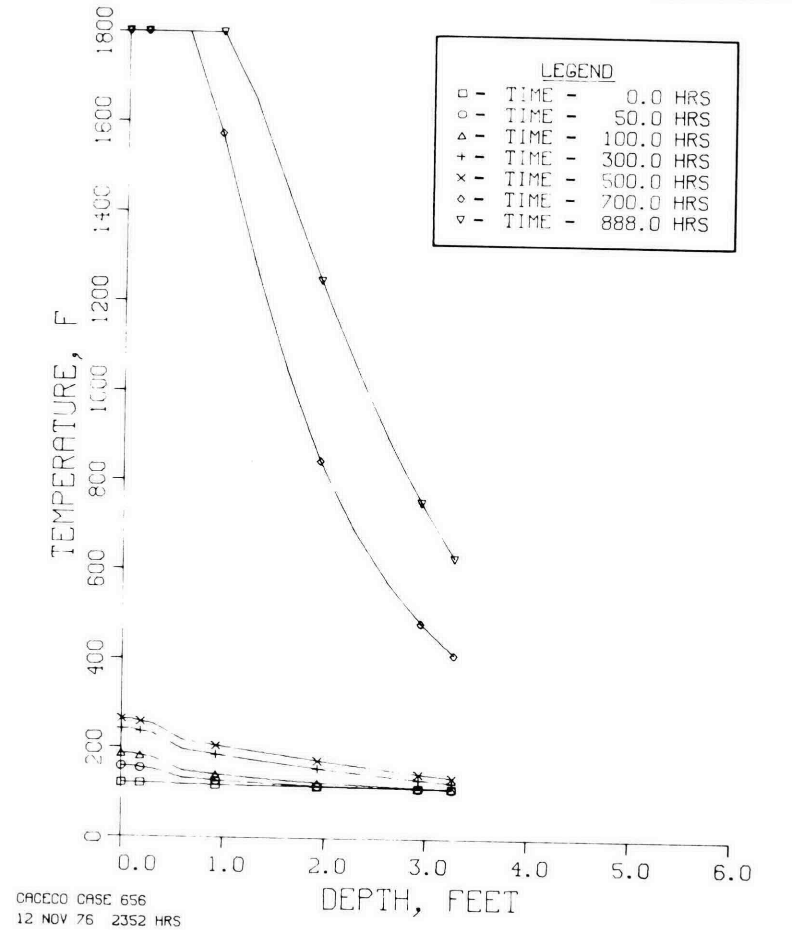


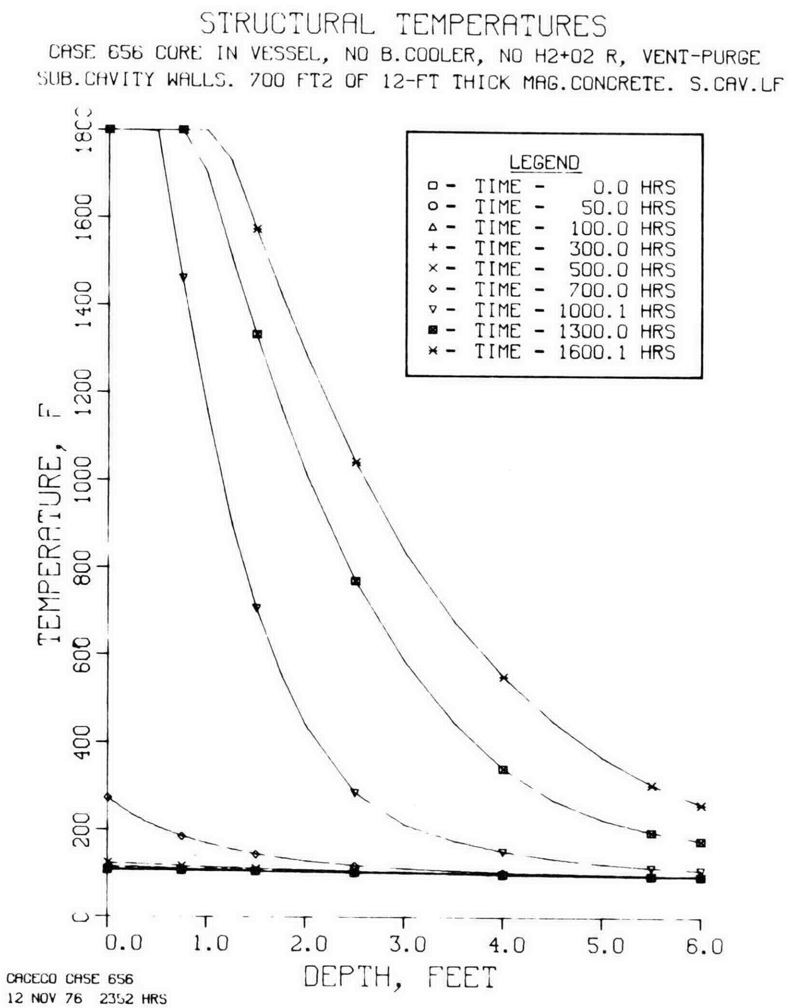
STRUCTURAL TEMPERATURES
CASE 656 CORE IN VESSEL, NO B.COOLER, NO H2+O2 R, VENT-PURGE
MID.16FT CAV.WALL. BECHTEL LINER+GAP+4.5FT MAG.CONCRETE. CAV.LFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 656
12 NOV 76 2352 HRS

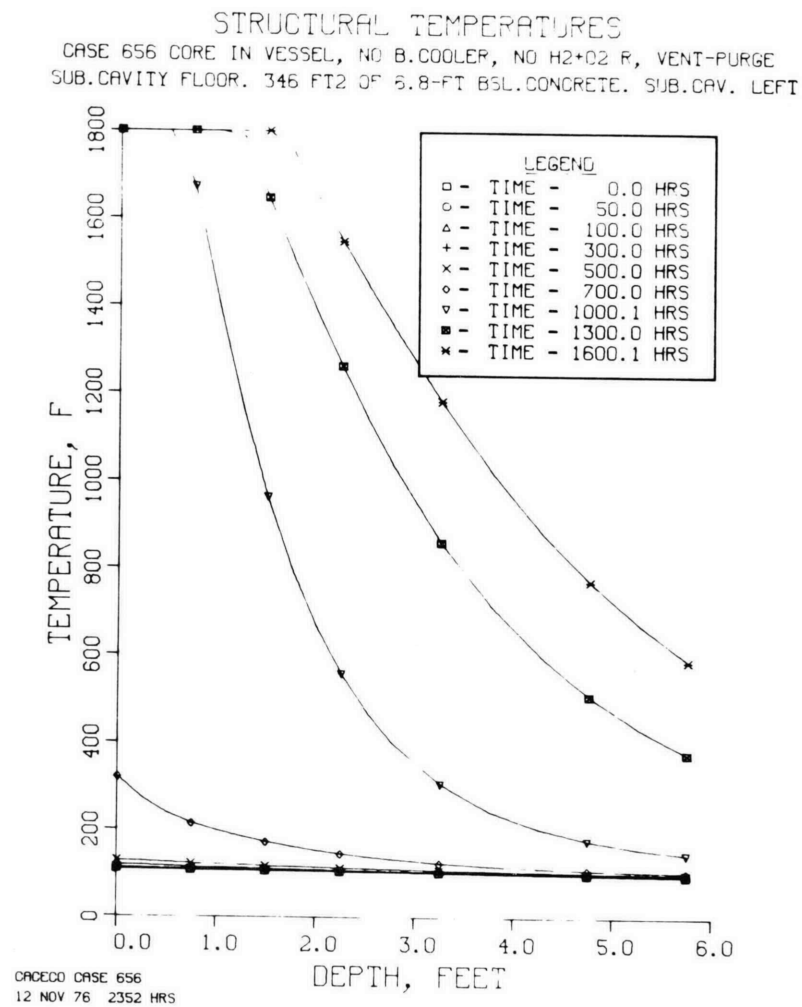
STRUCTURAL TEMPERATURES
CASE 656 CORE IN VESSEL, NO B.COOLER, NO H2+02 R, VENT-PURGE
LO.10FT WAL+OT.FLOR. HT.LINER+GAP+0.5FT.FIREBRICK+5.5FT MAG.CONC

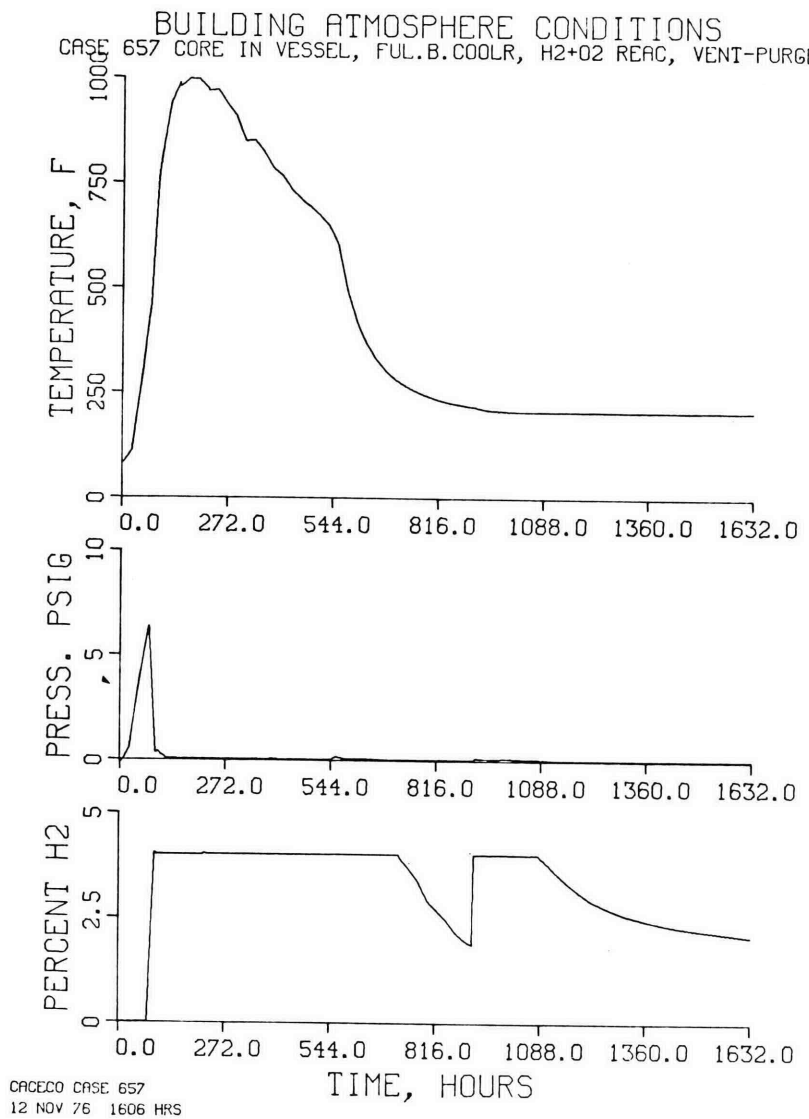


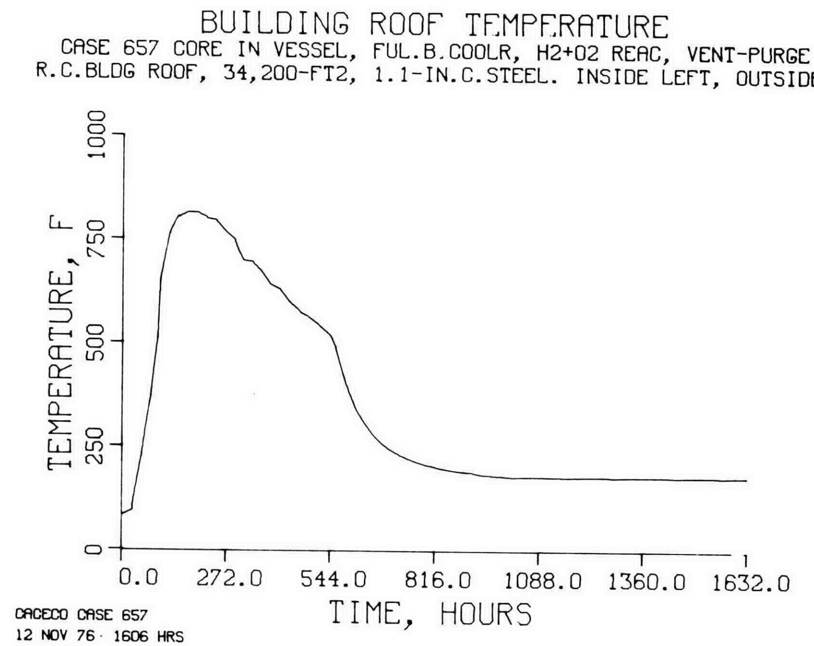
STRUCTURAL TEMPERATURES
CASE 656 CORE IN VESSEL, NO B.COOLER, NO H2+02 R, VENT-PURGE
CAV.FLOOR CENTER. 346FT2, LNR+F.BRK+I.BRK+32-IN.BSL.CONCRETE.

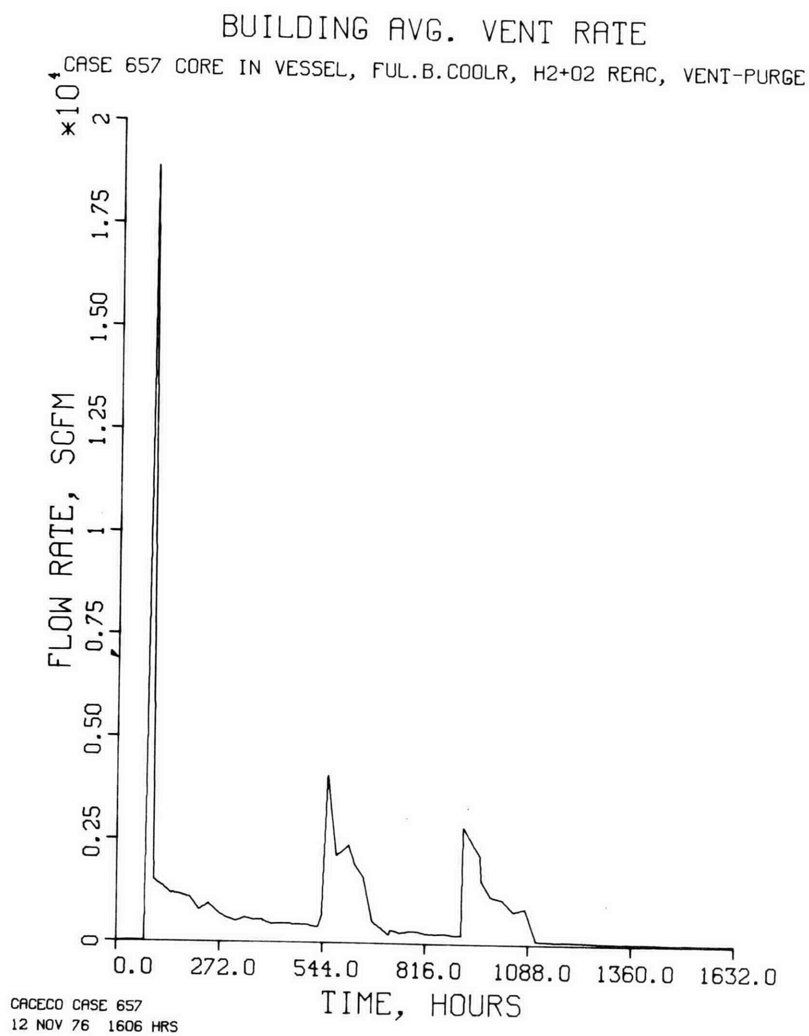


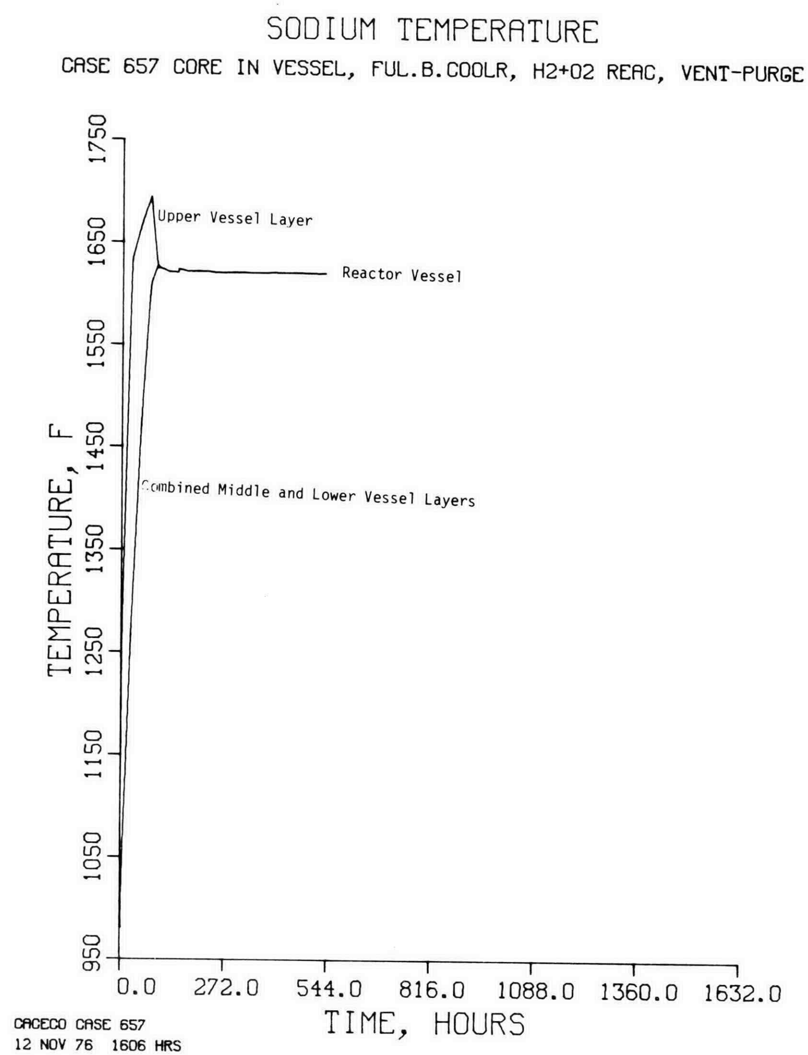

STRUCTURAL TEMPERATURES
CASE 656 CORE IN VESSEL, NO B.COOLER, NO H2+O2 R, VENT-PURGE
SUB.CAVITY WALLS. 700 FT2 OF 12-FT THICK MAG.CONCRETE. S.CAV.LF
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 656
12 NOV 76 2352 HRS


STRUCTURAL TEMPERATURES
CASE 656 CORE IN VESSEL, NO B.COOLER, NO H2+O2 R, VENT-PURGE
SUB.CAVITY FLOOR. 346 FT2 OF 6.8-FT BSL.CONCRETE. SUB.CAV. LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 656
12 NOV 76 2352 HRS


BUILDING ATMOSPHERE CONDITIONS
CASE 657 CORE IN VESSEL, FUL.B.COOLR, H2+02 REAC, VENT-PURGE
TEMPERATURE, F
1000
750
500
250
0
0.0 272.0 544.0 816.0 1088.0 1360.0 1632.0
PRESS. PSIG
10
5
0
0.0 272.0 544.0 816.0 1088.0 1360.0 1632.0
PERCENT H2
5
2.5
0
0.0 272.0 544.0 816.0 1088.0 1360.0 1632.0
TIME, HOURS
CACECO CASE 657
12 NOV 76 1606 HRS

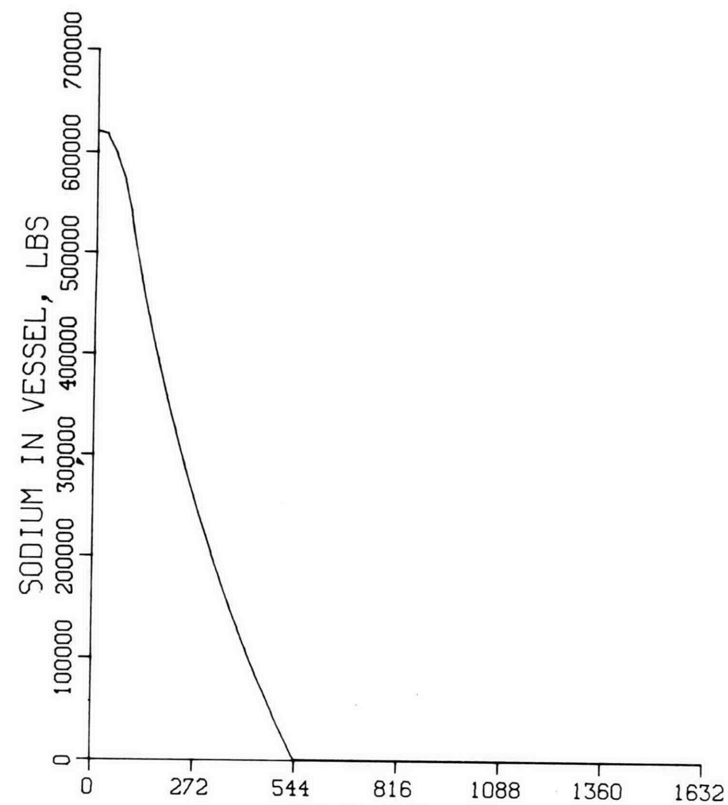

BUILDING ROOF TEMPERATURE
CASE 657 CORE IN VESSEL, FUL.B.COOLR, H2+02 REAC, VENT-PURGE
R.C.BLDG ROOF, 34,200-FT2, 1.1-IN.C.STEEL. INSIDE LEFT, OUTSIDE(
TEMPERATURE, F
1000
750
500
250
0
0.0 272.0 544.0 816.0 1088.0 1360.0 1632.0
TIME, HOURS
CACECO CASE 657
12 NOV 76 1606 HRS


BUILDING AVG. VENT RATE
CASE 657 CORE IN VESSEL, FUL.B.COOLR, H2+02 REAC, VENT-PURGE
*10⁴
FLOW RATE, SCFM
0
0.25
0.50
0.75
1
1.25
1.50
1.75
2
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 657
12 NOV 76 1606 HRS


SODIUM TEMPERATURE
CASE 657 CORE IN VESSEL, FUL.B.COOLR, H2+02 REAC, VENT-PURGE
TEMPERATURE, F
950
1050
1150
1250
1350
1450
1550
1650
1750
Upper Vessel Layer
Reactor Vessel
Combined Middle and Lower Vessel Layers
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 657
12 NOV 76 1606 HRS

SODIUM INVENTORY

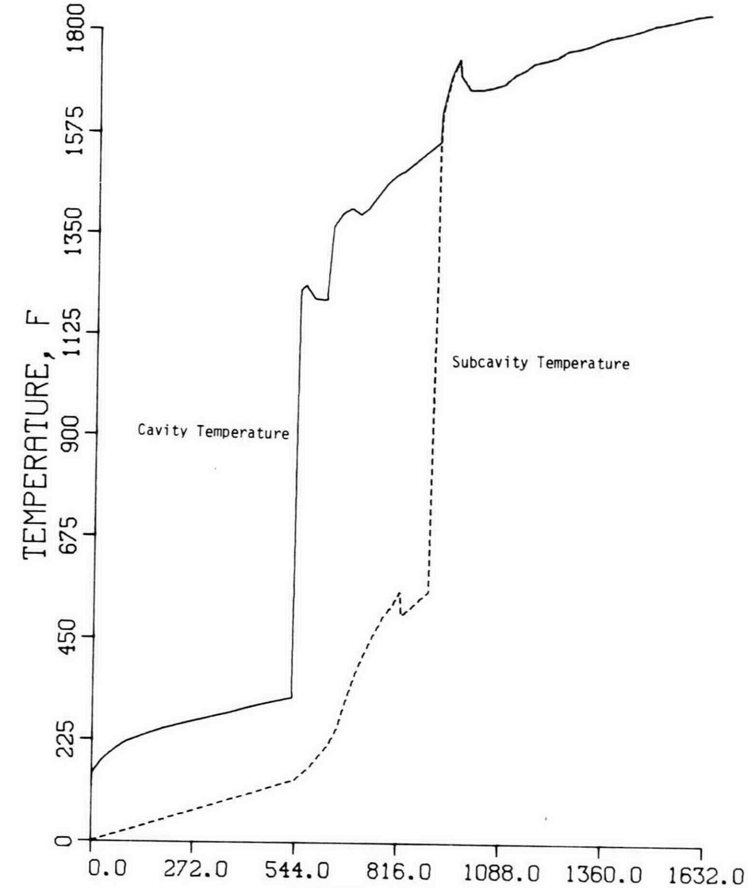
CASE 657 CORE IN VESSEL, FUL.B.COOLR, H2+02 REAC, VENT-PURGE



CACECO CASE 657
12 NOV 76 1606 HRS

CAVITY ATMOSPHERE TEMPERATURES

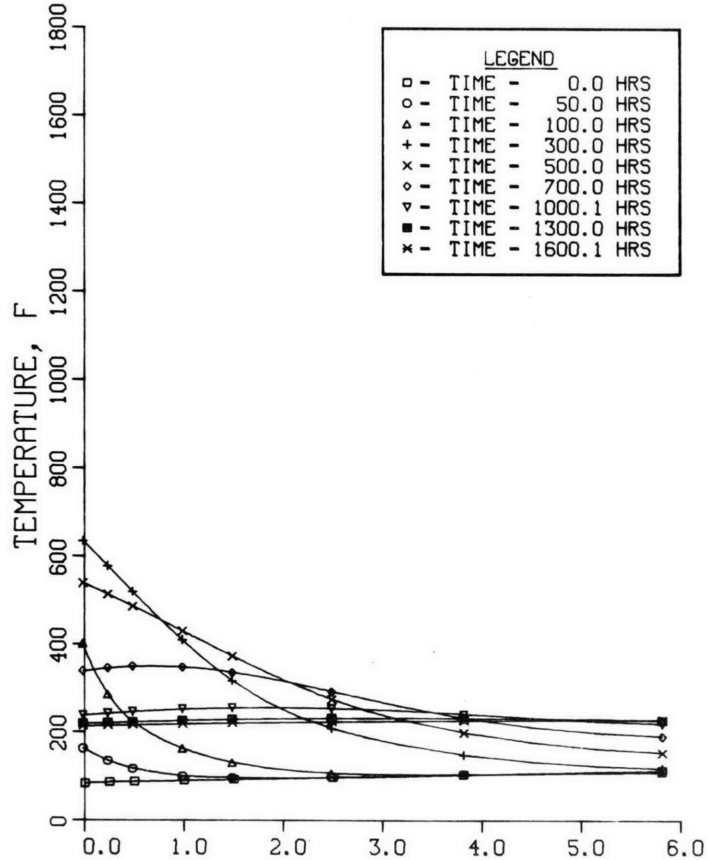
CASE 657 CORE IN VESSEL, FUL.B.COOLR, H2+02 REAC, VENT-PURGE



CACECO CASE 657
12 NOV 76 1606 HRS

STRUCTURAL TEMPERATURES

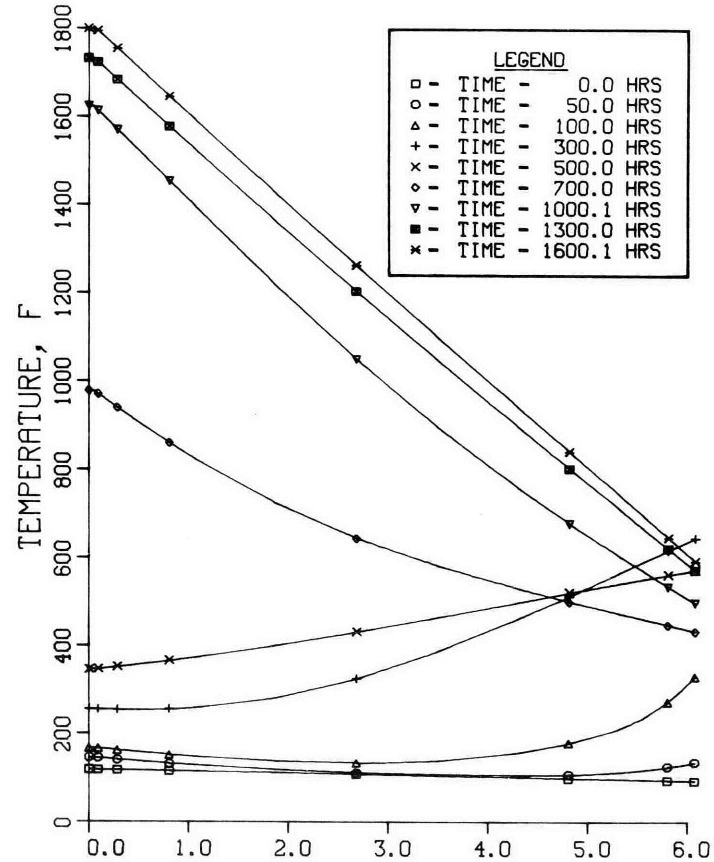
CASE 657 CORE IN VESSEL, FUL.B.COOLR, H2+02 REAC, VENT-PURGE
R.C.BLDG FLOOR. 13,000-FT2, EPOXY+6.5-FT.MAG.CONCRETE. BLDG LEFT



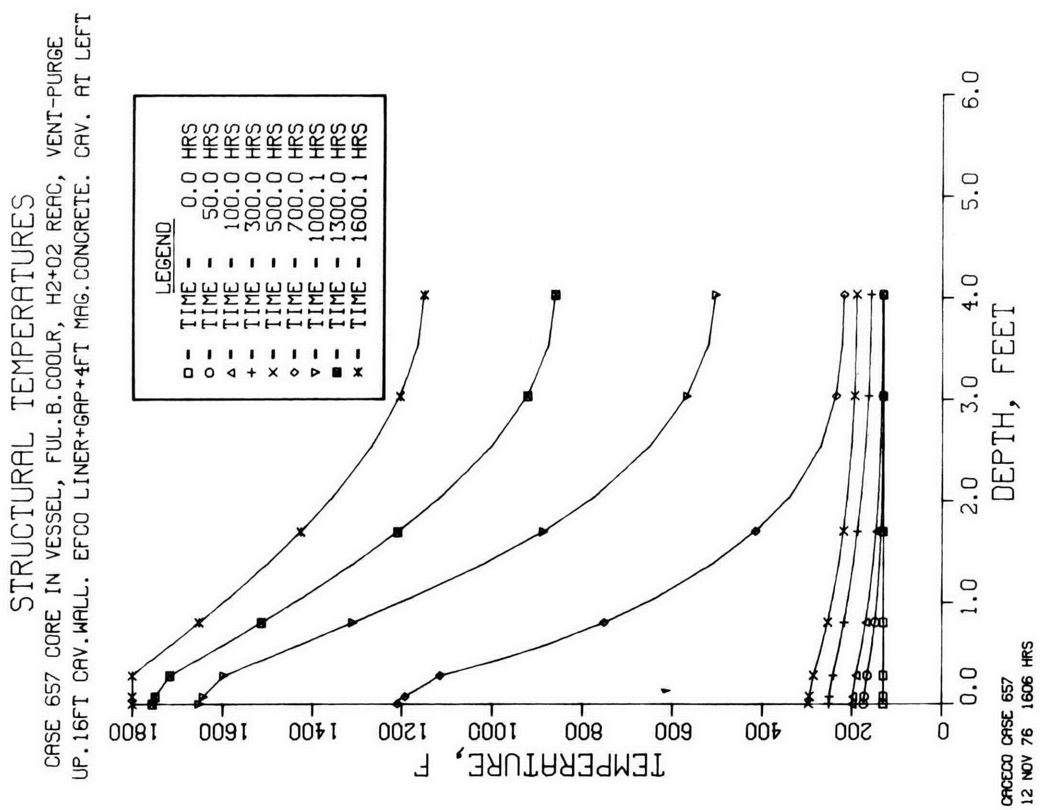
CACECO CASE 657
12 NOV 76 1606 HRS

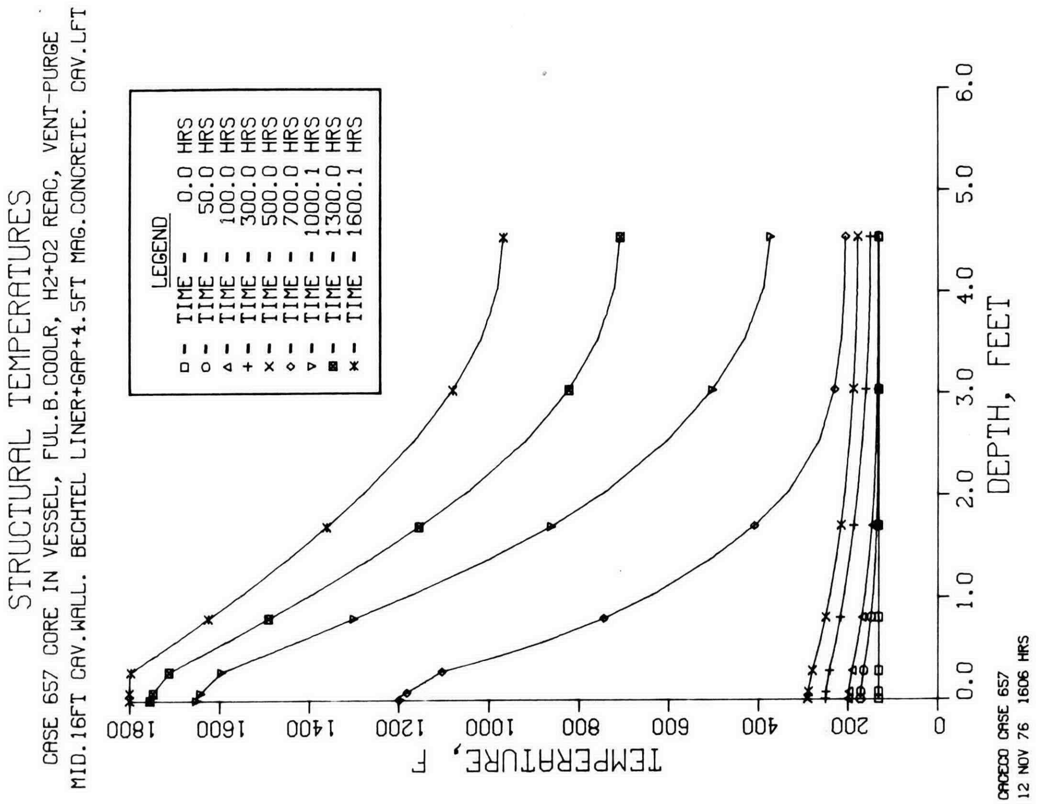
STRUCTURAL TEMPERATURES

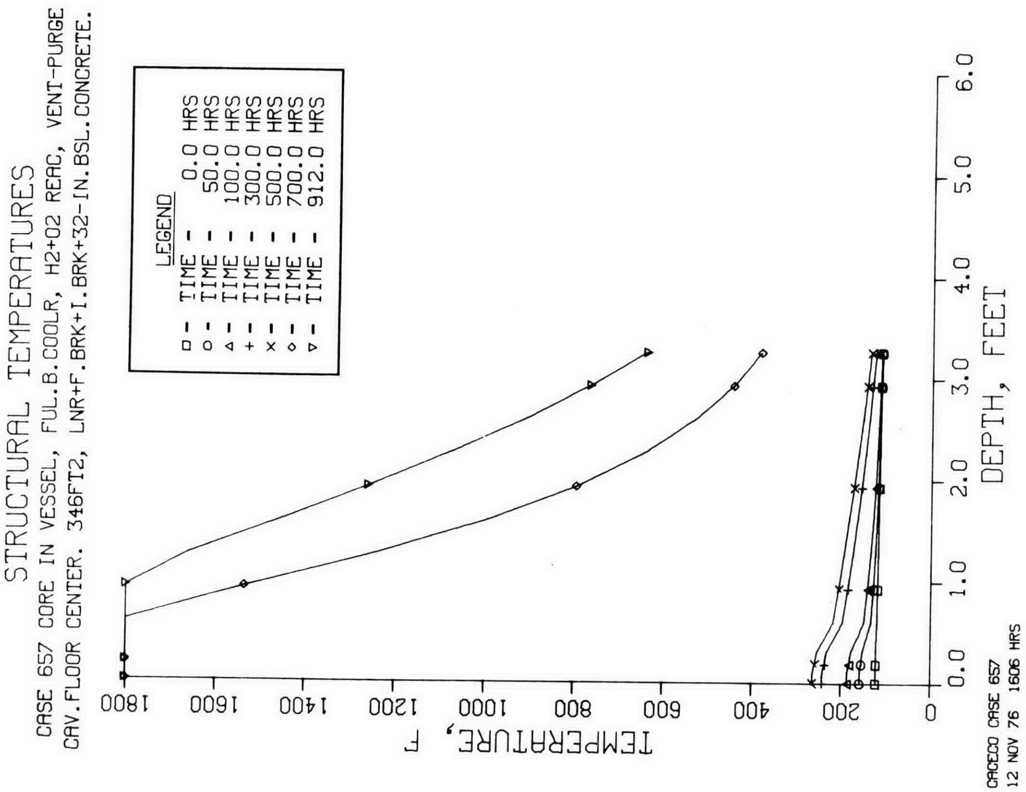
CASE 657 CORE IN VESSEL, FUL.B.COOLR, H2+02 REAC, VENT-PURGE
CAVITY ROOF. BECHTEL LINER+6.25FT STEEL+MAG.CONCRETE. CAV. LEFT



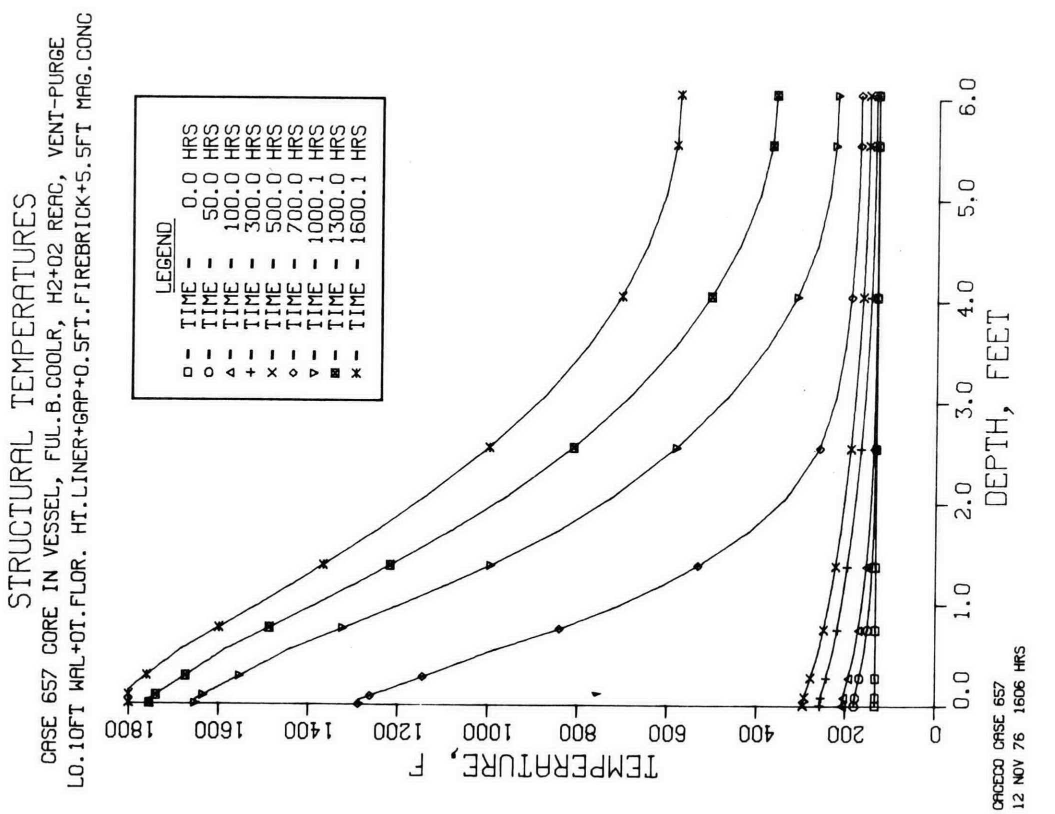
CACECO CASE 657
12 NOV 76 1606 HRS


STRUCTURAL TEMPERATURES
CASE 657 CORE IN VESSEL, FUL.B.COOLR, H2+02 REAC, VENT-PURGE
UP.16FT CAV.WALL. EFCO LINER+GAP+4FT MAG.CONCRETE. CAV. AT LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 657
12 NOV 76 1606 HRS


STRUCTURAL TEMPERATURES
CASE 657 CORE IN VESSEL, FUL.B.COOLR, H2+02 REAC, VENT-PURGE
MID.16FT CAV.WALL. BECHTEL LINER+GAP+4.5FT MAG.CONCRETE. CAV.LFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 657
12 NOV 76 1606 HRS



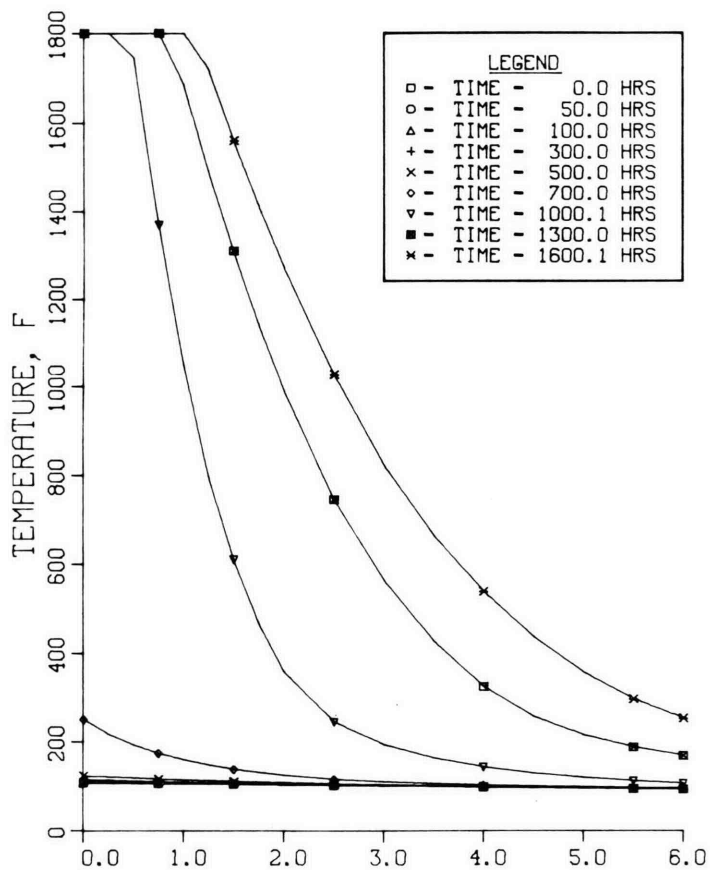
STRUCTURAL TEMPERATURES
CASE 657 CORE IN VESSEL, FUL.B.COOLR, H2+O2 REAC, VENT-PURGE
CAV.FLOOR CENTER. 346FT2, LNR+F.BRK+I.BRK+32-IN.BSL.CONCRETE.
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 912.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 657
12 NOV 76 1606 HRS



STRUCTURAL TEMPERATURES
CASE 657 CORE IN VESSEL, FUL.B.COOLR, H2+O2 REAC, VENT-PURGE
LO.10FT WAL+OT.FLOR. HT.LINER+GAP+0.5FT.FIREBRICK+5.5FT MAG.CONC
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.1 HRS
⊠ - TIME - 1300.0 HRS
✱ - TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 657
12 NOV 76 1606 HRS

STRUCTURAL TEMPERATURES

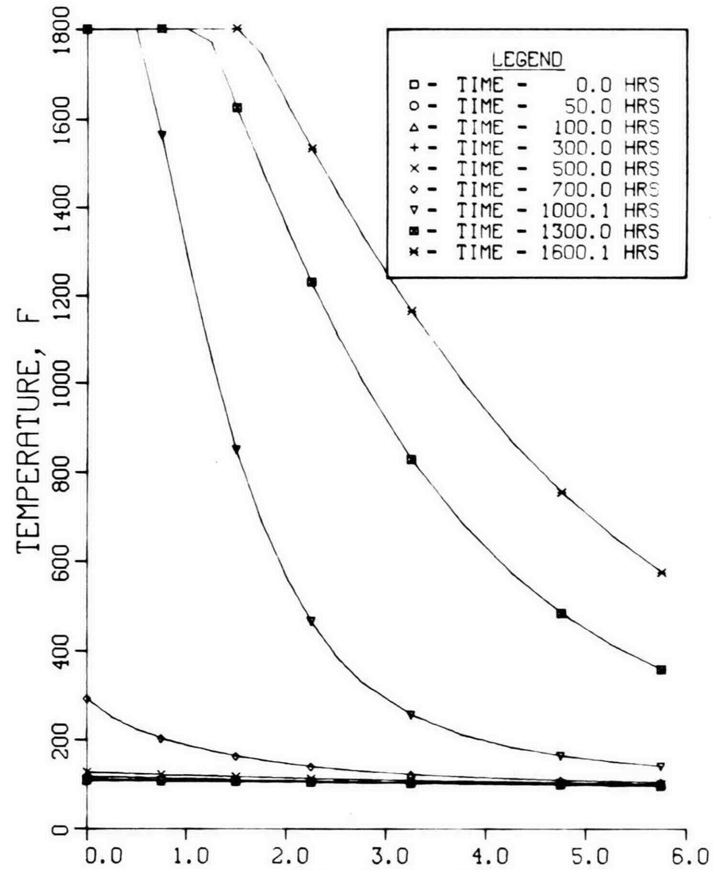
CASE 657 CORE IN VESSEL, FUL.B.COOLR, H2+O2 REAC, VENT-PURGE
SUB.CAVITY WALLS. 700 FT2 OF 12-FT THICK MAG.CONCRETE. S.CAV.LF



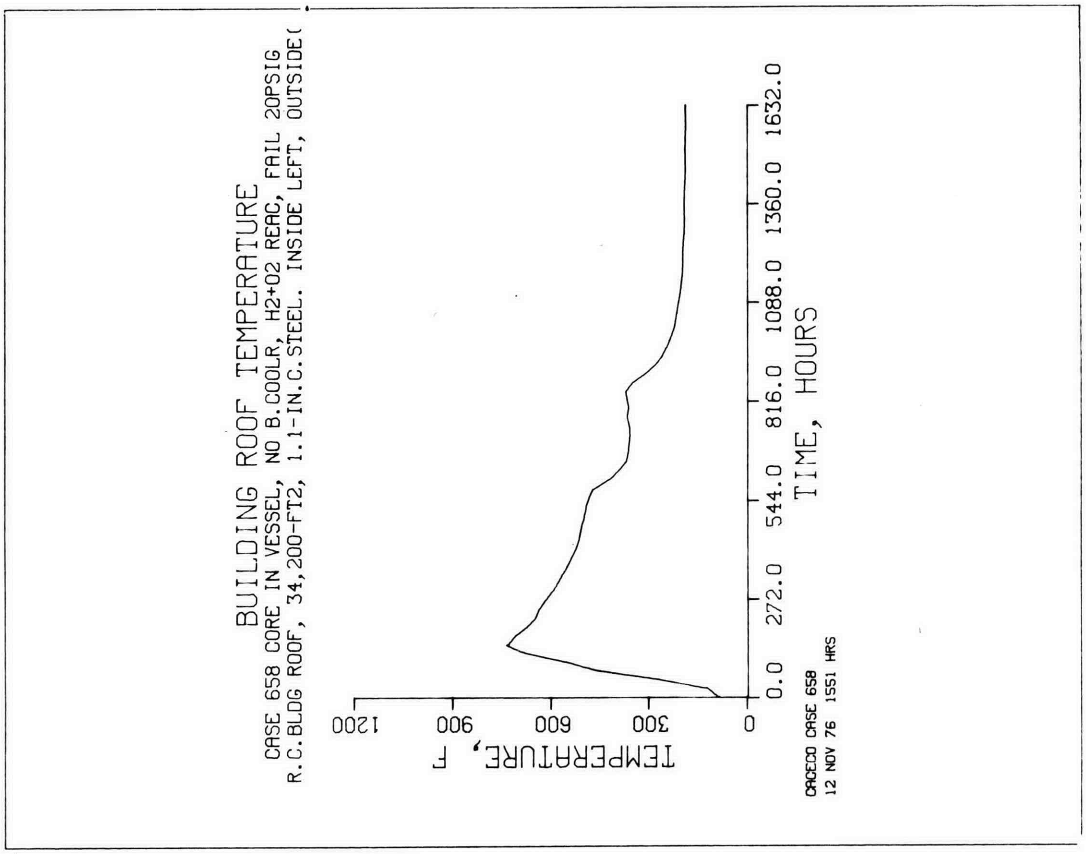
CACECO CASE 657
12 NOV 76 1606 HRS

STRUCTURAL TEMPERATURES

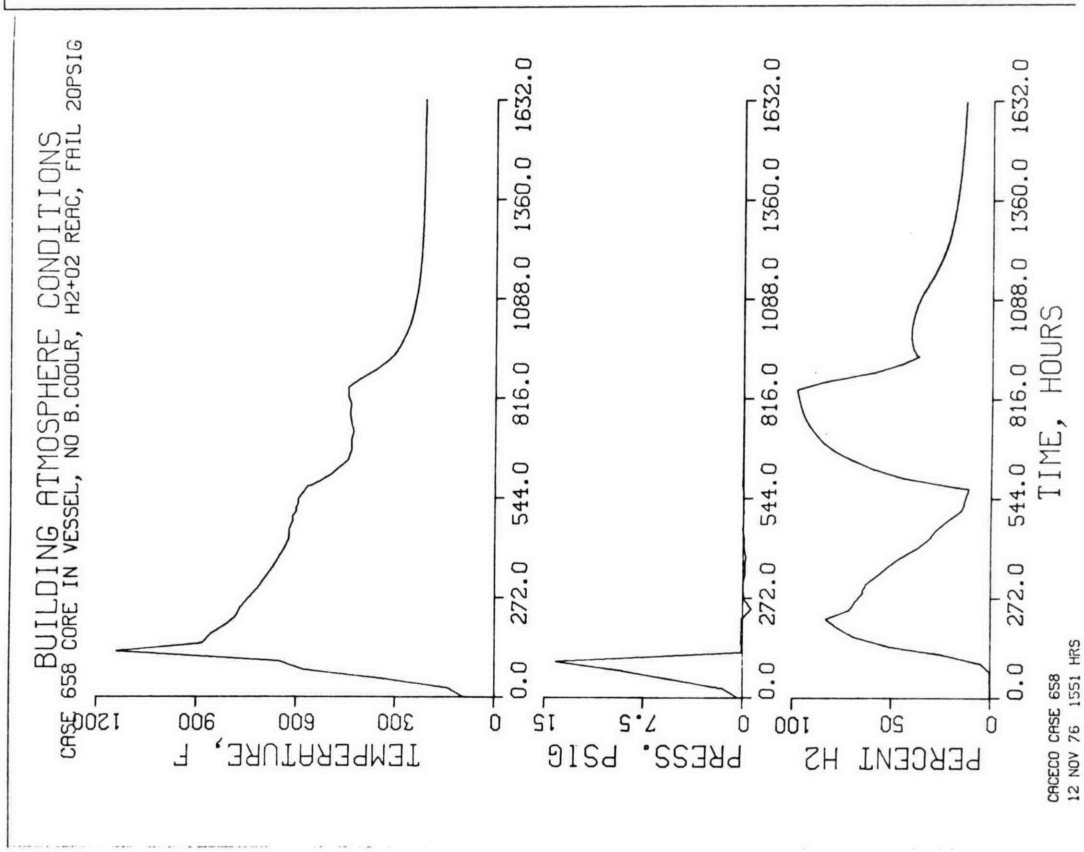
CASE 657 CORE IN VESSEL, FUL.B.COOLR, H2+O2 REAC, VENT-PURGE
SUB.CAVITY FLOOR. 346 FT2 OF 6.8-FT BSL.CONCRETE. SUB.CAV. LEFT



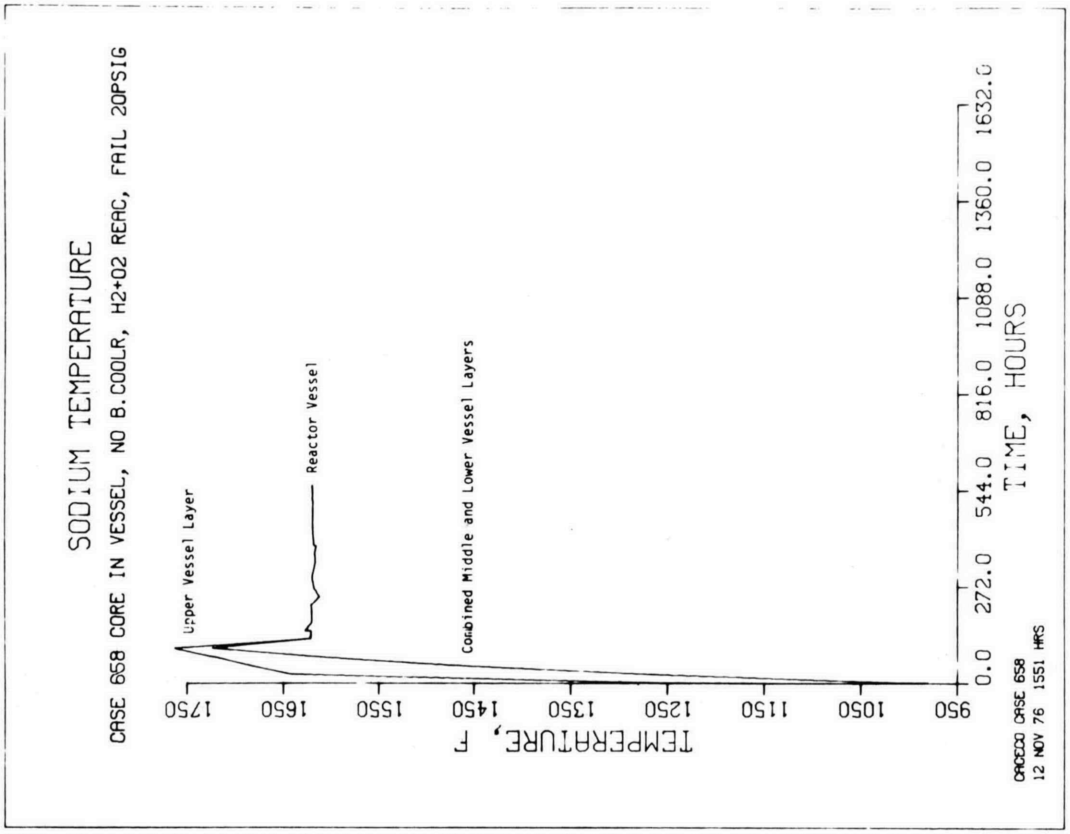
CACECO CASE 657
12 NOV 76 1606 HRS

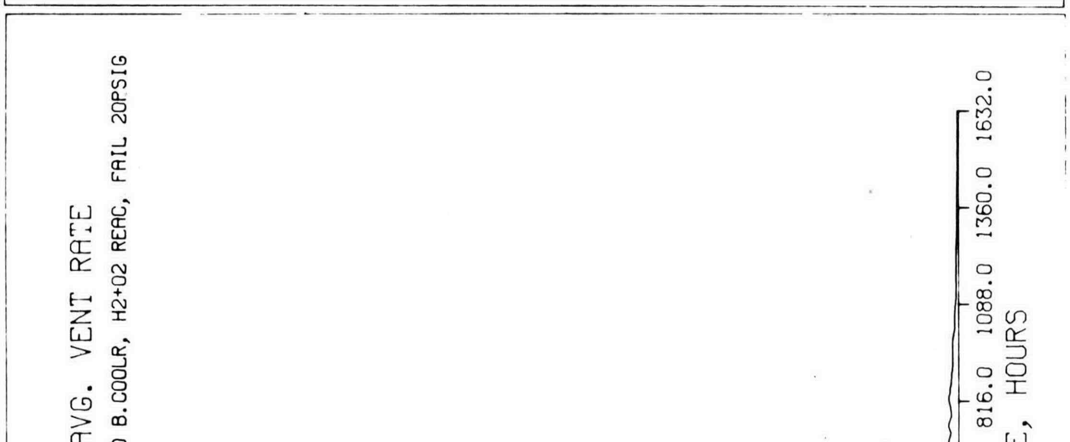


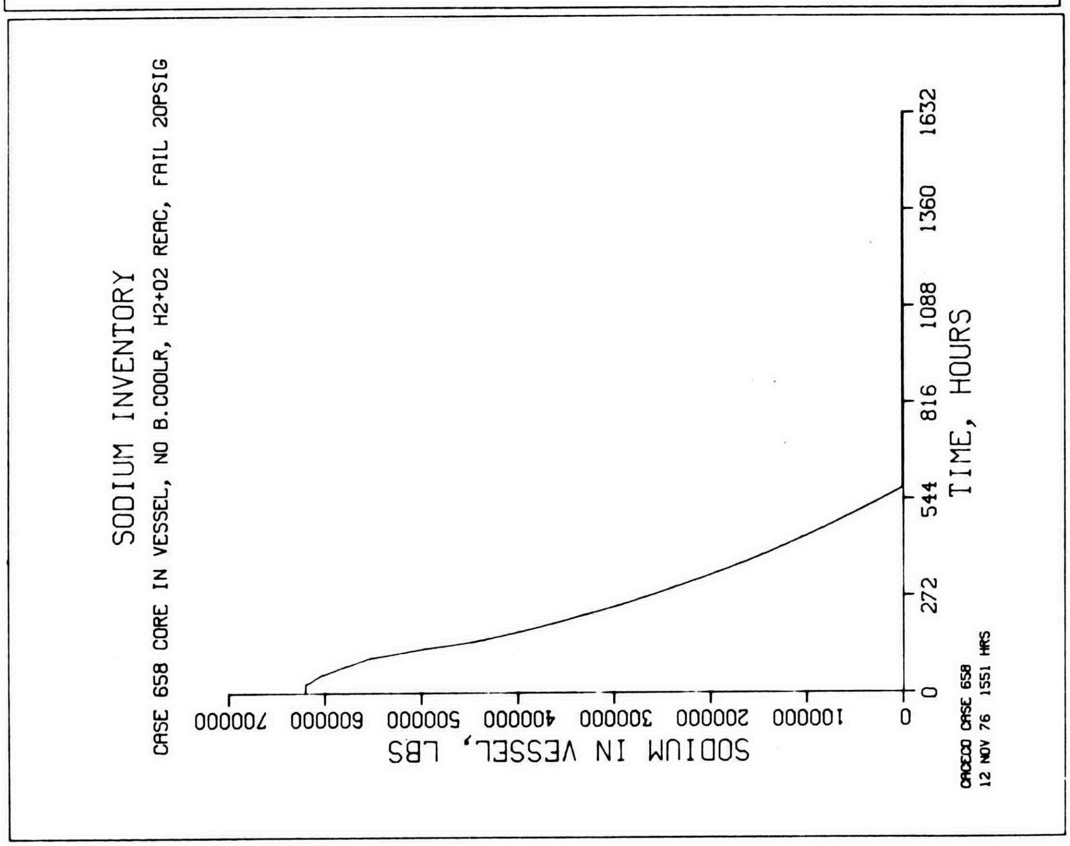
BUILDING ROOF TEMPERATURE
CASE 658 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, FAIL 20PSIG
R.C.BLDG ROOF, 34,200-FT2, 1.1-IN.C.STEEL. INSIDE LEFT, OUTSIDE(
TEMPERATURE, F
0
300
600
900
1200
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 658
12 NOV 76 1551 HRS

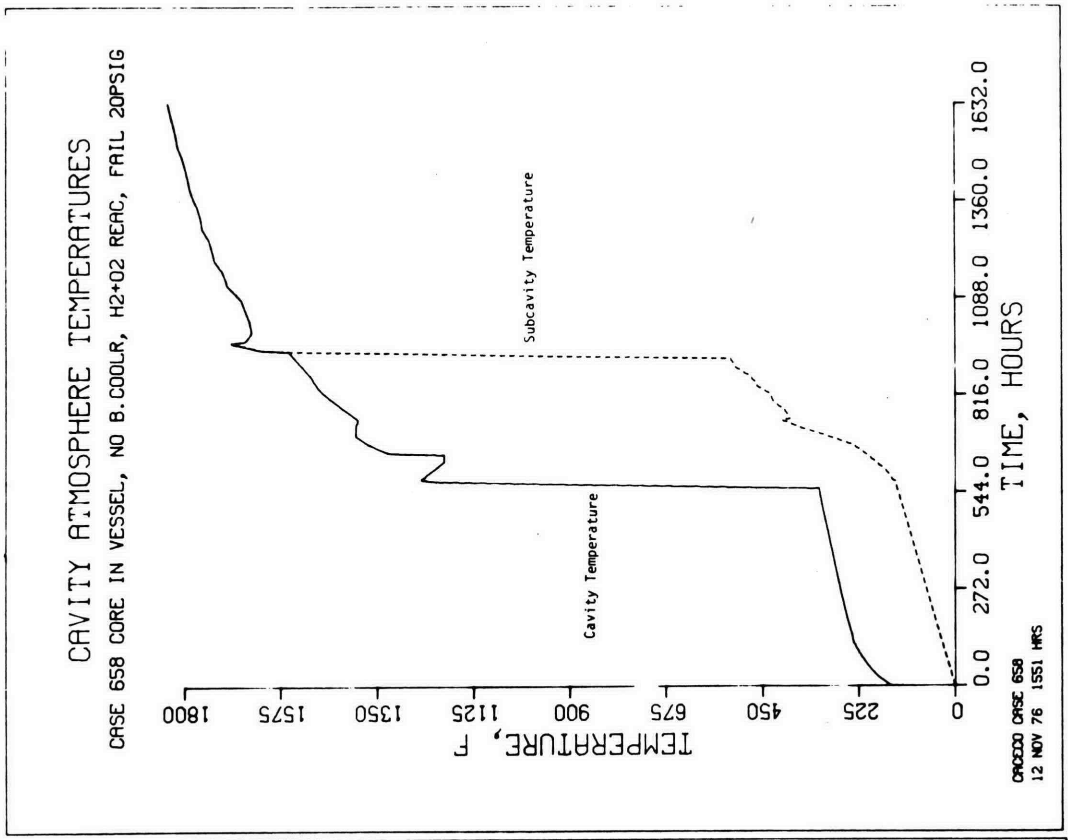


BUILDING ATMOSPHERE CONDITIONS
CASE 658 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, FAIL 20PSIG
TEMPERATURE, F
0
300
600
900
1200
PRESS. PSIG
0
7.5
15
PERCENT H2
0
50
100
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 658
12 NOV 76 1551 HRS


SODIUM TEMPERATURE
CASE 658 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, FAIL 20PSIG
Upper Vessel Layer
Reactor Vessel
Combined Middle and Lower Vessel Layers
TEMPERATURE, F
950
1050
1150
1250
1350
1450
1550
1650
1750
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 658
12 NOV 76 1551 HRS


BUILDING AVG. VENT RATE
CASE 658 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, FAIL 20PSIG
FLOW RATE, SCFM
0
4000
8000
12000
16000
20000
24000
28000
32000
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 658
12 NOV 76 1551 HRS

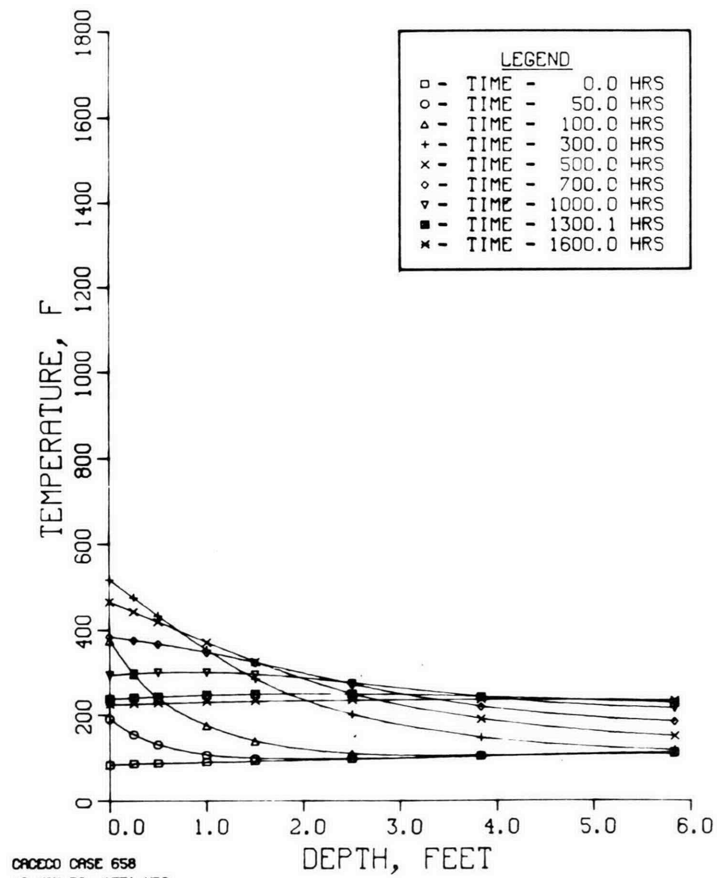

SODIUM INVENTORY
CASE 658 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, FAIL 20PSIG
SODIUM IN VESSEL, LBS
0
100000
200000
300000
400000
500000
600000
700000
0
272
544
816
1088
1360
1632
TIME, HOURS
CACECO CASE 658
12 NOV 76 1551 HRS


CAVITY ATMOSPHERE TEMPERATURES
CASE 658 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, FAIL 20PSIG
TEMPERATURE, F
0
225
450
675
900
1125
1350
1575
1800
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
Cavity Temperature
Subcavity Temperature
CACECO CASE 658
12 NOV 76 1551 HRS

STRUCTURAL TEMPERATURES

CASE 658 CORE IN VESSEL, NO B.COOLR, H2+02 REAC, FAIL 20PSIG

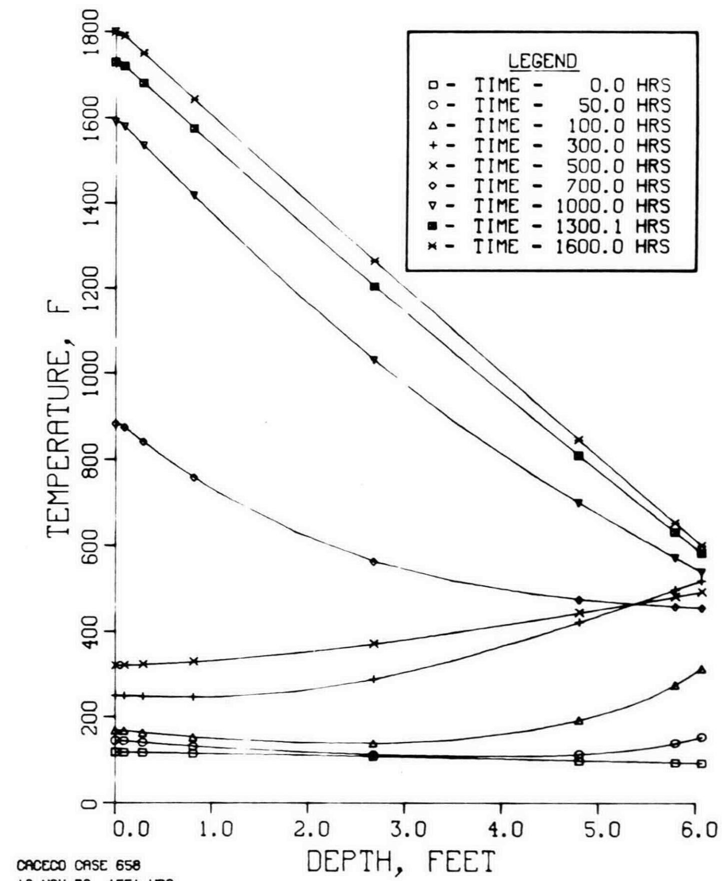
R.C.BLDG FLOOR. 13,000-FT2, EPOXY+6.5-FT.MAG.CONCRETE. BLDG LEFT

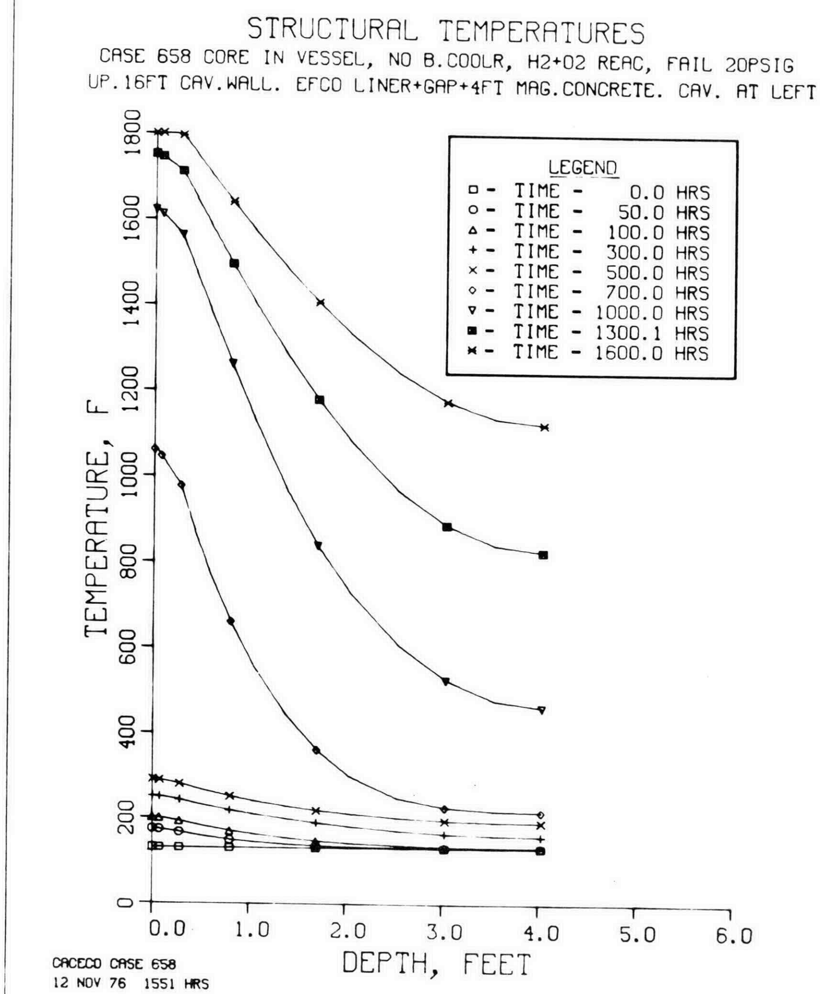


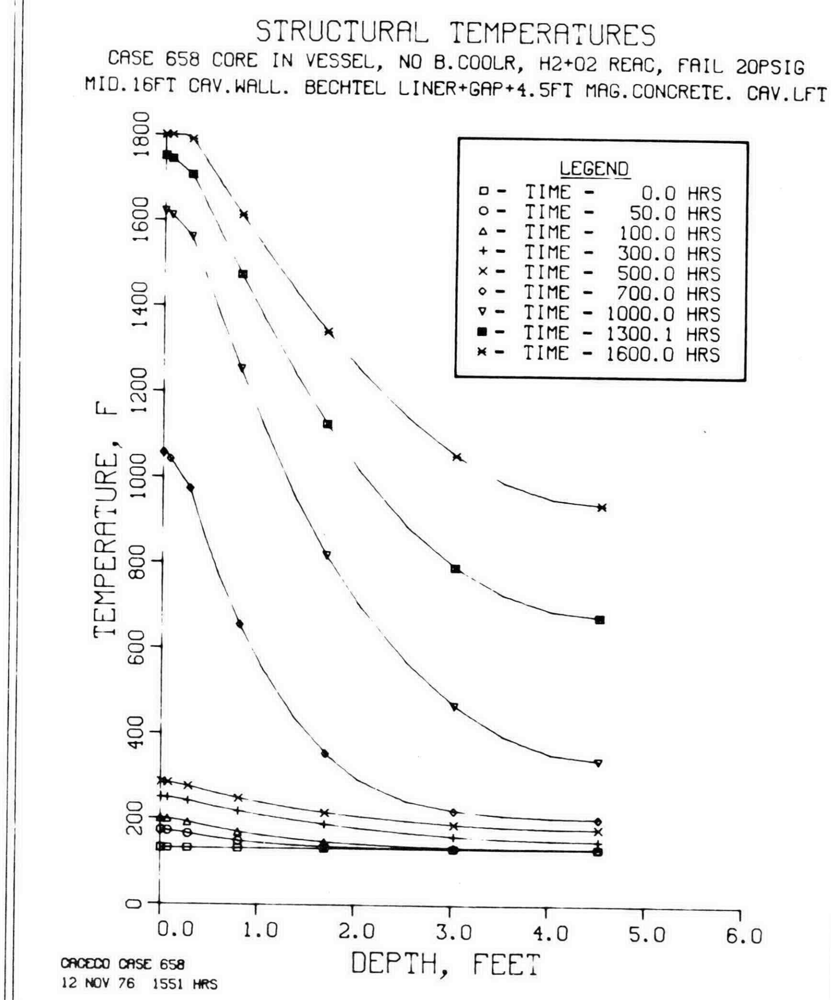
STRUCTURAL TEMPERATURES

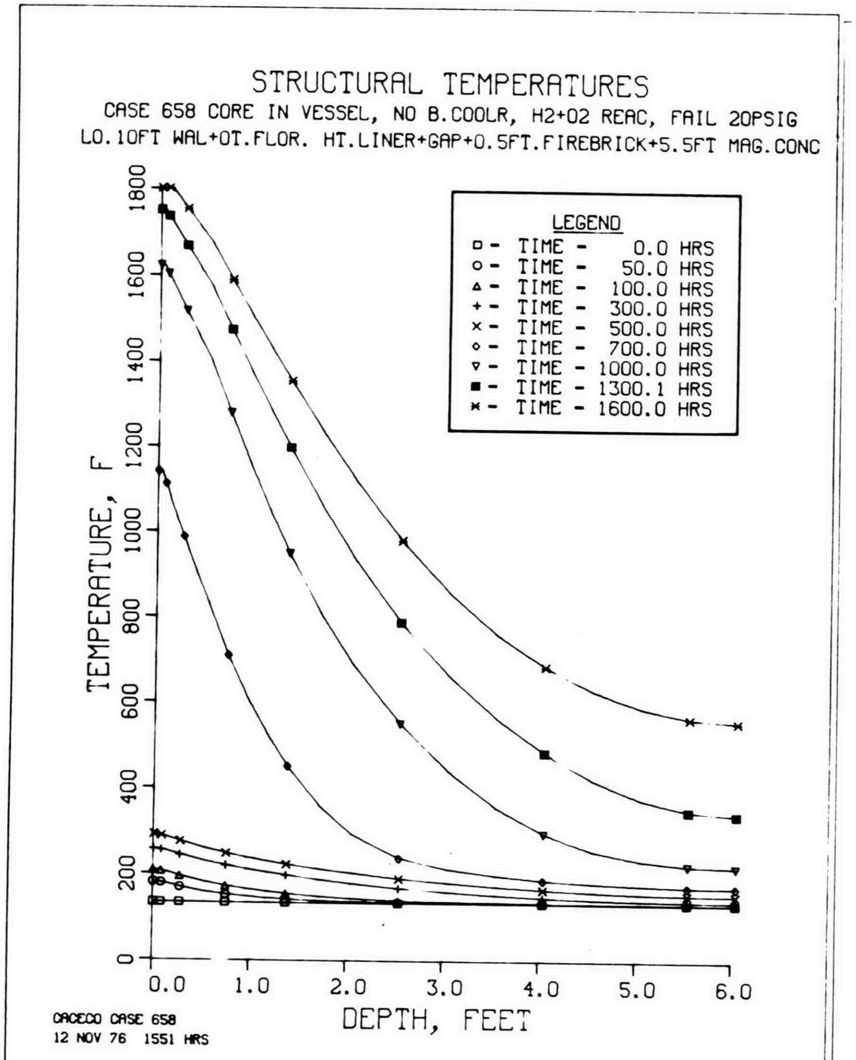
CASE 658 CORE IN VESSEL, NO B.COOLR, H2+02 REAC, FAIL 20PSIG

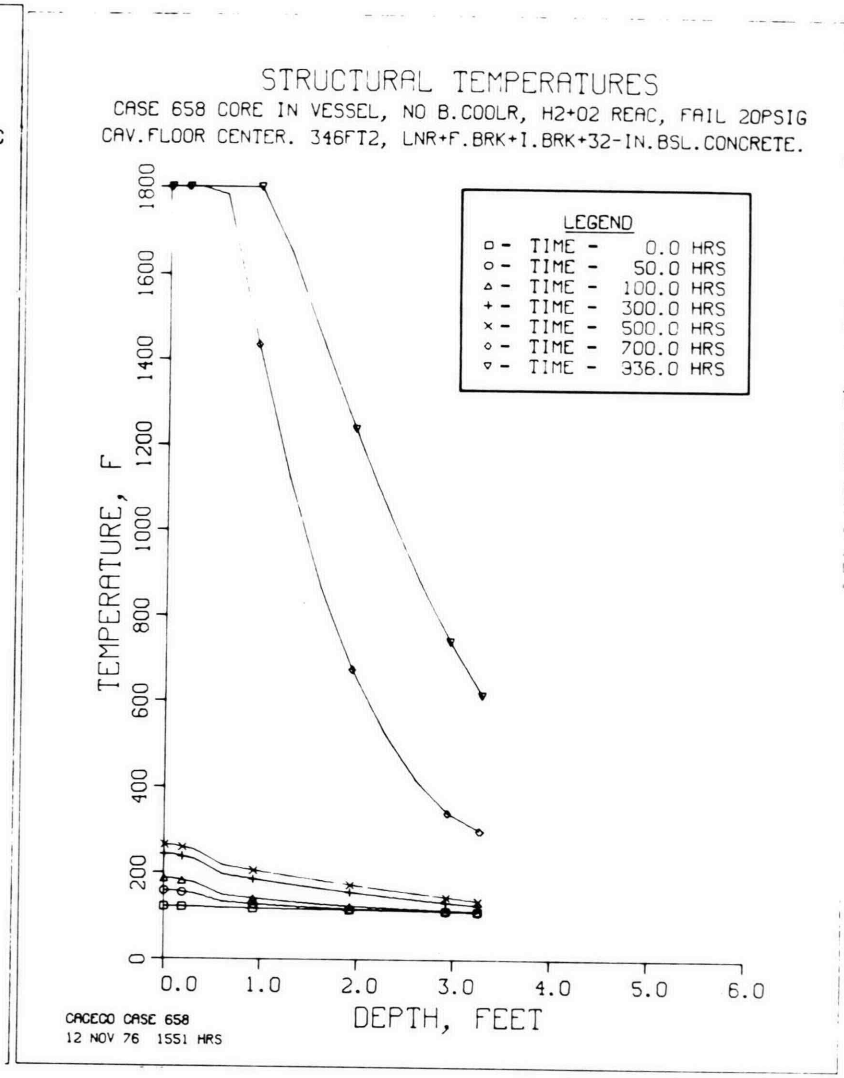
CAVITY ROOF. BECHTEL LINER+6.25FT STEEL+MAG.CONCRETE. CAV. LEFT

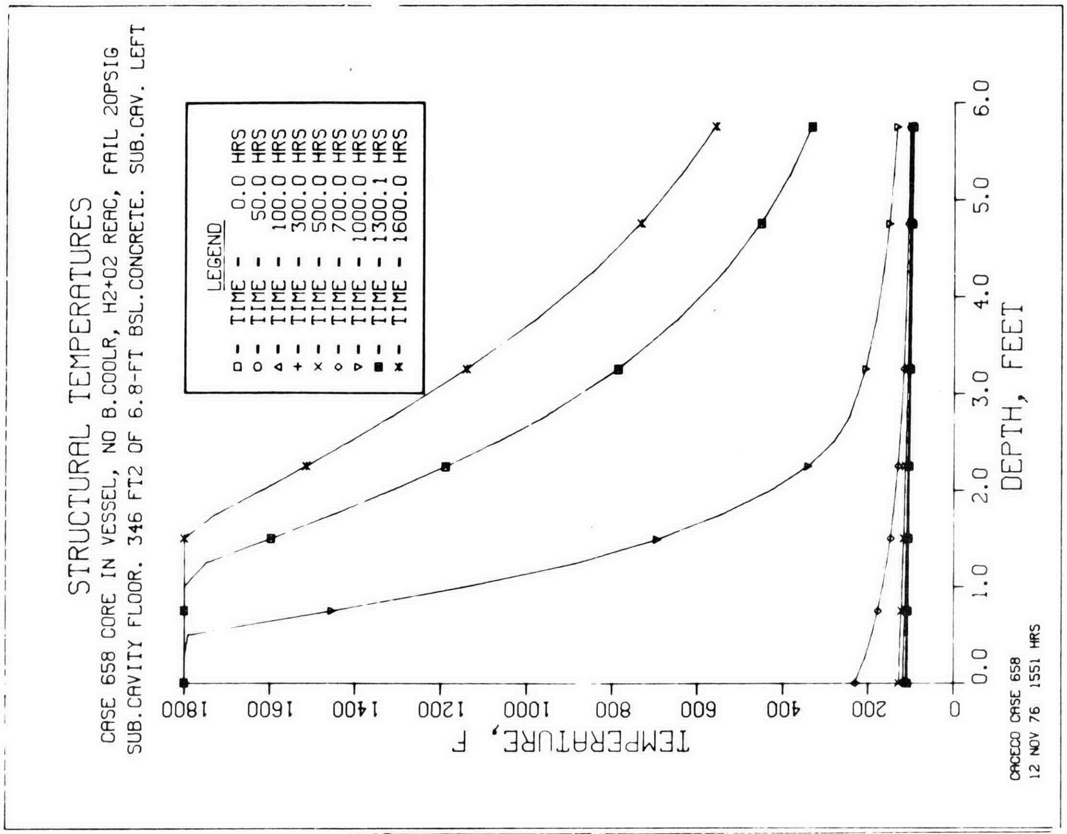


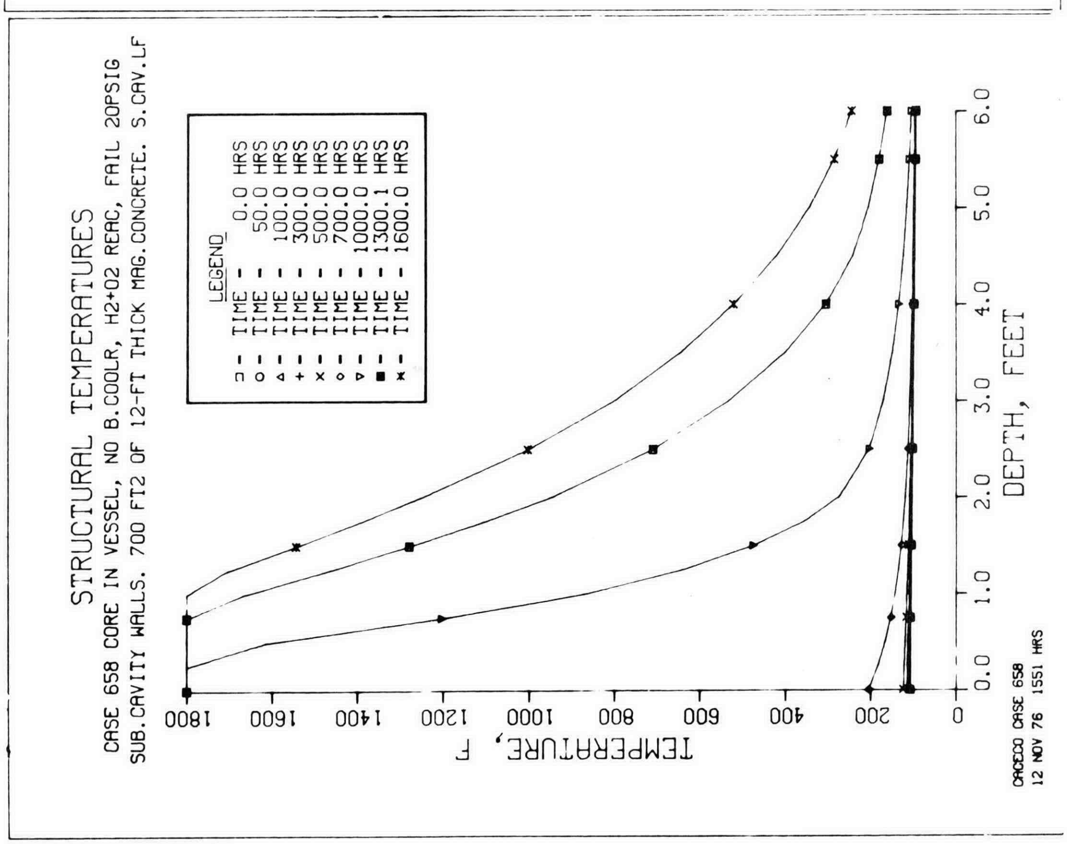

STRUCTURAL TEMPERATURES
CASE 658 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, FAIL 20PSIG
UP.16FT CAV.WALL. EFCO LINER+GAP+4FT MAG.CONCRETE. CAV. AT LEFT
TEMPERATURE, F
DEPTH, FEET
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✕ - TIME - 1600.0 HRS
CACECO CASE 658
12 NOV 76 1551 HRS

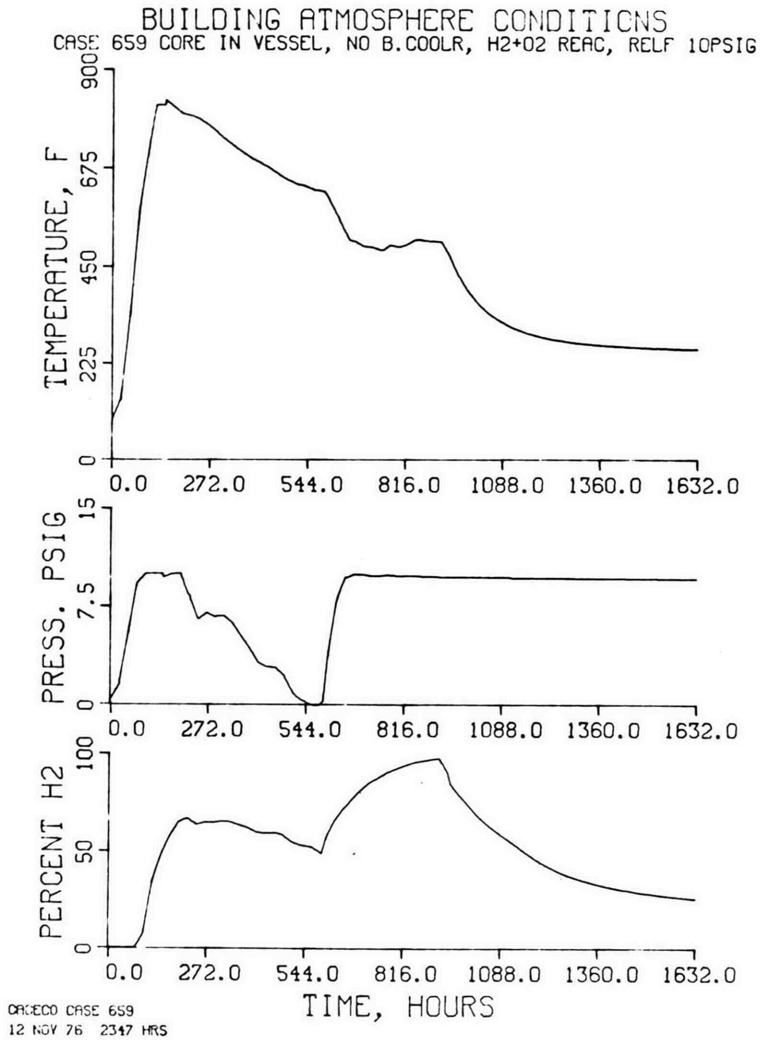

STRUCTURAL TEMPERATURES
CASE 658 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, FAIL 20PSIG
MID.16FT CAV.WALL. BECHTEL LINER+GAP+4.5FT MAG.CONCRETE. CAV.LFT
TEMPERATURE, F
DEPTH, FEET
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✕ - TIME - 1600.0 HRS
CACECO CASE 658
12 NOV 76 1551 HRS

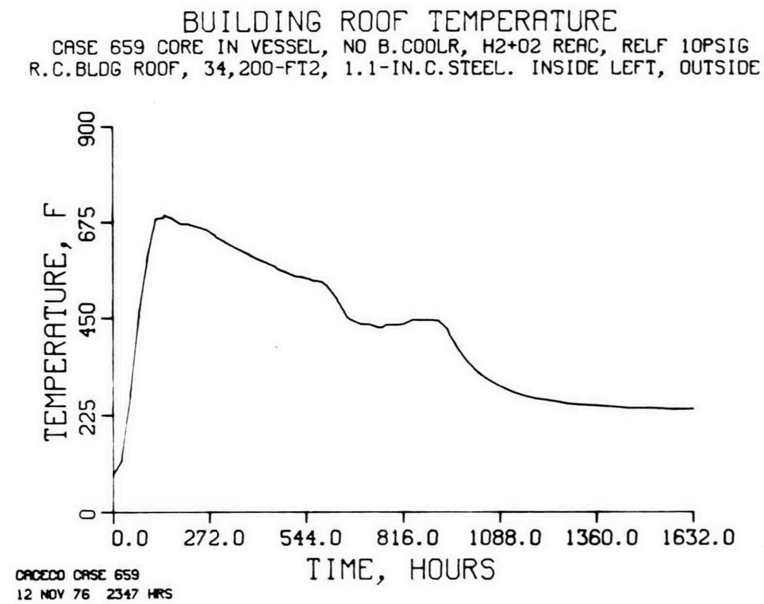

STRUCTURAL TEMPERATURES
CASE 658 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, FAIL 20PSIG
LO.10FT WAL+OT.FLOR. HT.LINER+GAP+0.5FT.FIREBRICK+5.5FT MAG.CONC
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 658
12 NOV 76 1551 HRS

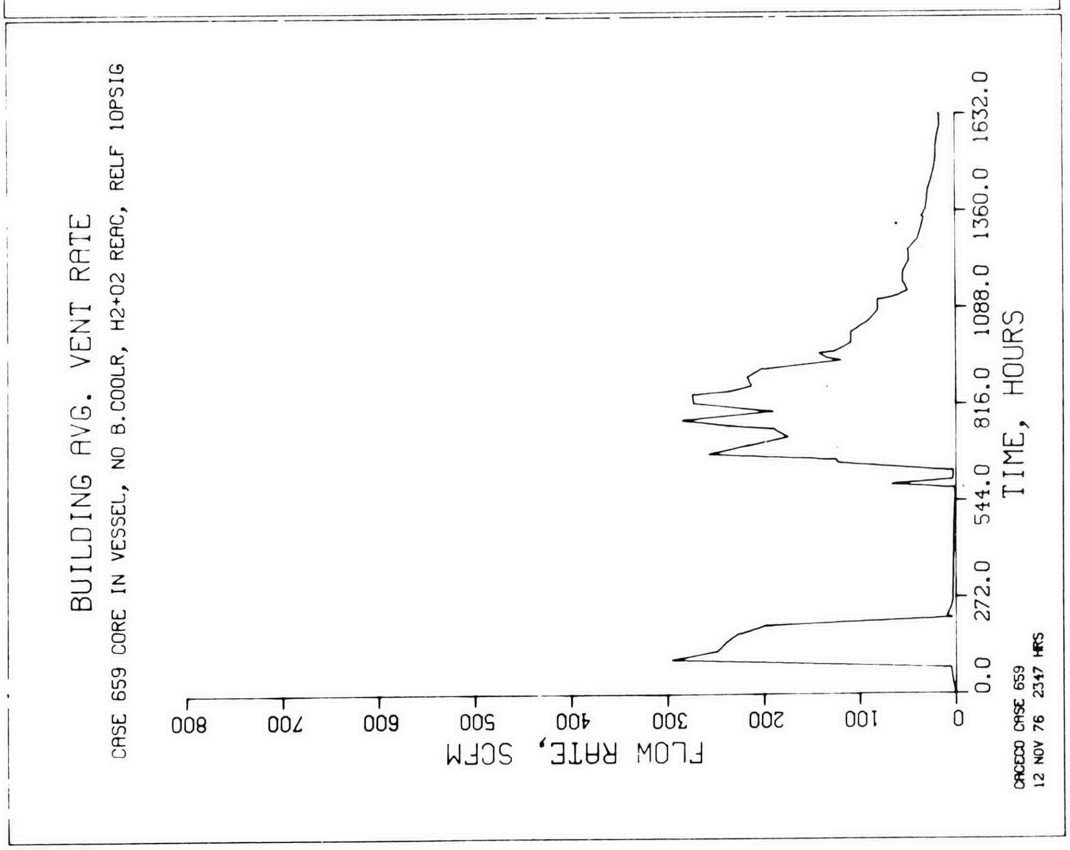

STRUCTURAL TEMPERATURES
CASE 658 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, FAIL 20PSIG
CAV.FLOOR CENTER. 346FT2, LNR+F.BRK+I.BRK+32-IN.BSL.CONCRETE.
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 336.0 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 658
12 NOV 76 1551 HRS

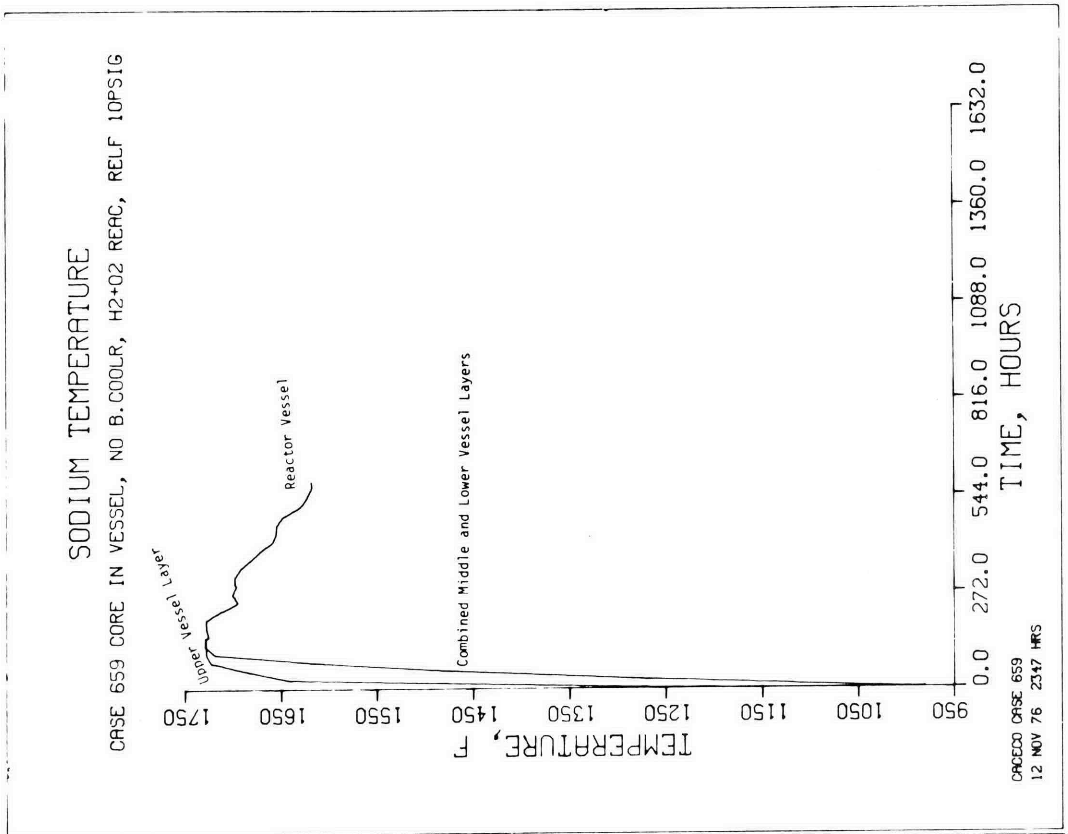

STRUCTURAL TEMPERATURES
CASE 658 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, FAIL 20PSIG
SUB.CAVITY FLOOR. 346 FT2 OF 6.8-FT BSL.CONCRETE. SUB.CAV. LEFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✱ - TIME - 1600.0 HRS
TEMPERATURE, F
1800
1600
1400
1200
1000
800
600
400
200
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 658
12 NOV 76 1551 HRS

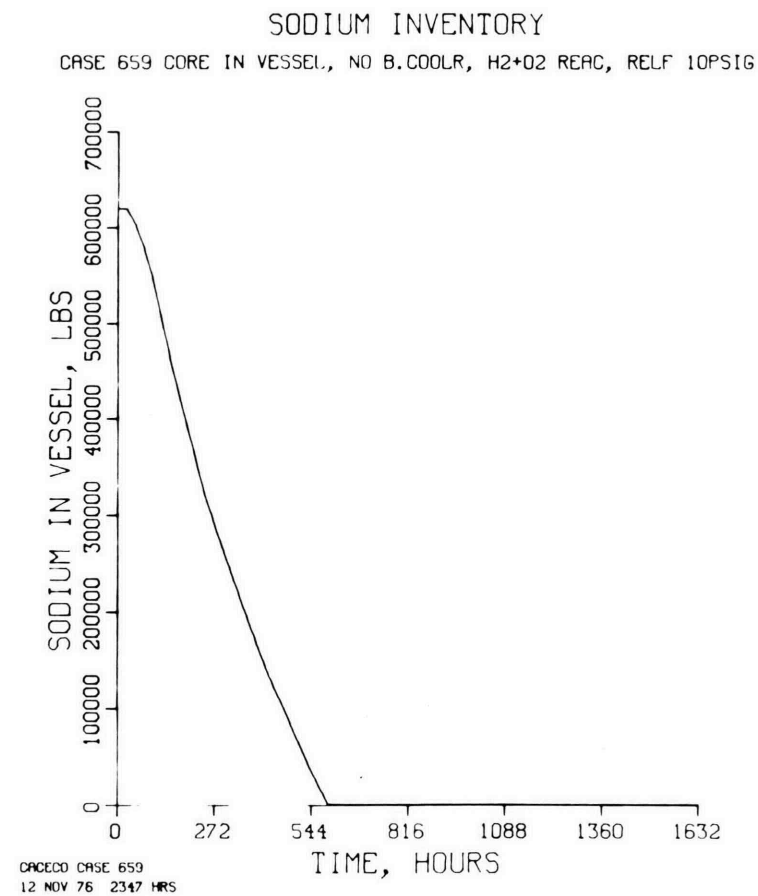

STRUCTURAL TEMPERATURES
CASE 658 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, FAIL 20PSIG
SUB.CAVITY WALLS. 700 FT2 OF 12-FT THICK MAG.CONCRETE. S.CAV.LF
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✱ - TIME - 1600.0 HRS
TEMPERATURE, F
1800
1600
1400
1200
1000
800
600
400
200
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 658
12 NOV 76 1551 HRS


BUILDING ATMOSPHERE CONDITICNS
CASE 659 CORE IN VESSEL, NO B.COOLR, H2+02 REAC, RELF 10PSIG
TEMPERATURE, F
0
225
450
675
900
PRESS. PSIG
0
7.5
15
PERCENT H2
0
50
100
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 659
12 NOV 76 2347 HRS

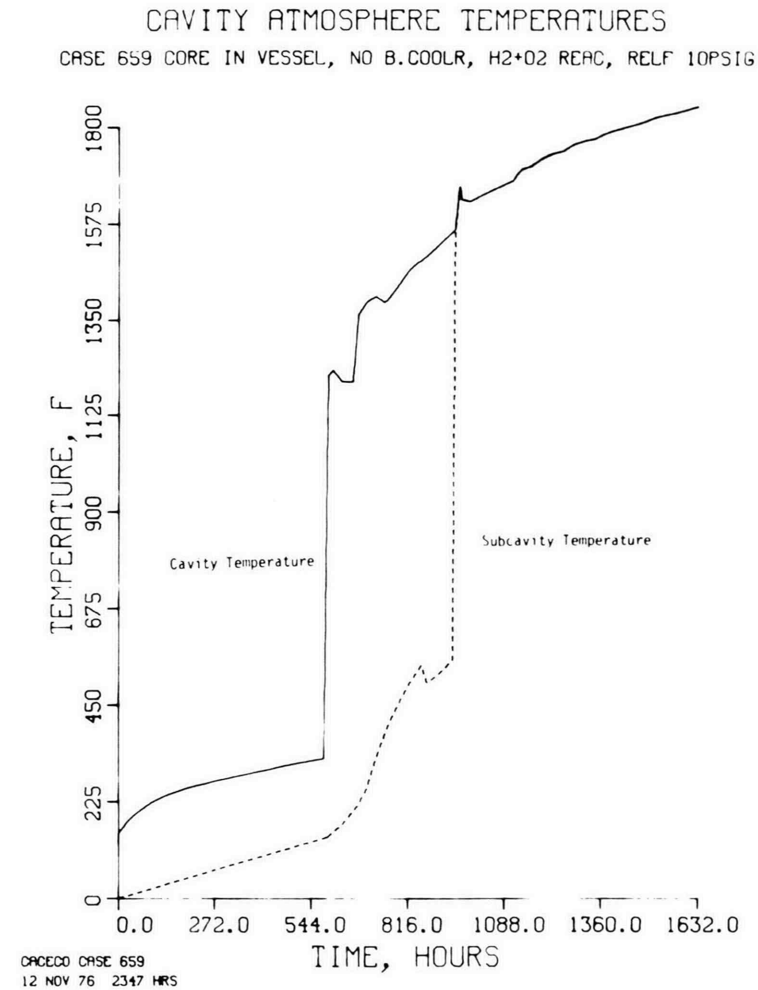

BUILDING ROOF TEMPERATURE
CASE 659 CORE IN VESSEL, NO B.COOLR, H2+02 REAC, RELF 10PSIG
R.C.BLDG ROOF, 34,200-FT2, 1.1-IN.C.STEEL. INSIDE LEFT, OUTSIDE(
TEMPERATURE, F
0
225
450
675
900
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 659
12 NOV 76 2347 HRS


BUILDING AVG. VENT RATE
CASE 659 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, RELF 10PSIG
FLOW RATE, SCFM
0
100
200
300
400
500
600
700
800
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 659
12 NOV 76 2347 HRS

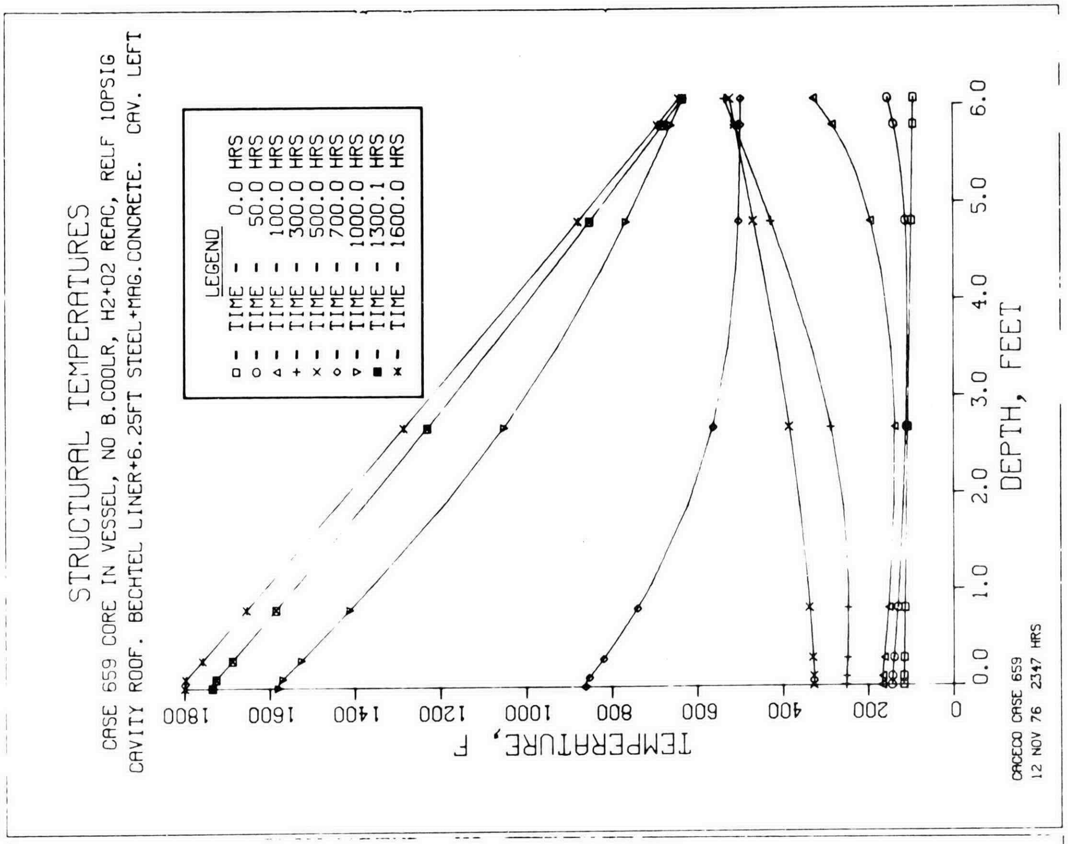

SODIUM TEMPERATURE
CASE 659 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, RELF 10PSIG
TEMPERATURE, F
950
1050
1150
1250
1350
1450
1550
1650
1750
Upper Vessel Layer
Reactor Vessel
Combined Middle and Lower Vessel Layers
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 659
12 NOV 76 2347 HRS



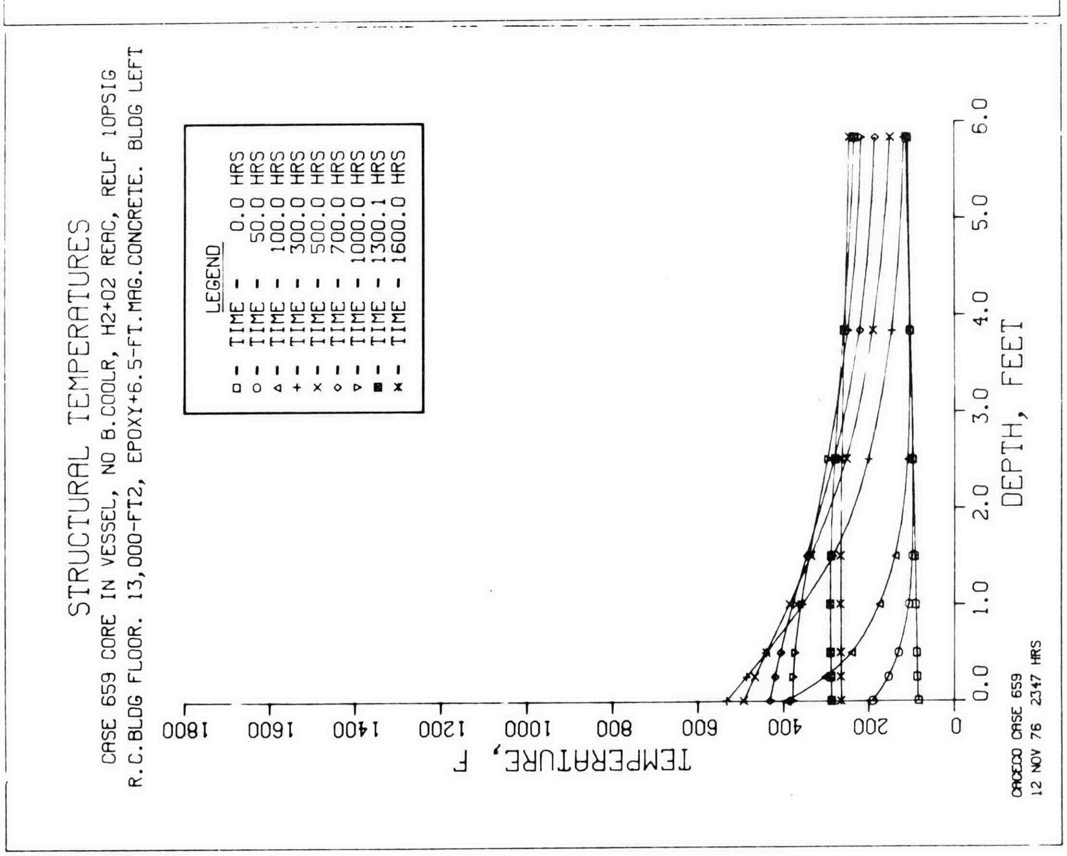
SODIUM INVENTORY
CASE 659 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, RELF 10PSIG
SODIUM IN VESSEL, LBS
0
100000
200000
300000
400000
500000
600000
700000
0
272
544
816
1088
1360
1632
TIME, HOURS
CACECO CASE 659
12 NOV 76 2347 HRS



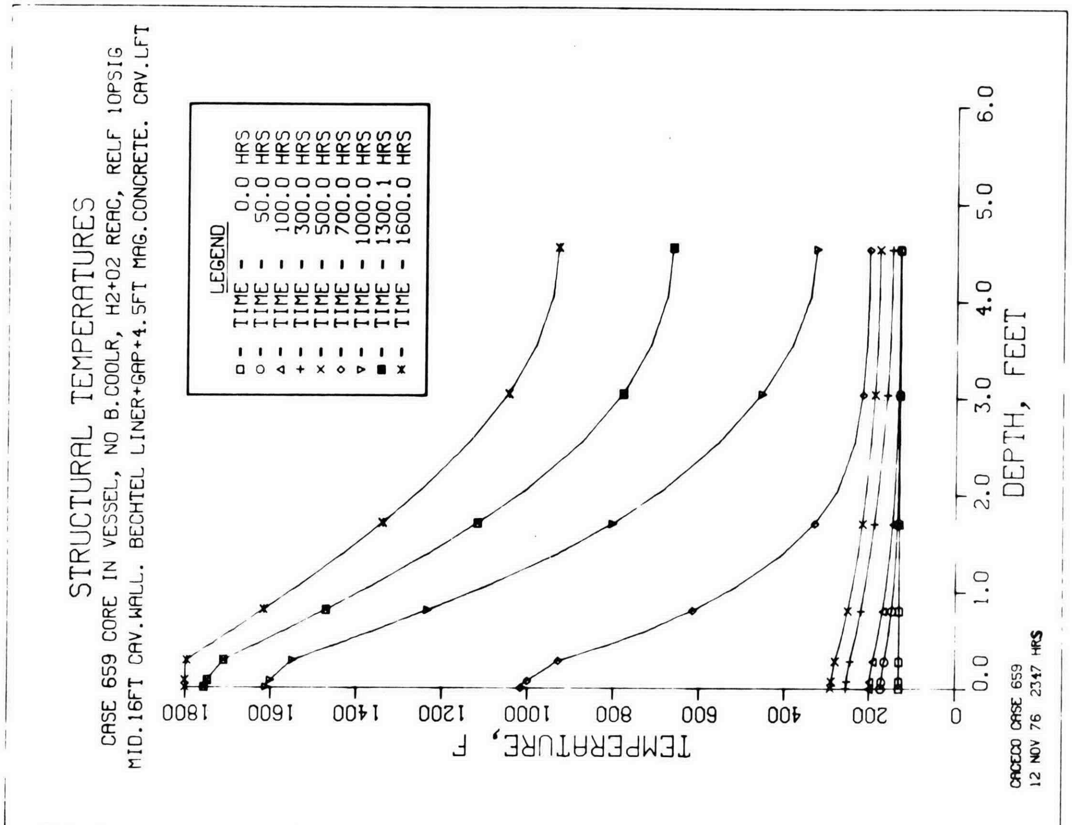
CAVITY ATMOSPHERE TEMPERATURES
CASE 659 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, RELF 10PSIG
TEMPERATURE, F
0
225
450
675
900
1125
1350
1575
1800
Cavity Temperature
Subcavity Temperature
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 659
12 NOV 76 2347 HRS

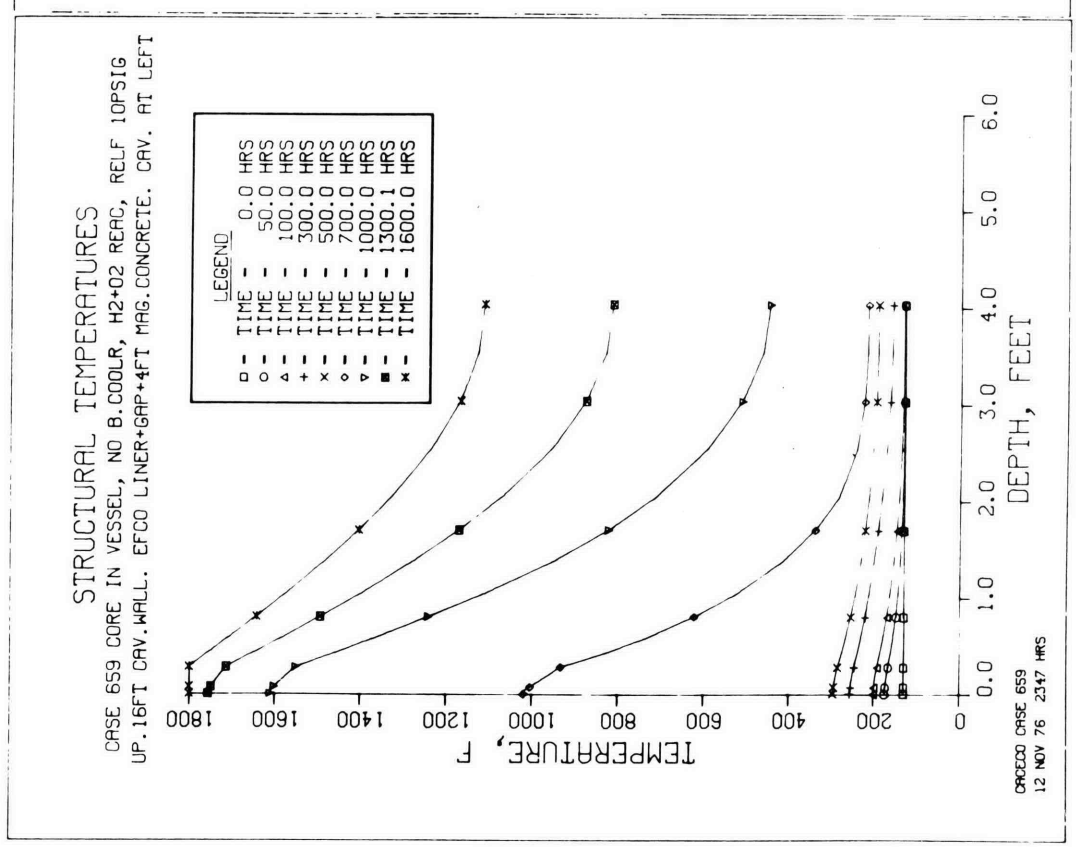


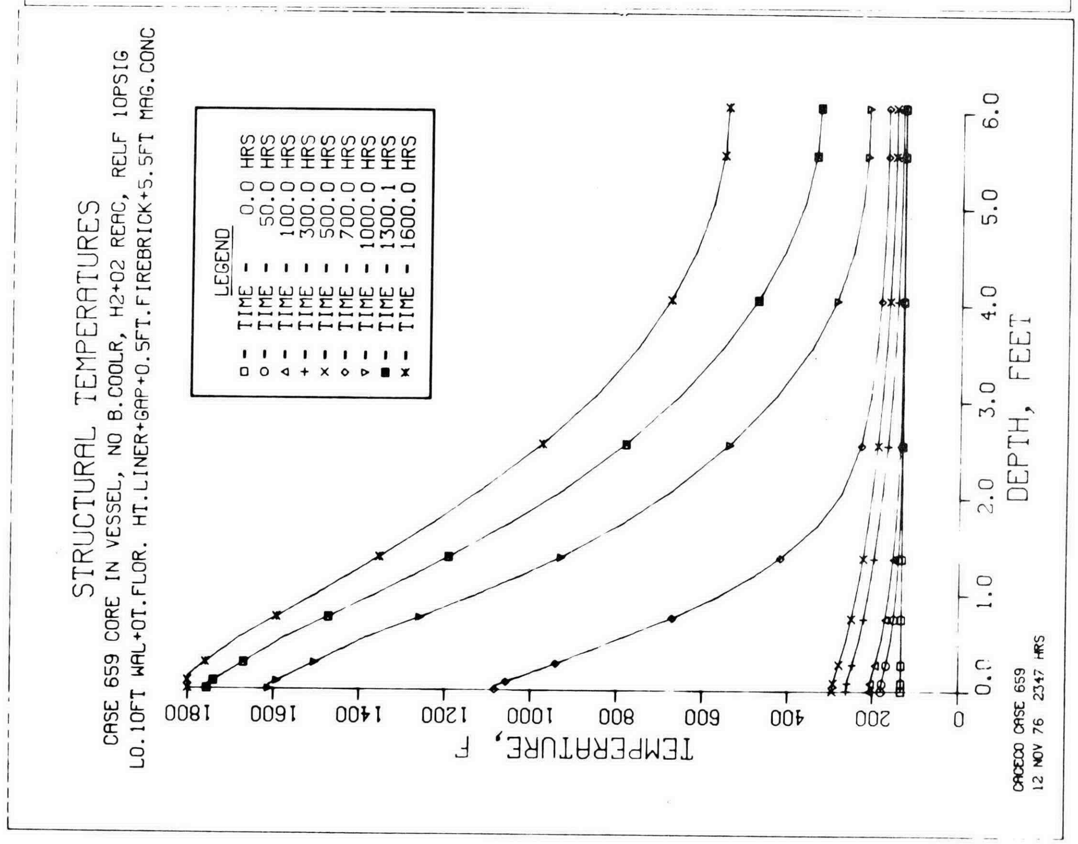
STRUCTURAL TEMPERATURES
CASE 659 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, RELF 10PSIG
CAVITY ROOF. BECHTEL LINER+6.25FT STEEL+MAG.CONCRETE. CAV. LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 659
12 NOV 76 2347 HRS

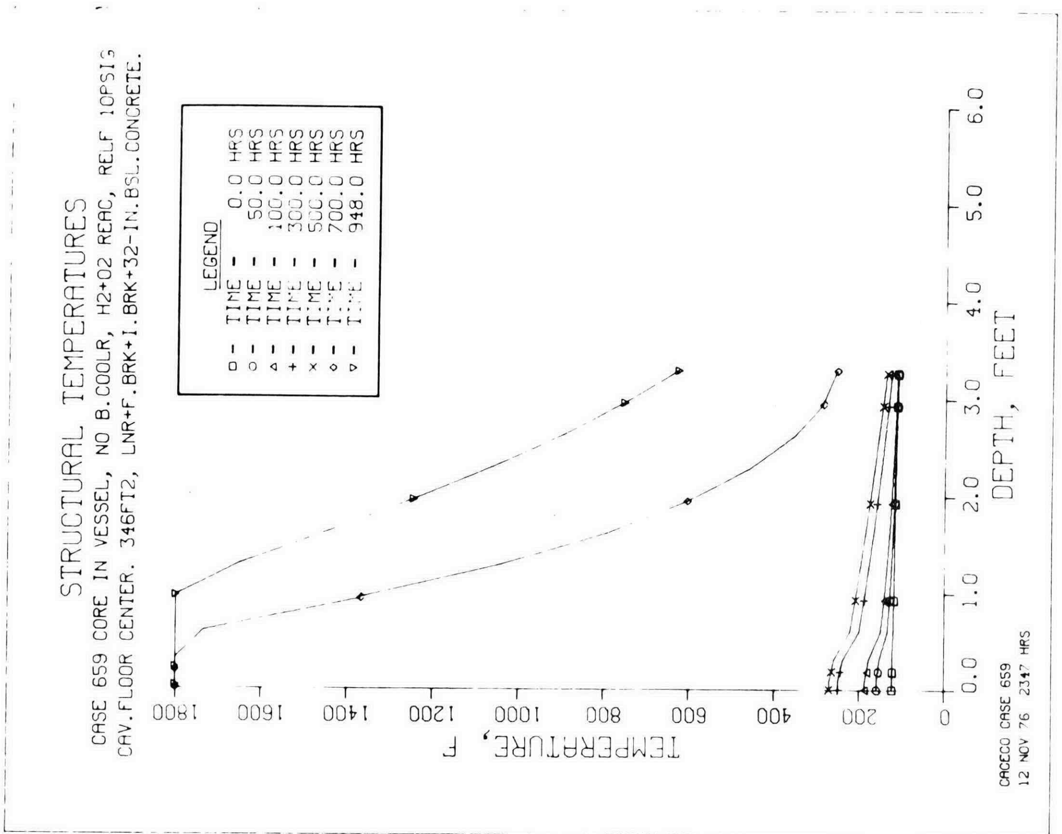


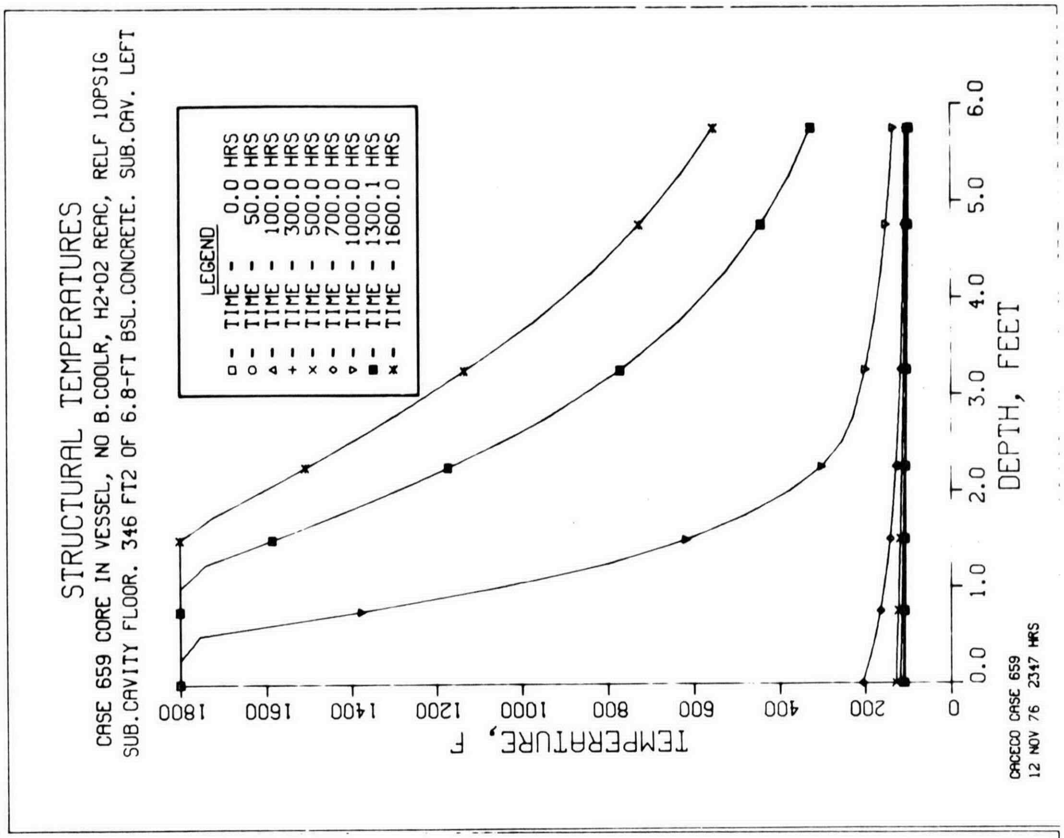
STRUCTURAL TEMPERATURES
CASE 659 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, RELF 10PSIG
R.C.BLDG FLOOR. 13,000-FT2, EPOXY+6.5-FT.MAG.CONCRETE. BLDG LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 659
12 NOV 76 2347 HRS

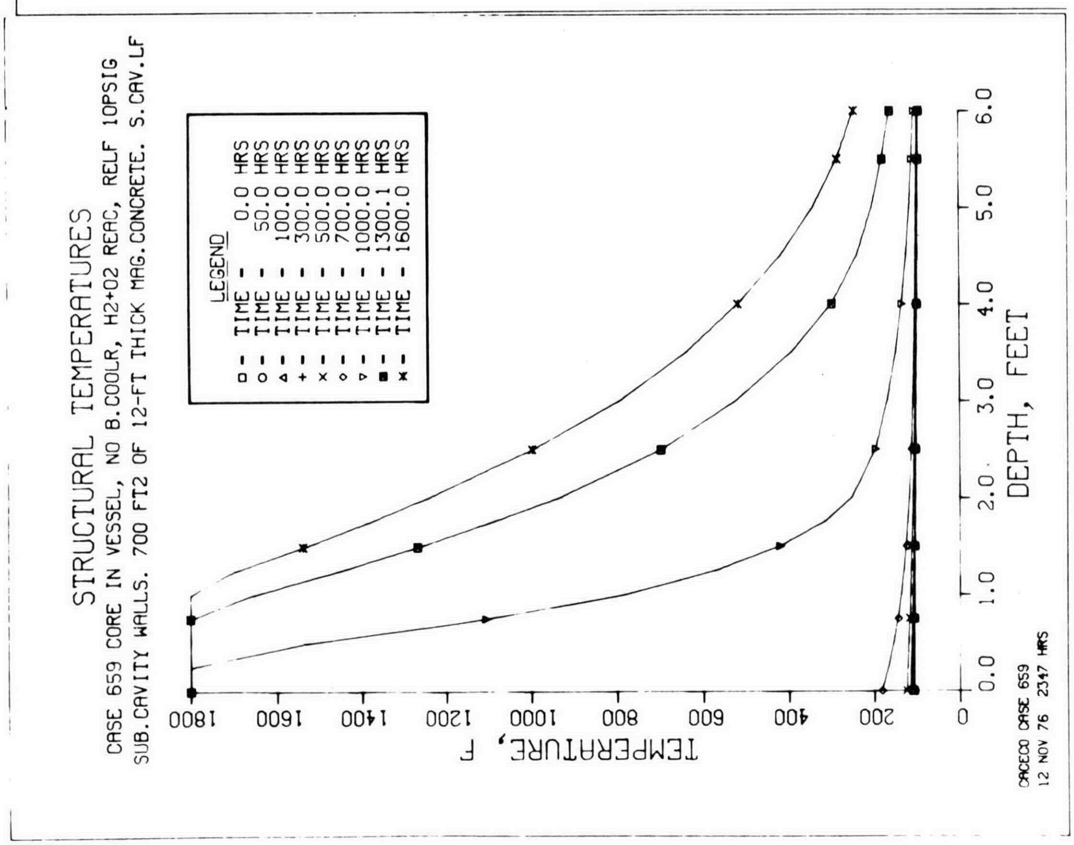

STRUCTURAL TEMPERATURES
CASE 659 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, RELF 10PSIG
MID.16FT CAV.WALL. BECHTEL LINER+GAP+4.5FT MAG.CONCRETE. CAV.LFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✕ - TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 659
12 NOV 76 2347 HRS

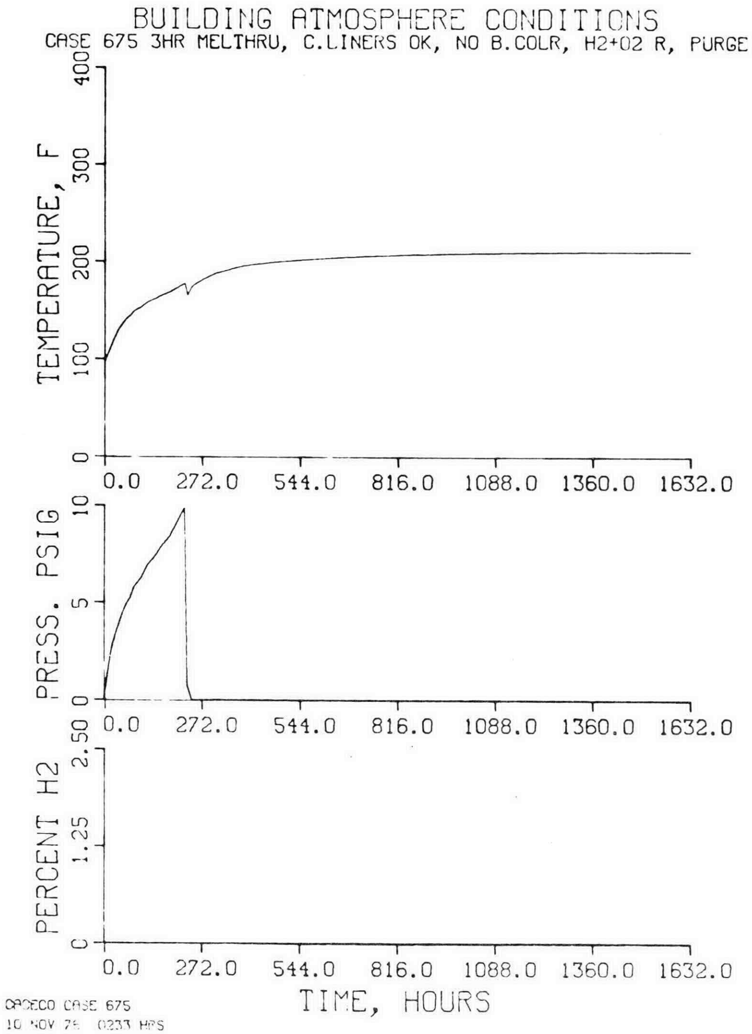

STRUCTURAL TEMPERATURES
CASE 659 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, RELF 10PSIG
UP.16FT CAV.WALL. EFCO LINER+GAP+4FT MAG.CONCRETE. CAV. AT LEFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✕ - TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 659
12 NOV 76 2347 HRS

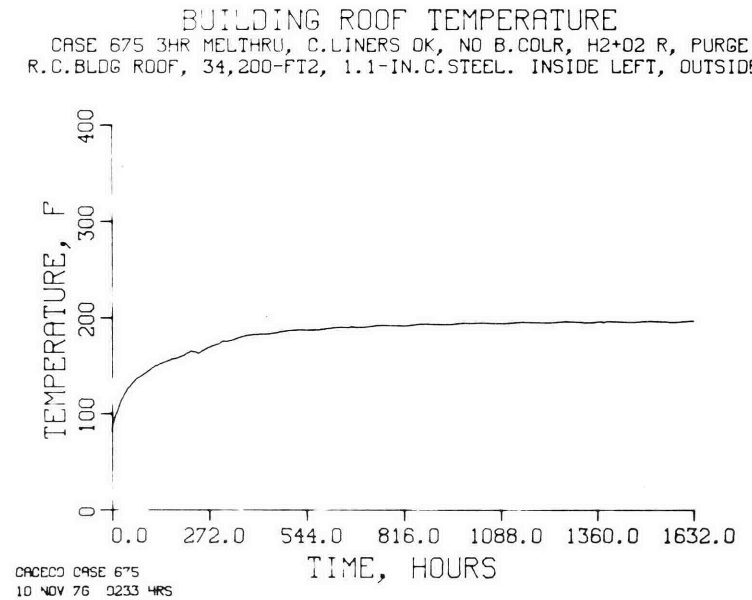

STRUCTURAL TEMPERATURES
CASE 659 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, RELF 10PSIG
LO.10FT WAL+OT.FLOR. HT.LINER+GAP+0.5FT.FIREBRICK+5.5FT MAG.CONC
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✕ - TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 659
12 NOV 76 2347 HRS

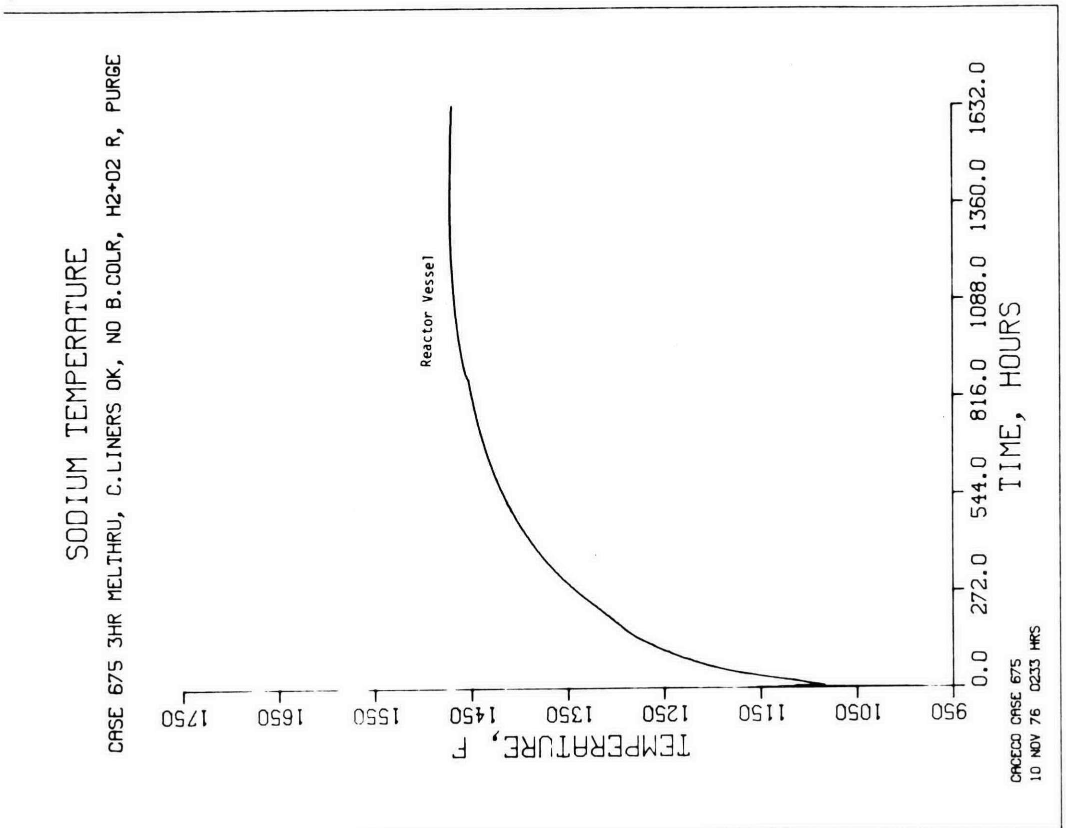

STRUCTURAL TEMPERATURES
CASE 659 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, RELF 10PSIG
CAV.FLOOR CENTER. 346FT2, LNR+F.BRK+I.BRK+32-IN.BSL.CONCRETE.
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 948.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 659
12 NOV 76 2347 HRS

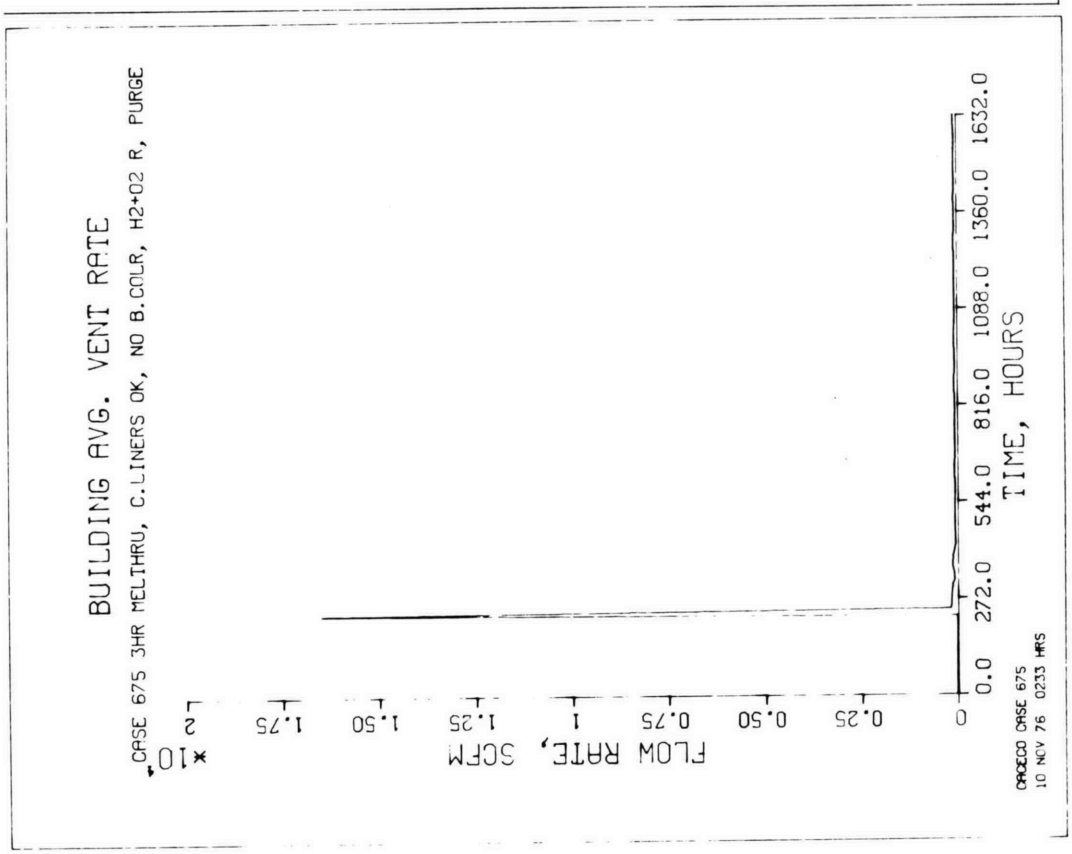

STRUCTURAL TEMPERATURES
CASE 659 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, RELF 10PSIG
SUB.CAVITY FLOOR. 346 FT2 OF 6.8-FT BSL.CONCRETE. SUB.CAV. LEFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✕ - TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 659
12 NOV 76 2347 HRS

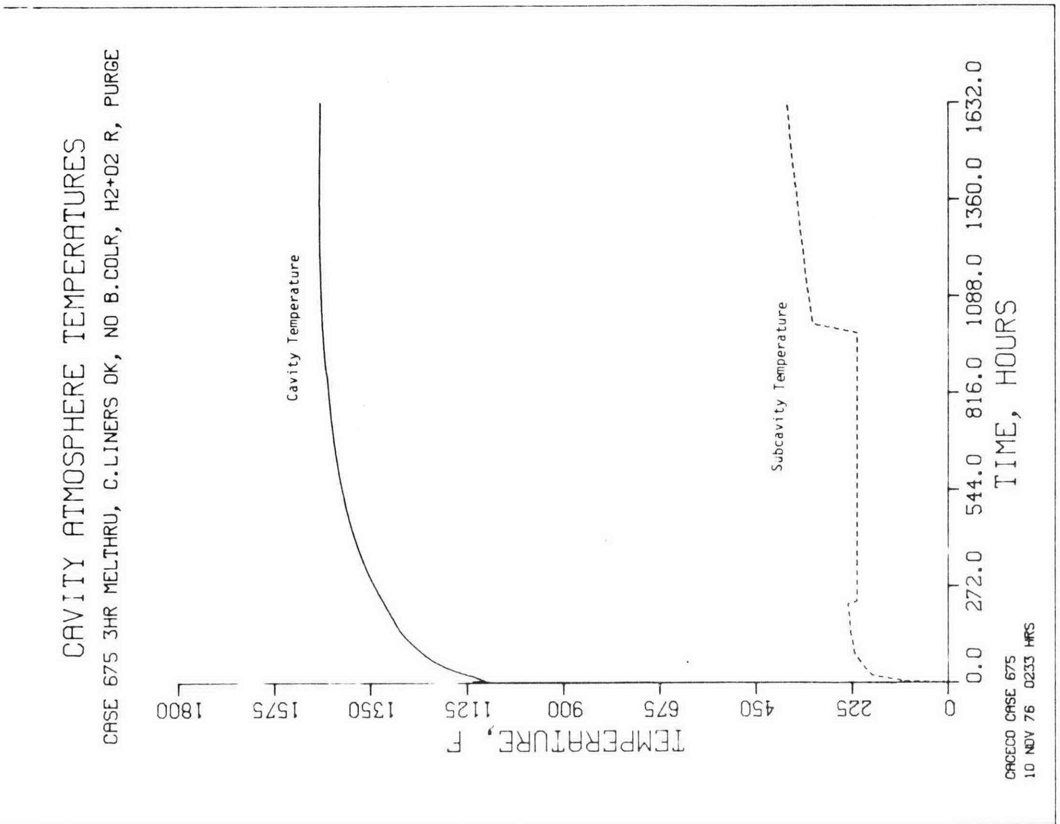

STRUCTURAL TEMPERATURES
CASE 659 CORE IN VESSEL, NO B.COOLR, H2+O2 REAC, RELF 10PSIG
SUB.CAVITY WALLS. 700 FT2 OF 12-FT THICK MAG.CONCRETE. S.CAV.LF
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✕ - TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 659
12 NOV 76 2347 HRS

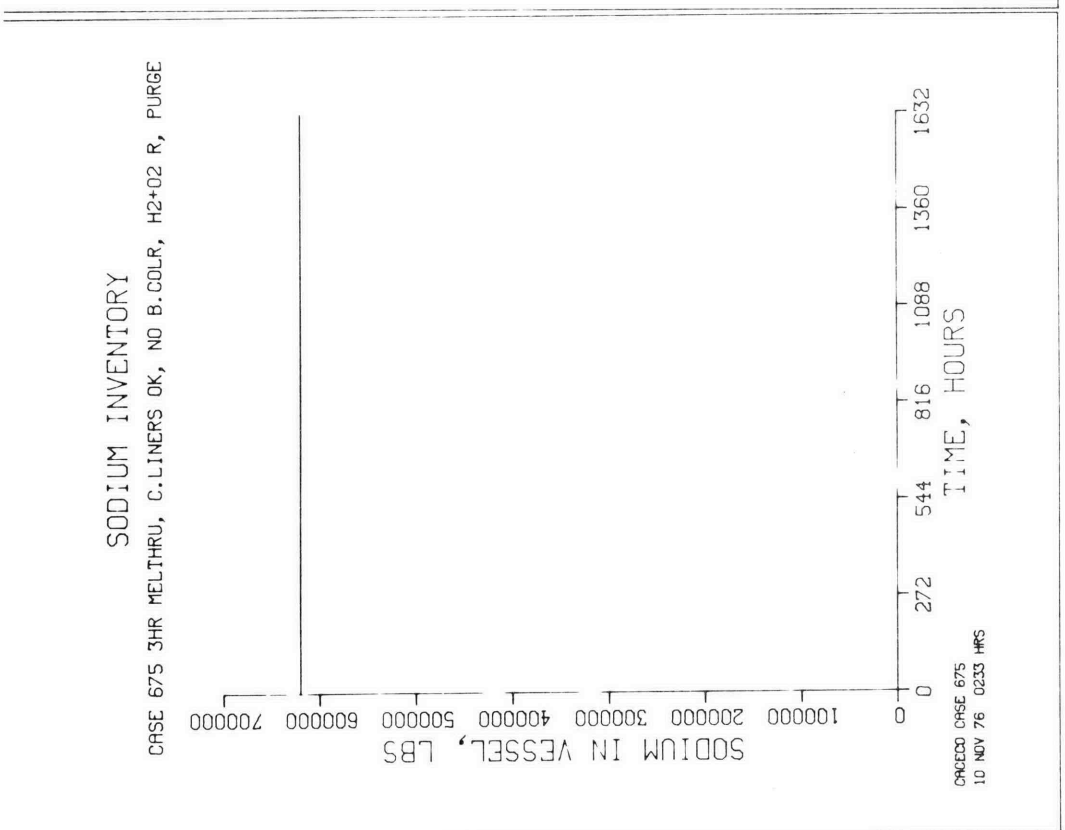

BUILDING ATMOSPHERE CONDITIONS
CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+02 R, PURGE
TEMPERATURE, F
0
100
200
300
400
PRESS. PSIG
0
5
10
PERCENT H2
0
1.25
2.50
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 675
10 NOV 76 0233 HRS

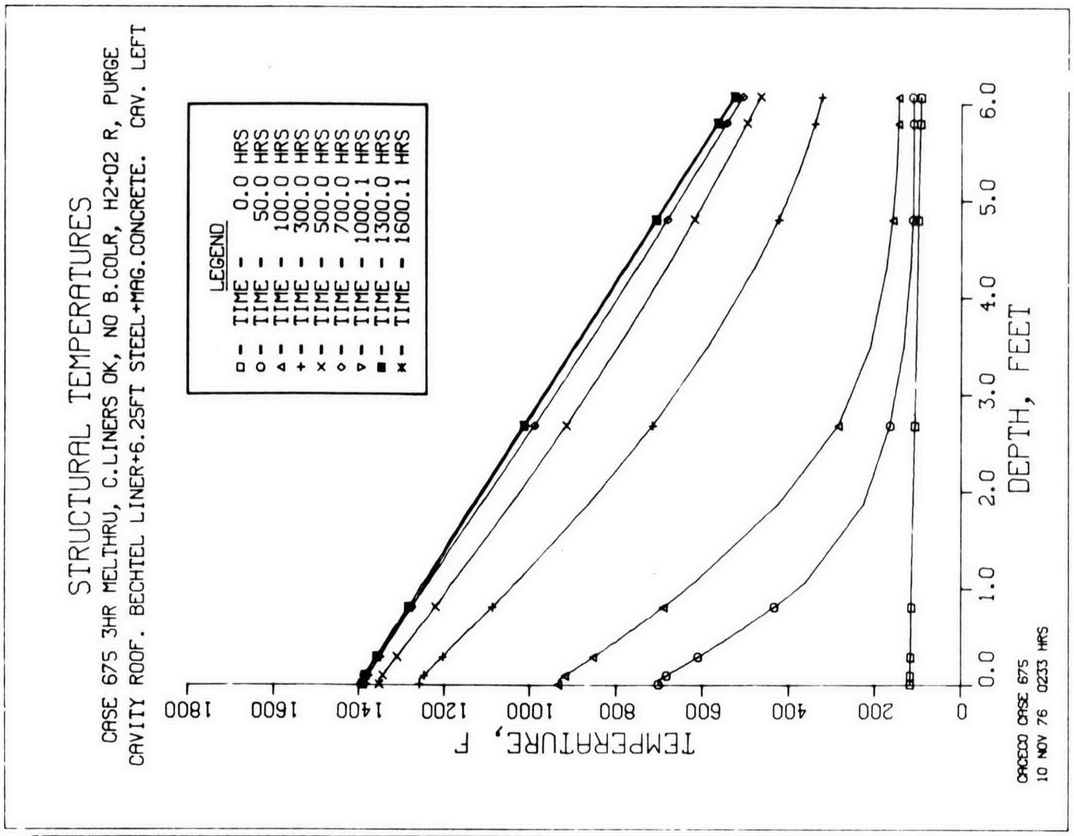

BUILDING ROOF TEMPERATURE
CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+02 R, PURGE
R.C.BLDG ROOF, 34,200-FT2, 1.1-IN.C.STEEL. INSIDE LEFT, OUTSIDE(
TEMPERATURE, F
0
100
200
300
400
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 675
10 NOV 76 0233 HRS

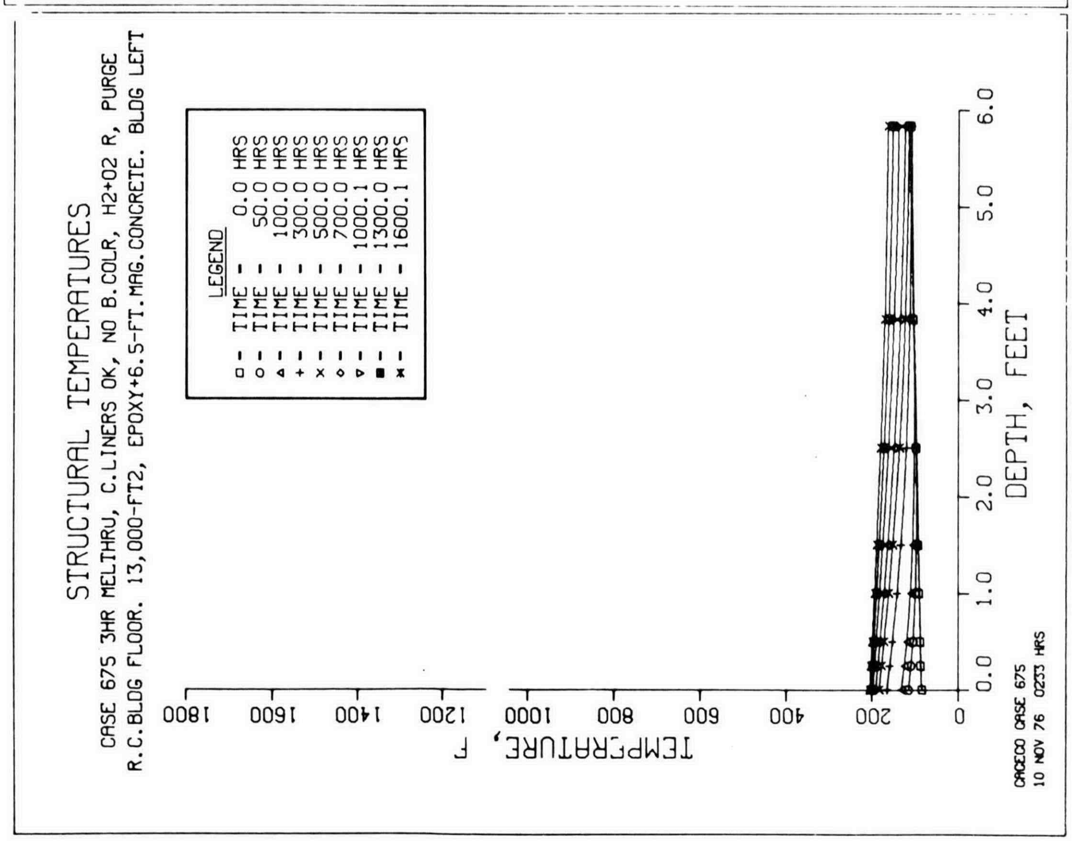

SODIUM TEMPERATURE
CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+O2 R, PURGE
Reactor Vessel
TEMPERATURE, F
950
1050
1150
1250
1350
1450
1550
1650
1750
TIME, HOURS
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
CACECO CASE 675
10 NOV 76 0233 HRS

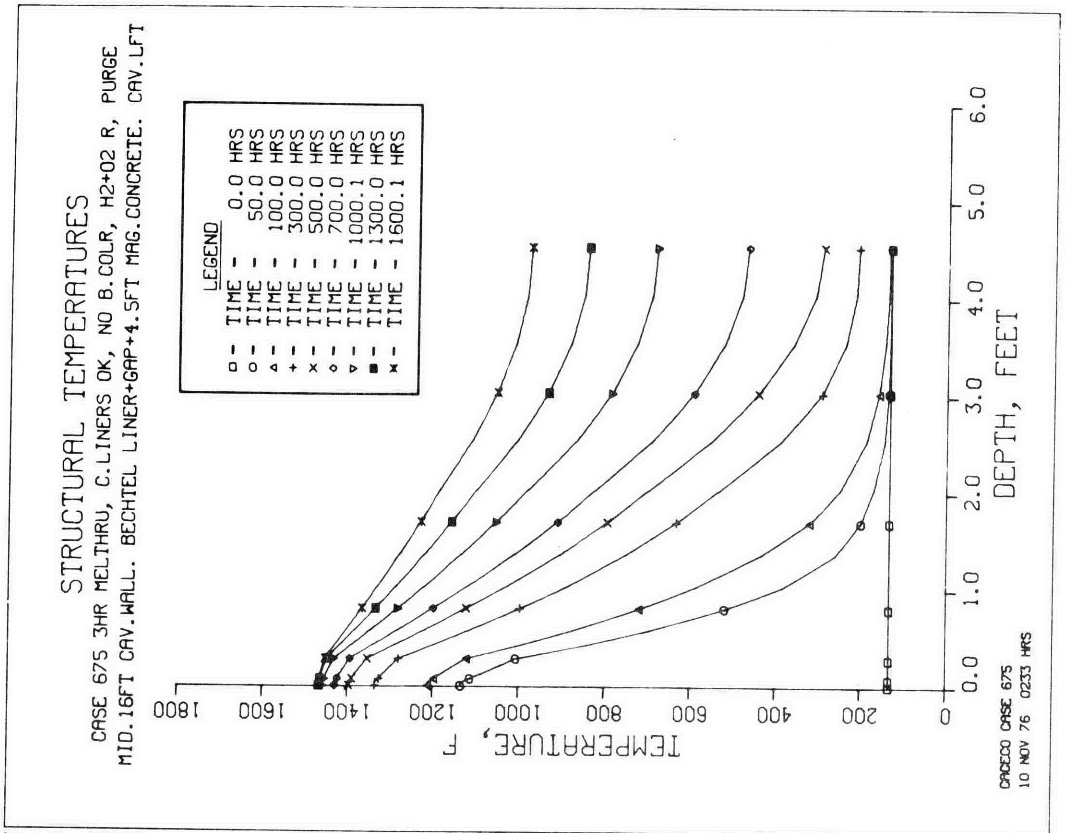

BUILDING AVG. VENT RATE
CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+O2 R, PURGE
FLOW RATE, SCFM
×10⁴
0
0.25
0.50
0.75
1
1.25
1.50
1.75
2
TIME, HOURS
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
CACECO CASE 675
10 NOV 76 0233 HRS


CAVITY ATMOSPHERE TEMPERATURES
CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+O2 R, PURGE
Cavity Temperature
Subcavity Temperature
TEMPERATURE, F
0
225
450
675
900
1125
1350
1575
1800
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 675
10 NOV 76 0233 HRS

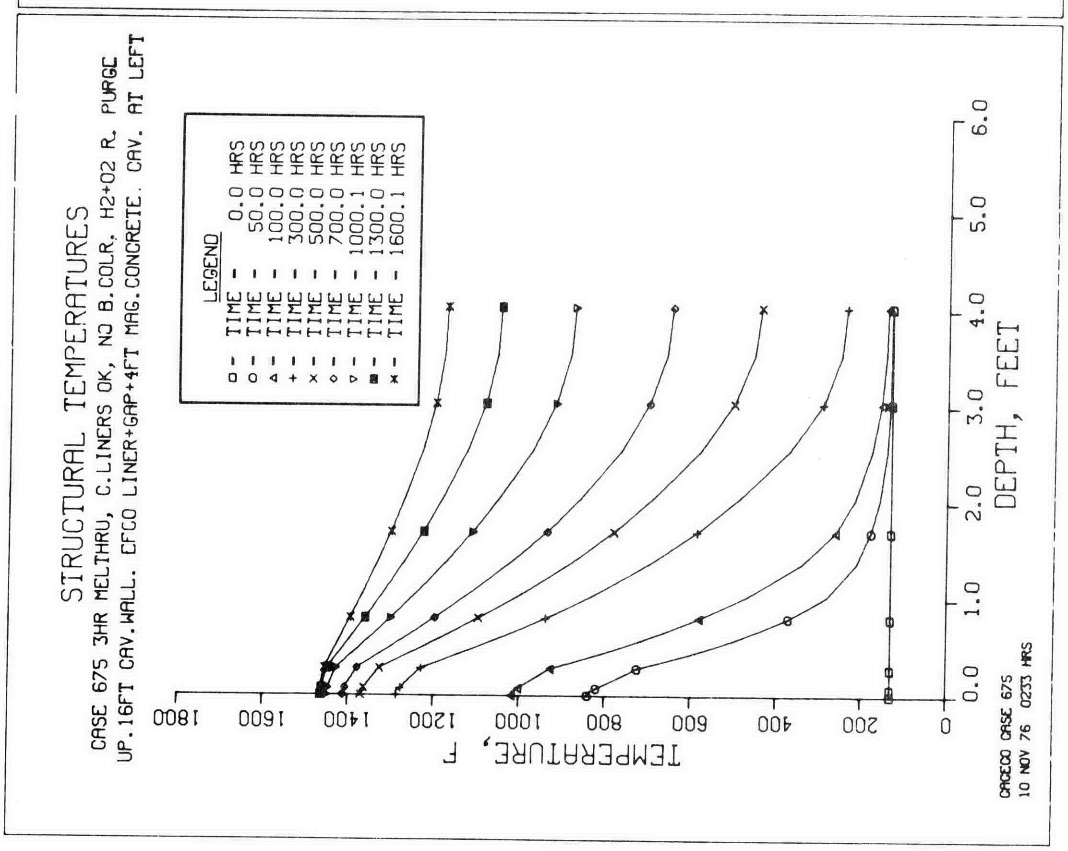

SODIUM INVENTORY
CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+O2 R, PURGE
SODIUM IN VESSEL, LBS
0
100000
200000
300000
400000
500000
600000
700000
0
272
544
816
1088
1360
1632
TIME, HOURS
CACECO CASE 675
10 NOV 76 0233 HRS


STRUCTURAL TEMPERATURES
CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+O2 R, PURGE
CAVITY ROOF. BECHTEL LINER+6.25FT STEEL+MAG.CONCRETE. CAV. LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 675
10 NOV 76 0233 HRS

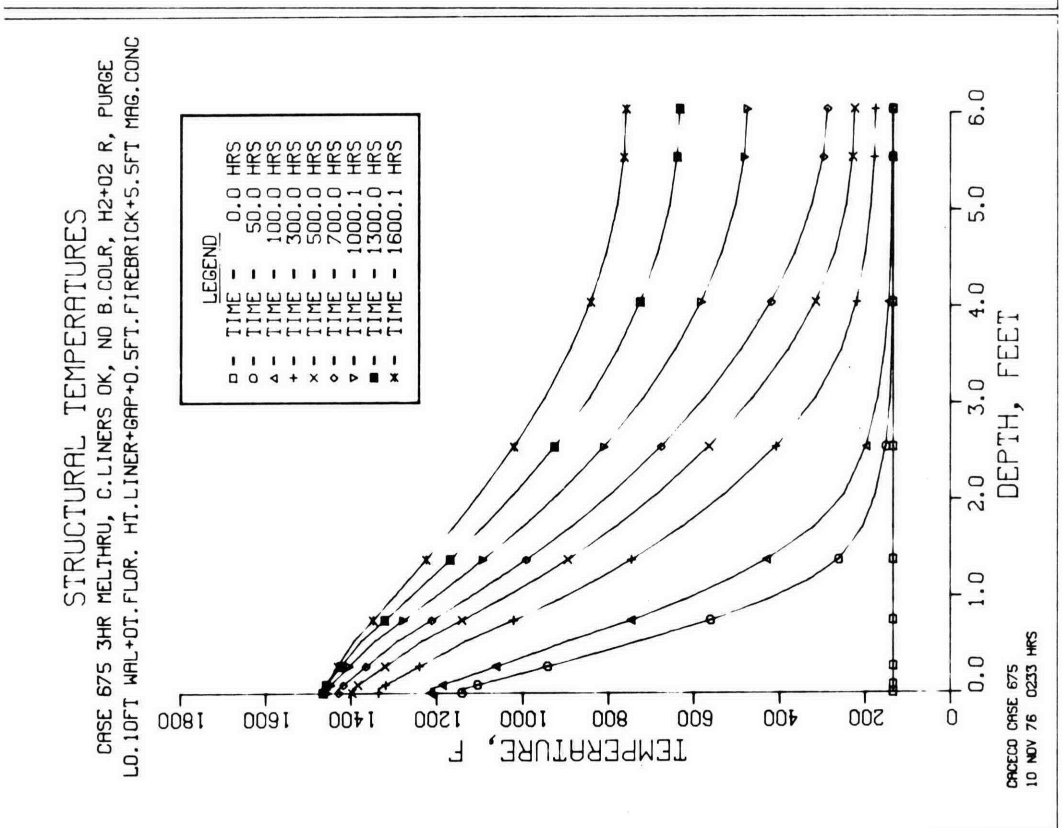

STRUCTURAL TEMPERATURES
CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+O2 R, PURGE
R.C.BLDG FLOOR. 13,000-FT2, EPOXY+6.5-FT.MAG.CONCRETE. BLDG LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 675
10 NOV 76 0233 HRS

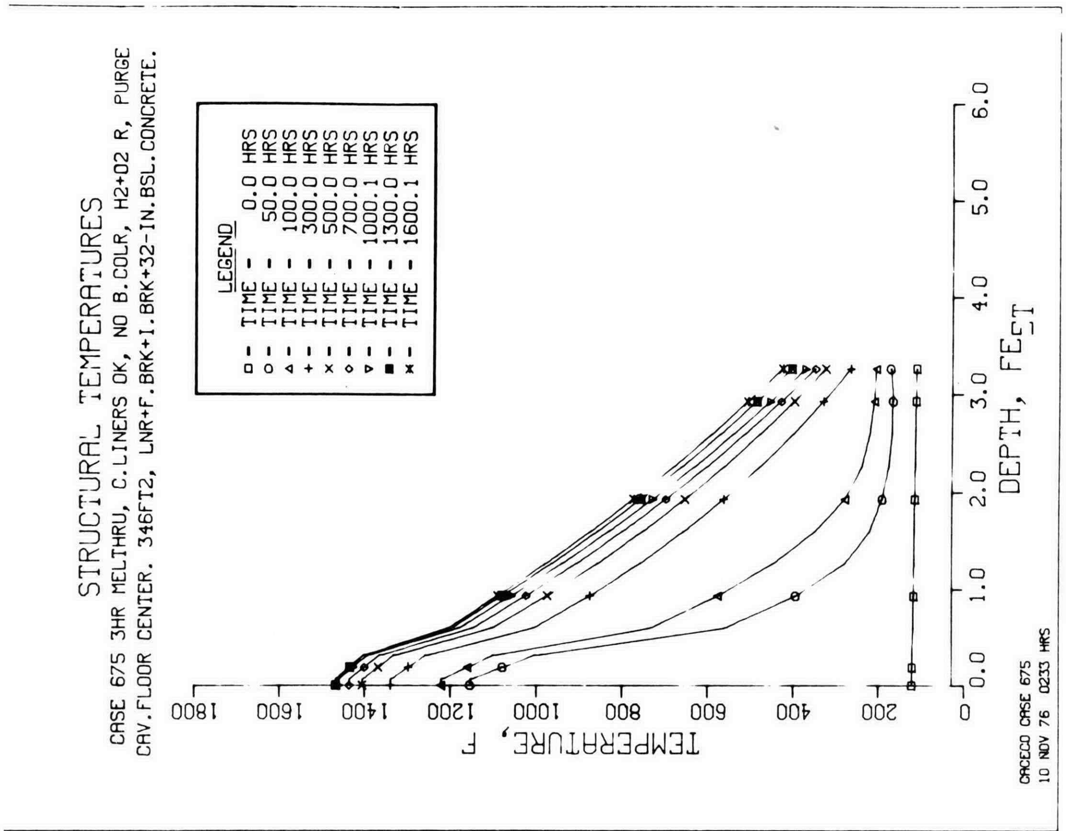


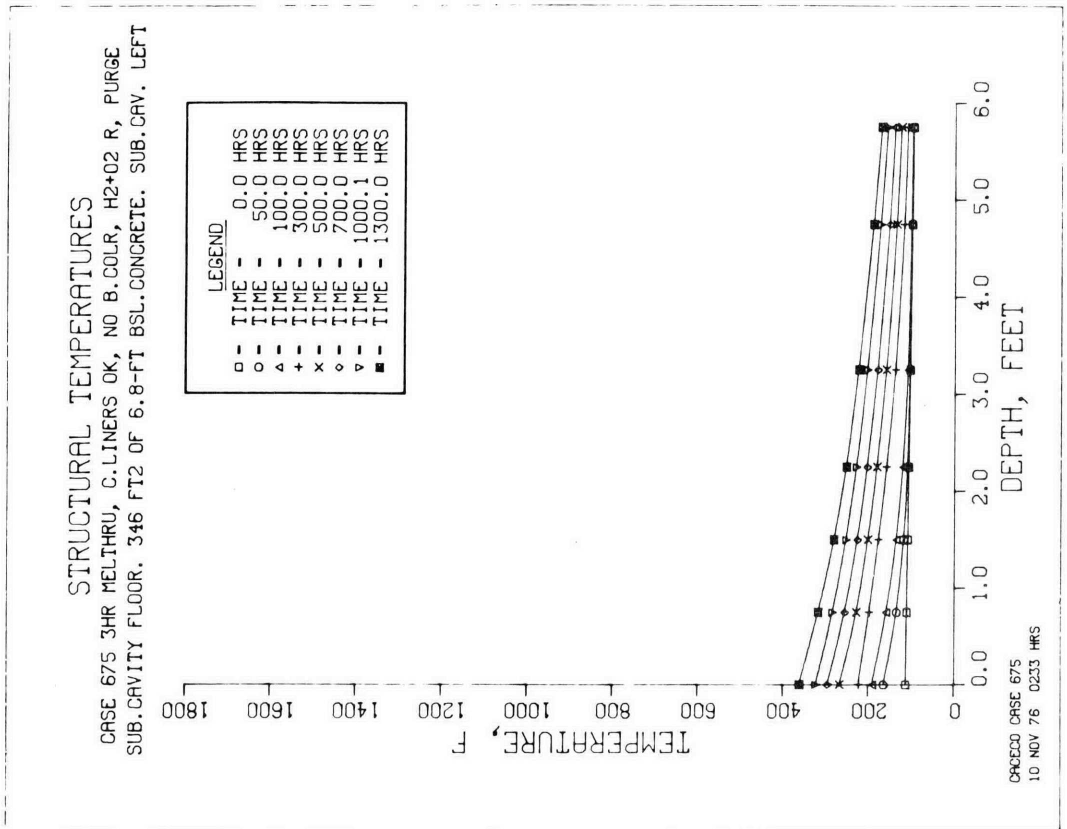
STRUCTURAL TEMPERATURES
CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+02 R, PURGE
MID.16FT CAV.WALL. BECHTEL LINER+GAP+4.5FT MAG.CONCRETE. CAV.LFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
1800
1600
1400
1200
1000
800
600
400
200
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 675
10 NOV 76 0233 HRS

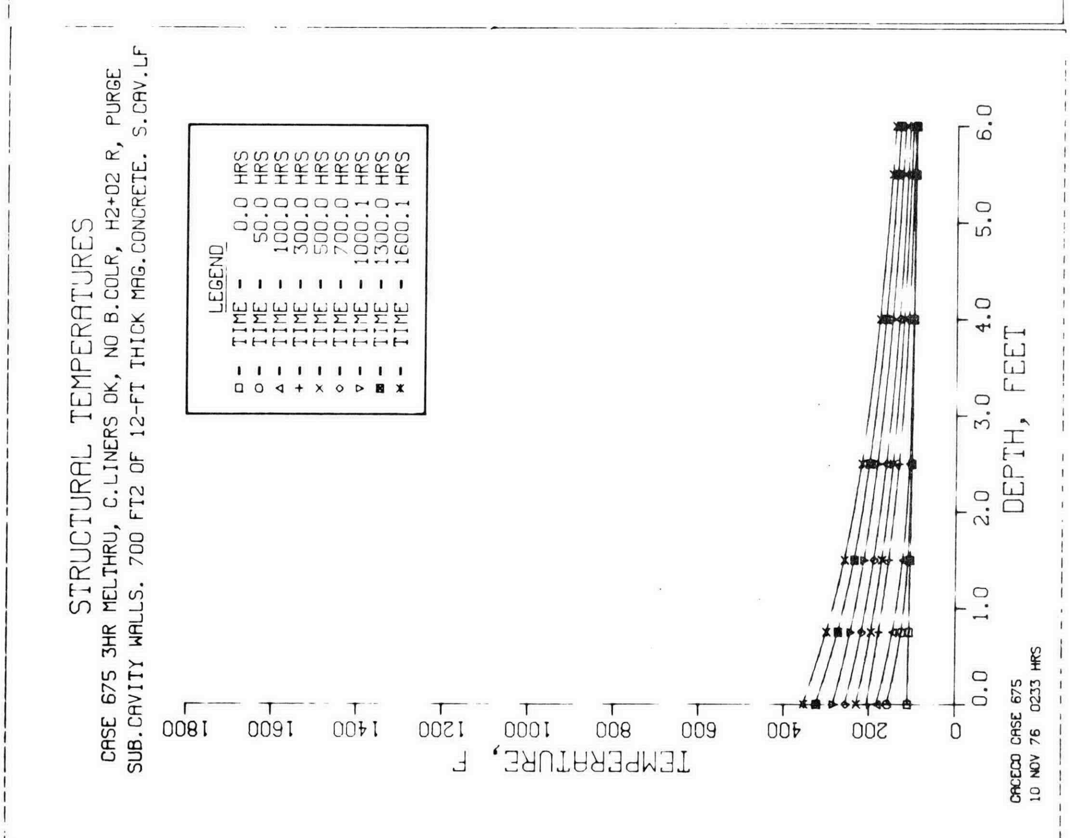


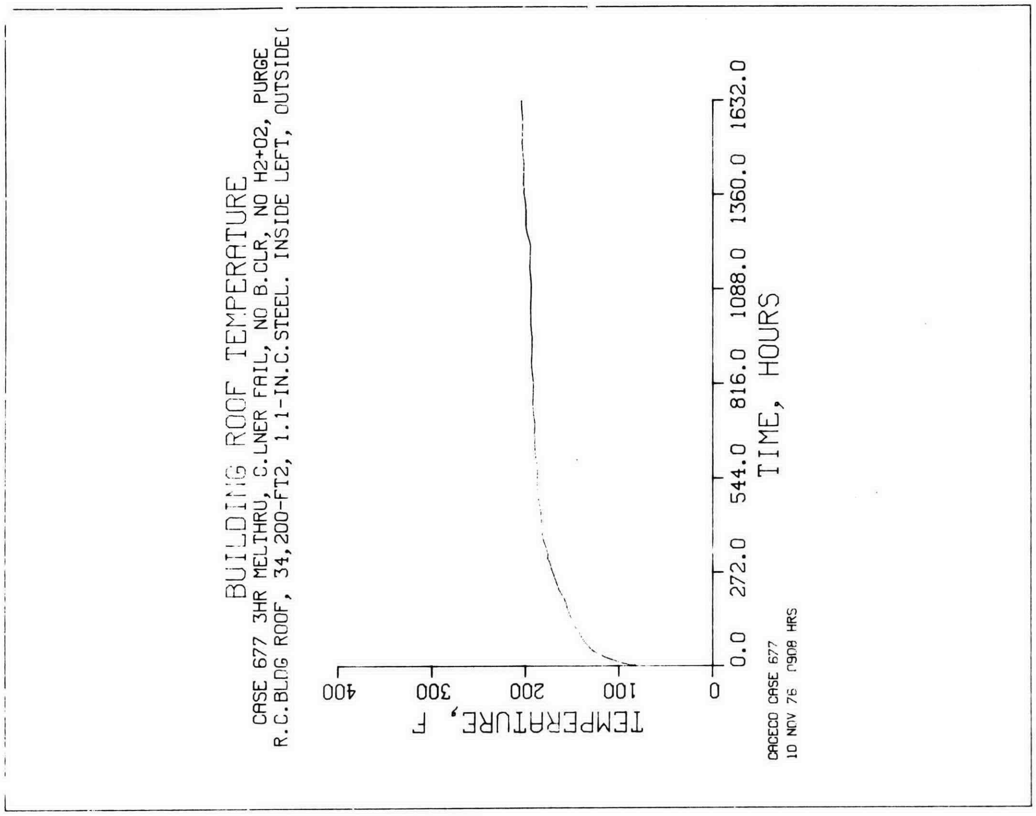
STRUCTURAL TEMPERATURES
CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+02 R. PURGE
UP.16FT CAV.WALL. CFCO LINER+GAP+4FT MAG.CONCRETE. CAV. AT LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
1800
1600
1400
1200
1000
800
600
400
200
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 675
10 NOV 76 0233 HRS

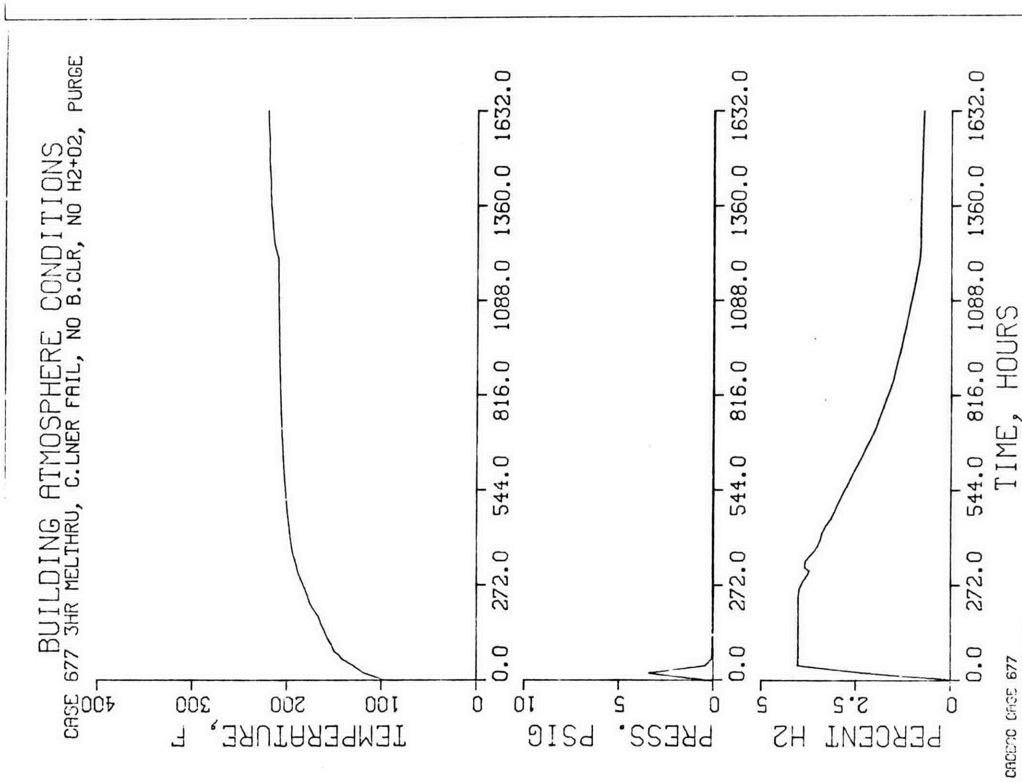

STRUCTURAL TEMPERATURES
CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+O2 R, PURGE
LO.10FT WAL+OT.FLOR. HT.LINER+GAP+0.5FT.FIREBRICK+5.5FT MAG.CONC
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 675
10 NOV 76 0233 HRS

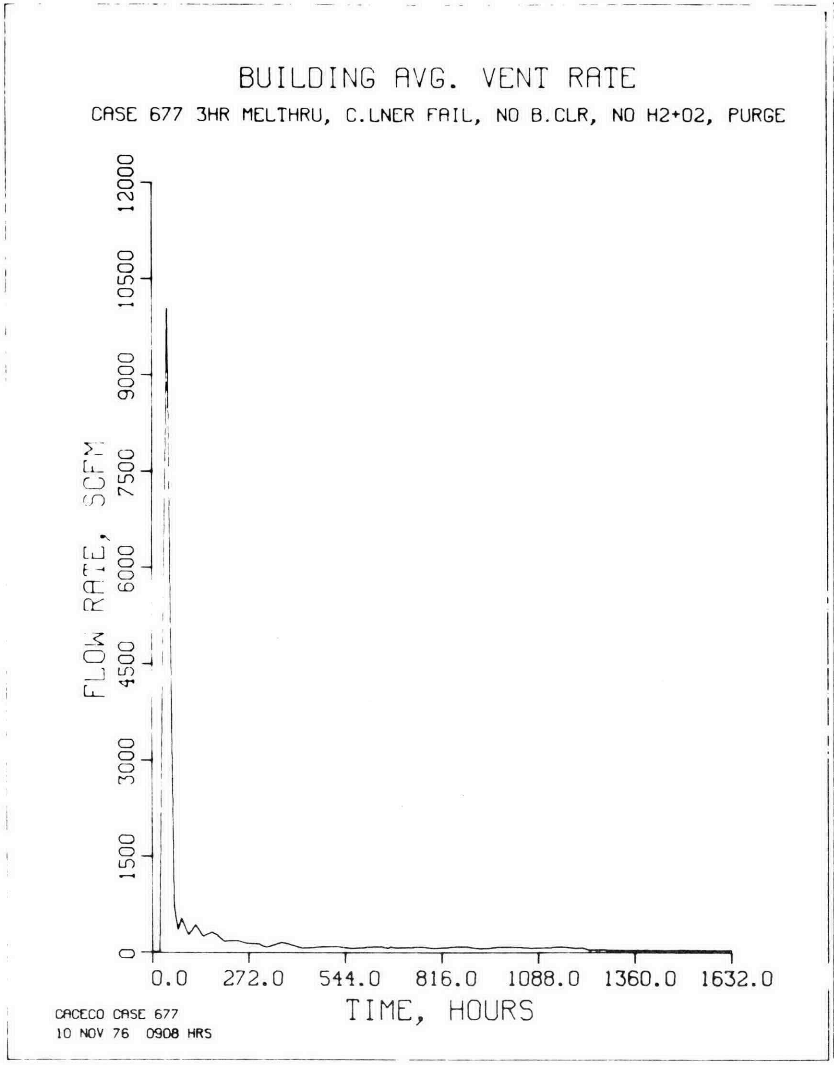

STRUCTURAL TEMPERATURES
CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+O2 R, PURGE
CAV.FLOOR CENTER. 346FT2, LNR+F.BRK+I.BRK+32-IN.BSL.CONCRETE.
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.0 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 675
10 NOV 76 0233 HRS

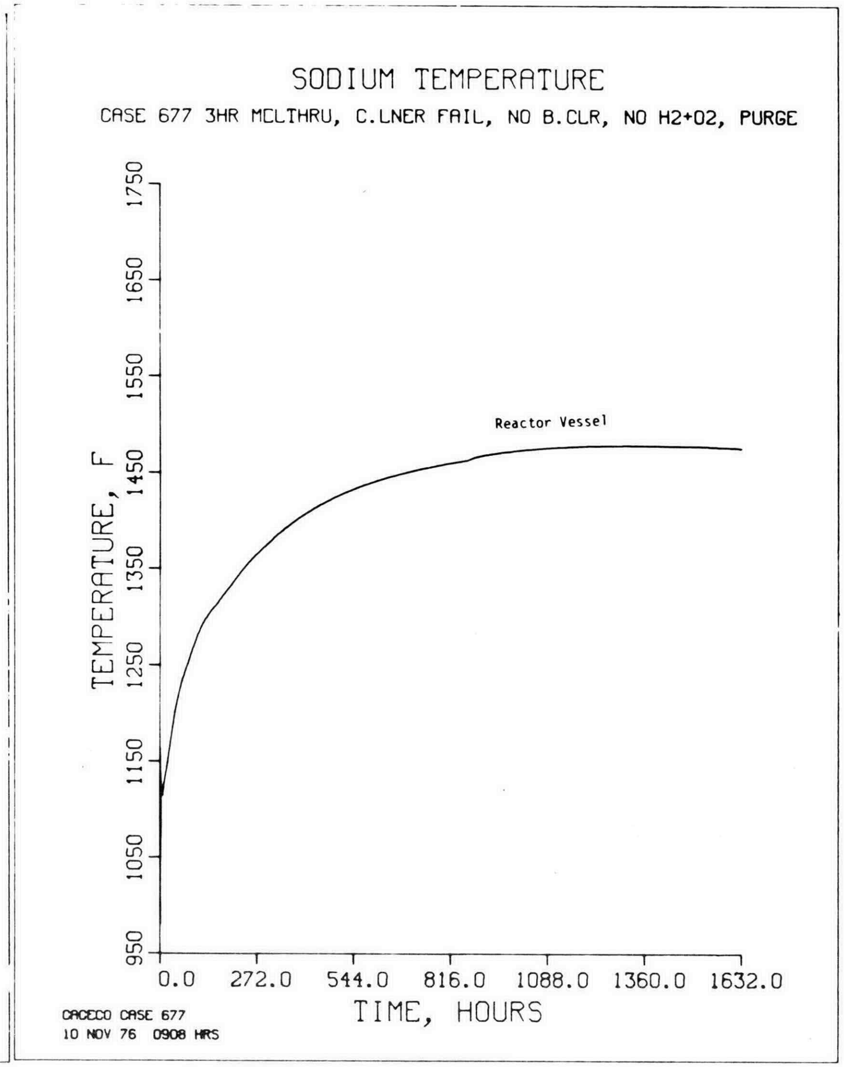

STRUCTURAL TEMPERATURES
CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+O2 R, PURGE
SUB.CAVITY FLOOR. 346 FT2 OF 6.8-FT BSL.CONCRETE. SUB.CAV. LEFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.1 HRS
■ - TIME - 1300.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 675
10 NOV 76 0233 HRS

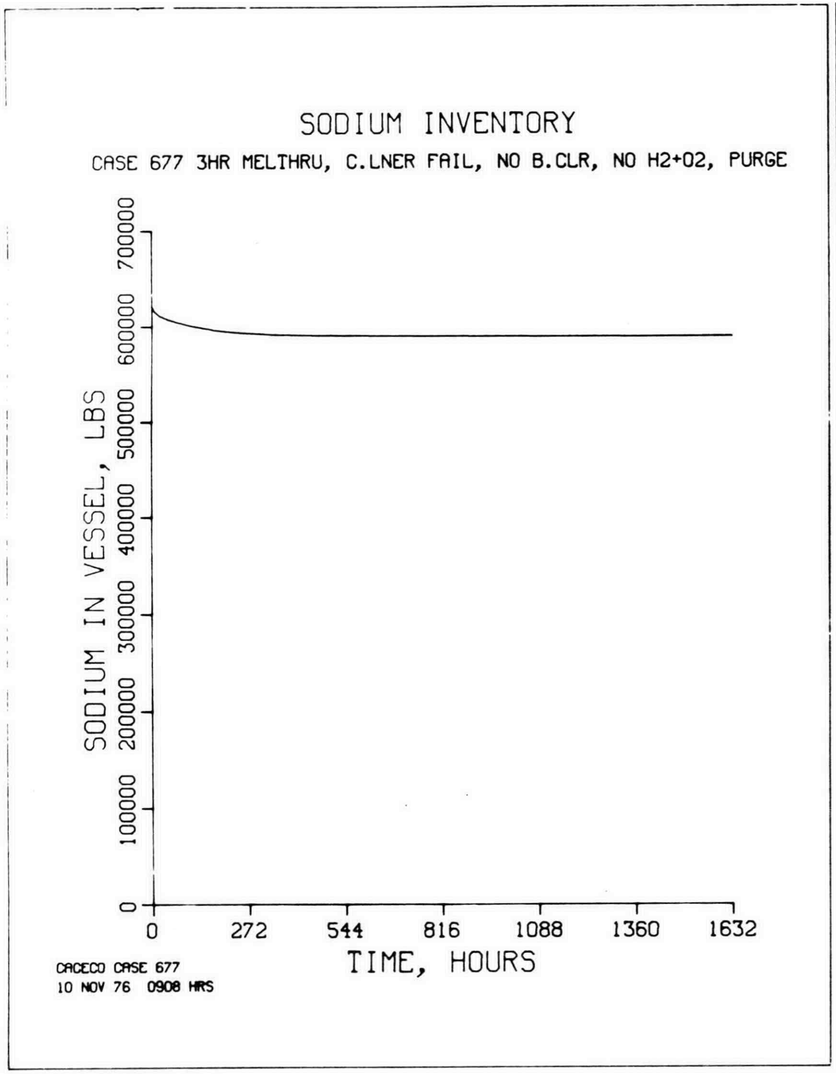

STRUCTURAL TEMPERATURES
CASE 675 3HR MELTHRU, C.LINERS OK, NO B.COLR, H2+O2 R, PURGE
SUB.CAVITY WALLS. 700 FT2 OF 12-FT THICK MAG.CONCRETE. S.CAV.LF
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.1 HRS
■ - TIME - 1300.0 HRS
✱ - TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 675
10 NOV 76 0233 HRS

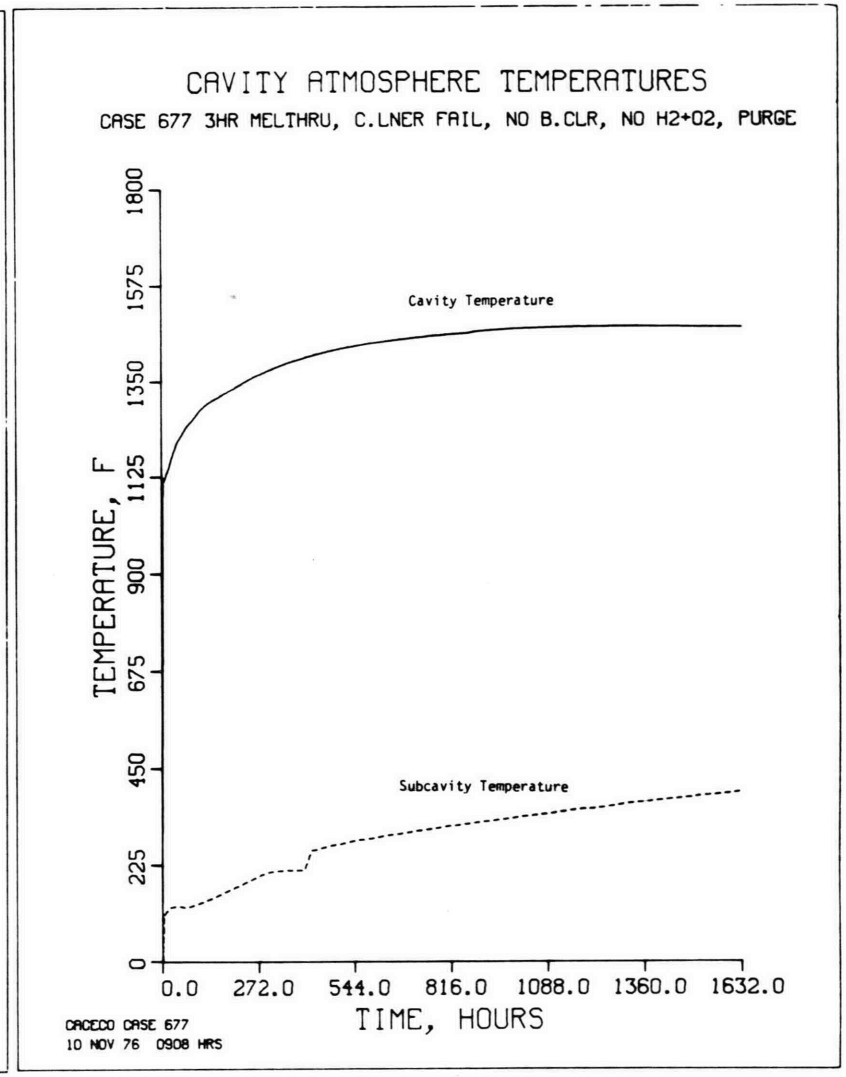

BUILDING ROOF TEMPERATURE
CASE 677 3HR MELTHRU, C.LNER FAIL, NO B.CLR, NO H2+02, PURGE
R.C.BLDG ROOF, 34,200-FT2, 1.1-IN.C.STEEL. INSIDE LEFT, OUTSIDE(
TEMPERATURE, F
0
100
200
300
400
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 677
10 NOV 76 0908 HRS

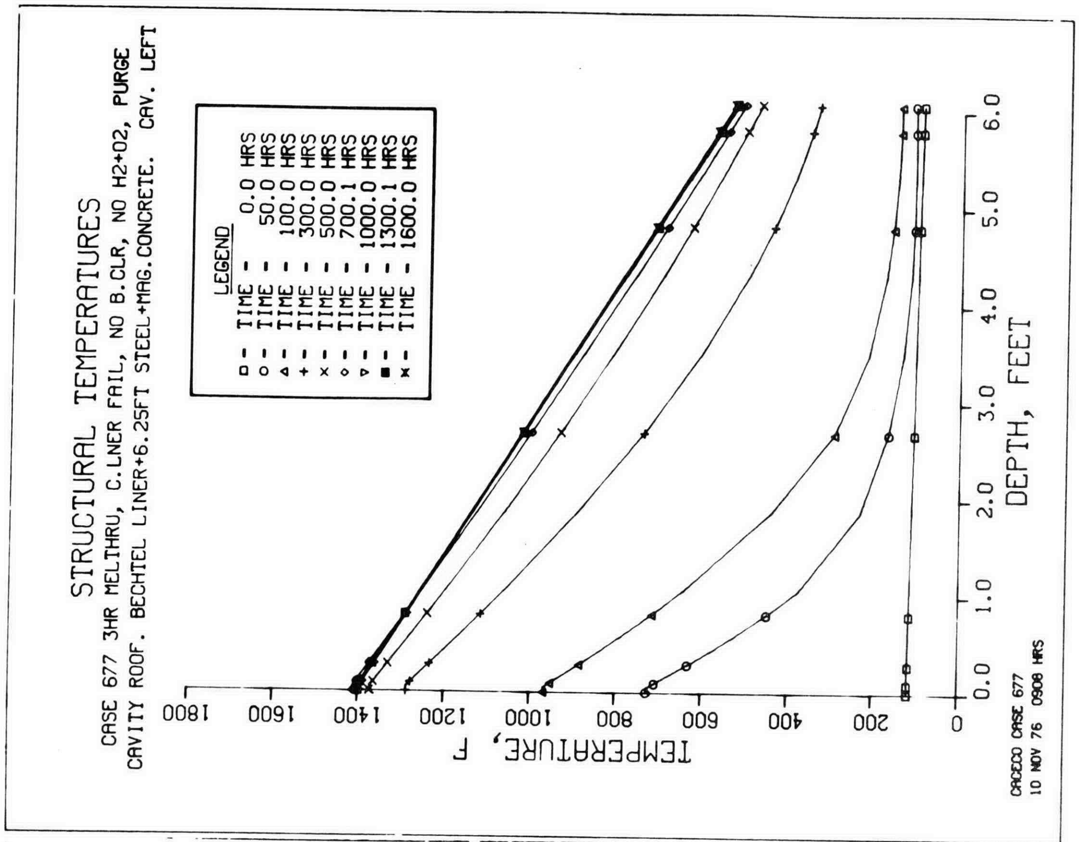

BUILDING ATMOSPHERE CONDITIONS
CASE 677 3HR MELTHRU, C.LNER FAIL, NO B.CLR, NO H2+02, PURGE
TEMPERATURE, F
0
100
200
300
400
PRESS. PSIG
0
5
10
PERCENT H2
0
2.5
5
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS

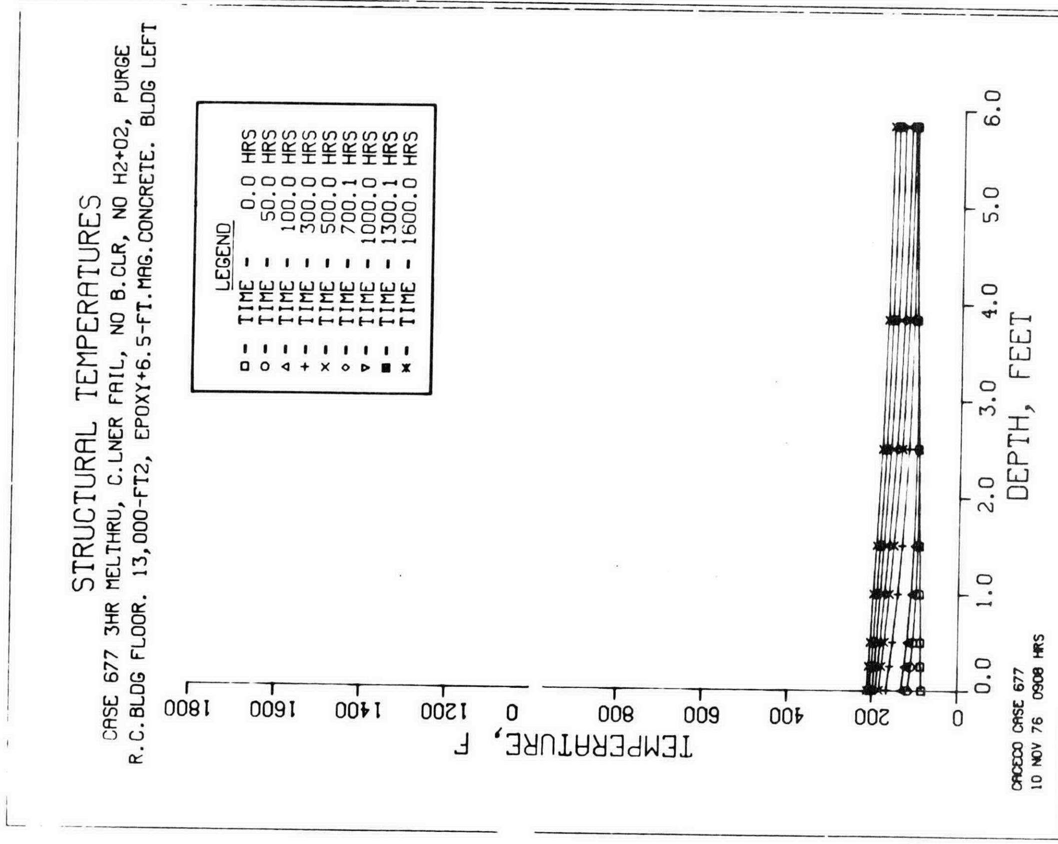

BUILDING AVG. VENT RATE
CASE 677 3HR MELTHRU, C.LNER FAIL, NO B.CLR, NO H2+O2, PURGE
FLOW RATE, SCFM
0
1500
3000
4500
6000
7500
9000
10500
12000
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 677
10 NOV 76 0908 HRS

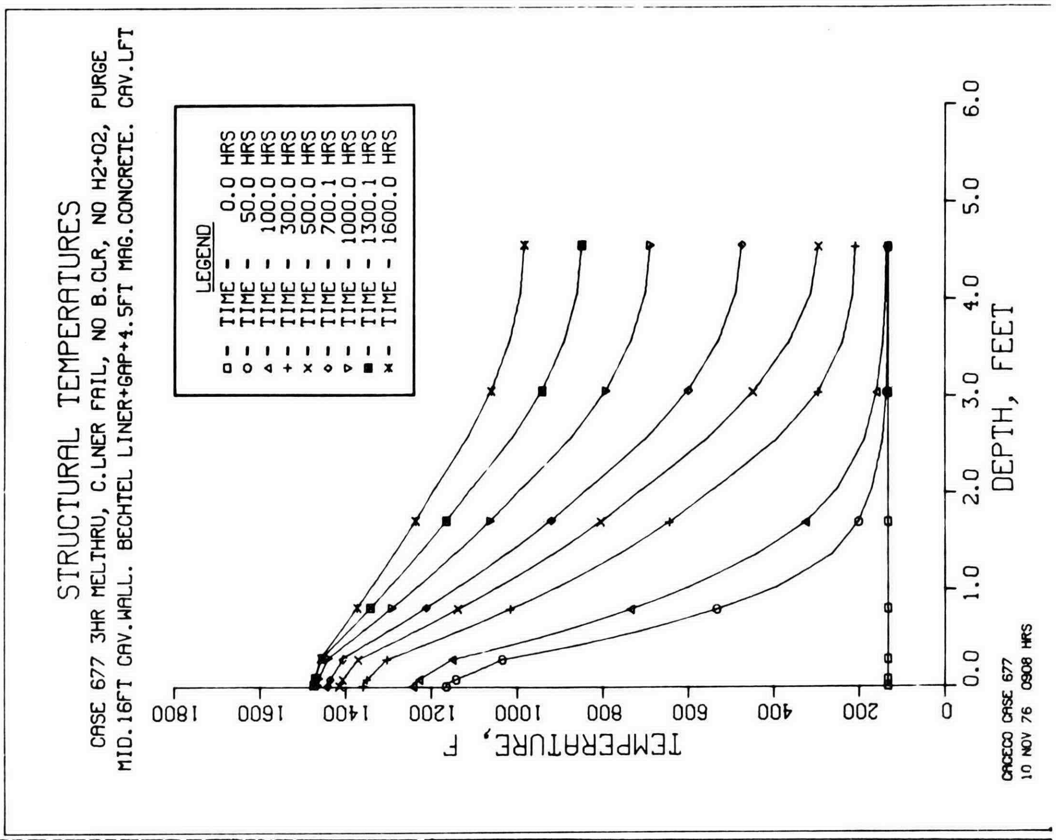

SODIUM TEMPERATURE
CASE 677 3HR MCLTHRU, C.LNER FAIL, NO B.CLR, NO H2+O2, PURGE
TEMPERATURE, F
950
1050
1150
1250
1350
1450
1550
1650
1750
Reactor Vessel
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 677
10 NOV 76 0908 HRS

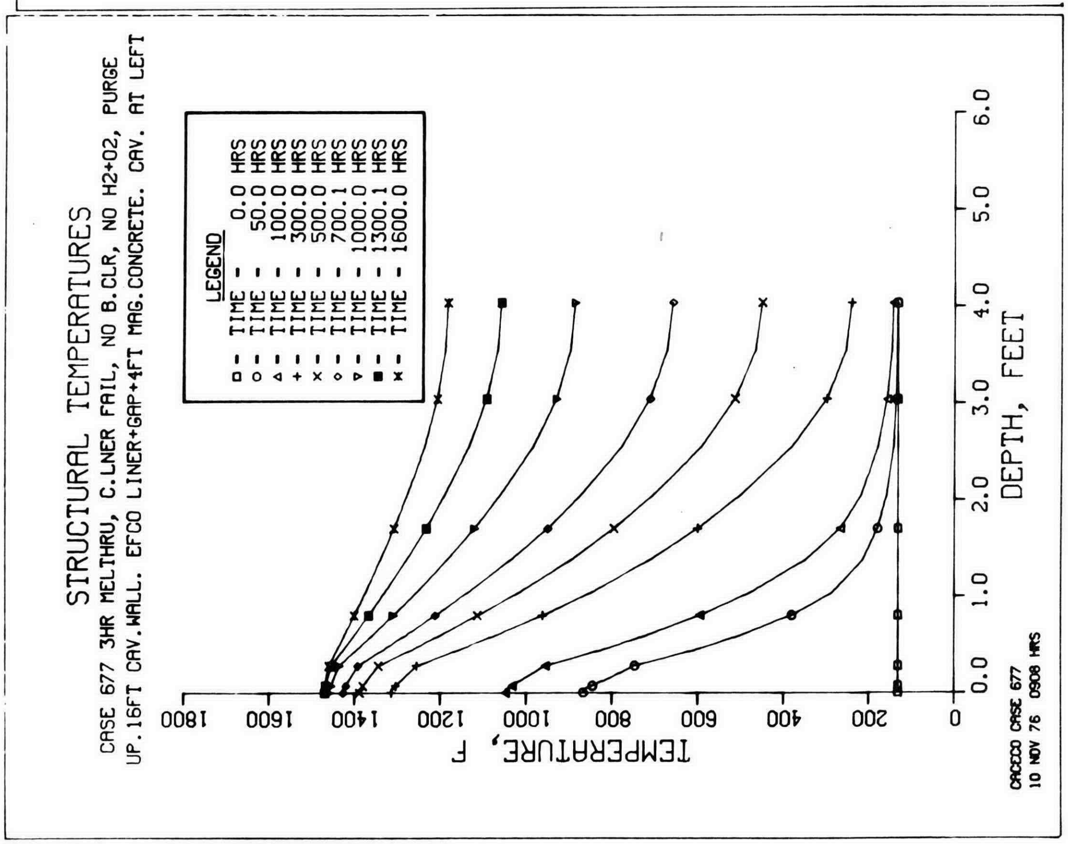

SODIUM INVENTORY
CASE 677 3HR MELTHRU, C.LNER FAIL, NO B.CLR, NO H2+02, PURGE
SODIUM IN VESSEL, LBS
0
100000
200000
300000
400000
500000
600000
700000
0
272
544
816
1088
1360
1632
TIME, HOURS
CACECO CASE 677
10 NOV 76 0908 HRS

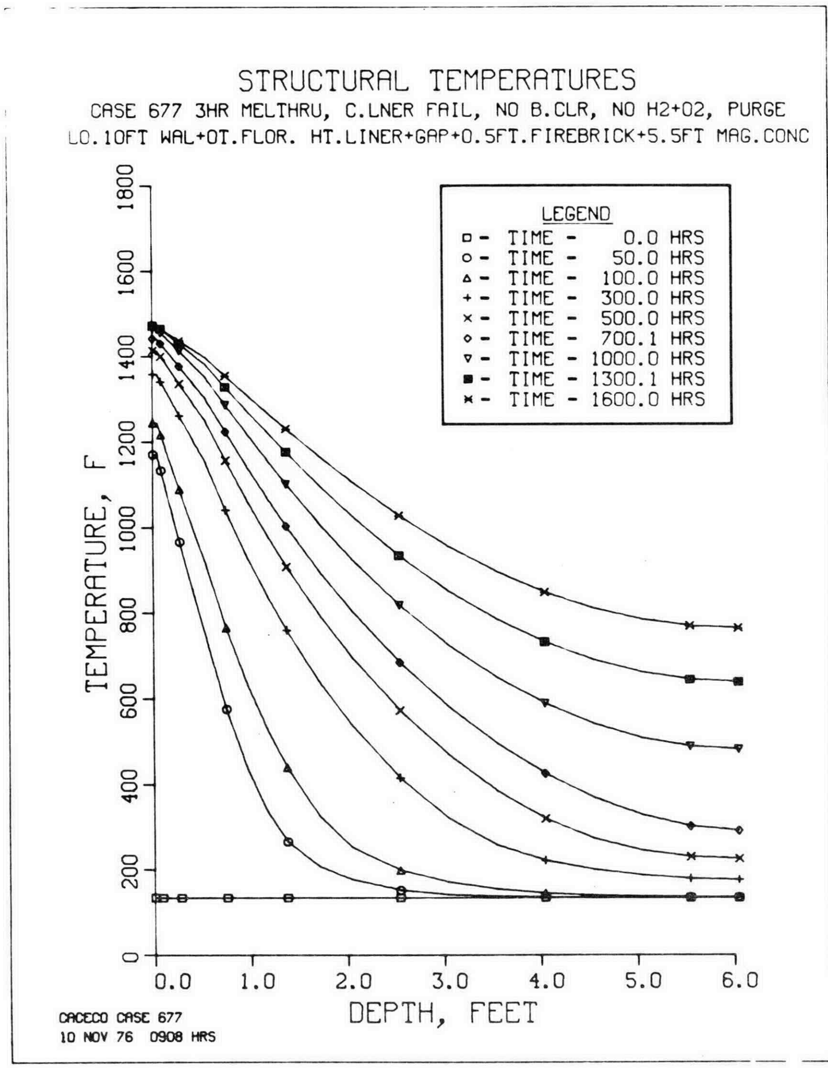

CAVITY ATMOSPHERE TEMPERATURES
CASE 677 3HR MELTHRU, C.LNER FAIL, NO B.CLR, NO H2+02, PURGE
TEMPERATURE, F
0
225
450
675
900
1125
1350
1575
1800
Cavity Temperature
Subcavity Temperature
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 677
10 NOV 76 0908 HRS

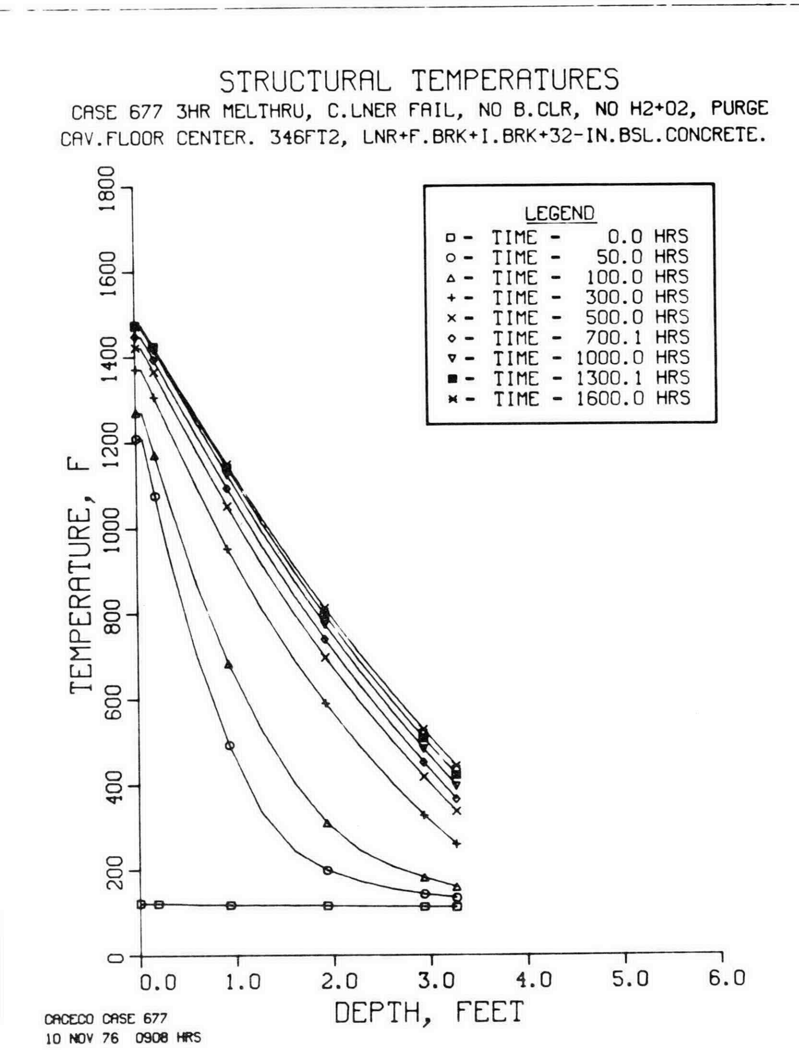

STRUCTURAL TEMPERATURES
CASE 677 3HR MELTHRU, C.LNER FAIL, NO B.CLR, NO H2+O2, PURGE
CAVITY ROOF. BECHTEL LINER+6.25FT STEEL+MAG.CONCRETE. CAV. LEFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.1 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✕ - TIME - 1600.0 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 677
10 NOV 76 0908 HRS


STRUCTURAL TEMPERATURES
CASE 677 3HR MELTHRU, C.LNER FAIL, NO B.CLR, NO H2+O2, PURGE
R.C.BLDG FLOOR. 13,000-FT2, EPOXY+6.5-FT.MAG.CONCRETE. BLDG LEFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.1 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✕ - TIME - 1600.0 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 677
10 NOV 76 0908 HRS


STRUCTURAL TEMPERATURES
CASE 677 3HR MELTHRU, C.LNER FAIL, NO B.CLR, NO H2+O2, PURGE
MID.16FT CAV.WALL. BECHTEL LINER+GAP+4.5FT MAG.CONCRETE. CAV.LFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.1 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✕ - TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 677
10 NOV 76 0908 HRS

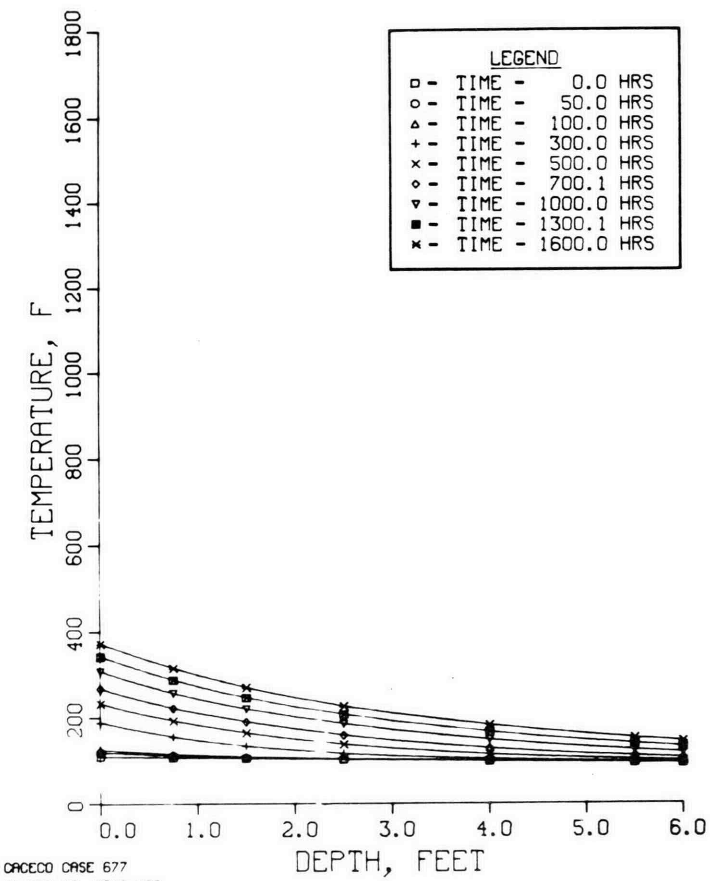

STRUCTURAL TEMPERATURES
CASE 677 3HR MELTHRU, C.LNER FAIL, NO B.CLR, NO H2+O2, PURGE
UP.16FT CAV.WALL. EFCO LINER+GAP+4FT MAG.CONCRETE. CAV. AT LEFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.1 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✕ - TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 677
10 NOV 76 0908 HRS


STRUCTURAL TEMPERATURES
CASE 677 3HR MELTHRU, C.LNER FAIL, NO B.CLR, NO H2+O2, PURGE
LO.10FT WAL+OT.FLOR. HT.LINER+GAP+0.5FT.FIREBRICK+5.5FT MAG.CONC
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.1 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 677
10 NOV 76 0908 HRS


STRUCTURAL TEMPERATURES
CASE 677 3HR MELTHRU, C.LNER FAIL, NO B.CLR, NO H2+O2, PURGE
CAV.FLOOR CENTER. 346FT2, LNR+F.BRK+I.BRK+32-IN.BSL.CONCRETE.
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.1 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 677
10 NOV 76 0908 HRS

STRUCTURAL TEMPERATURES

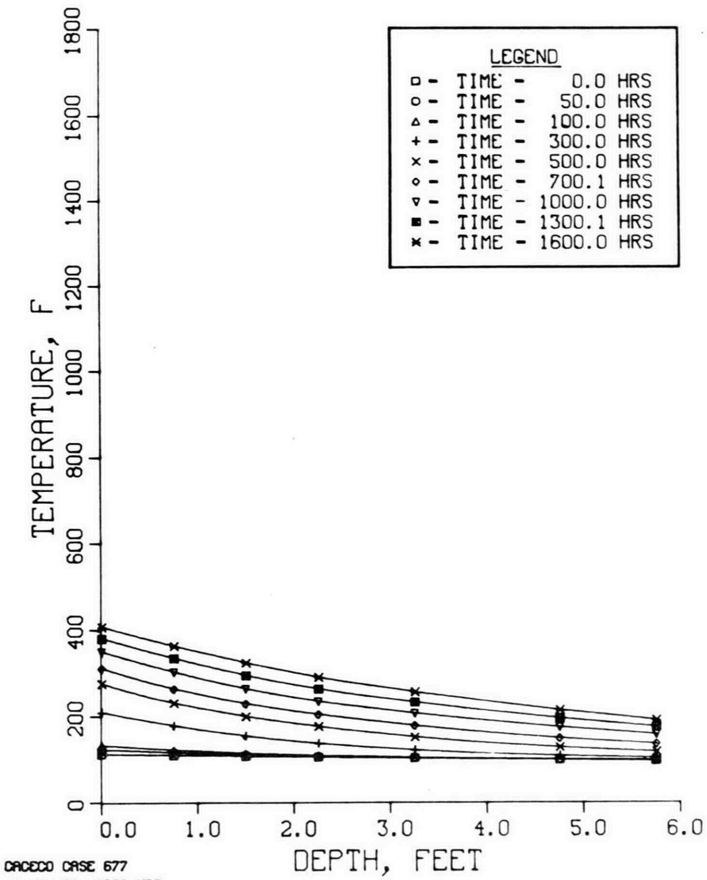
CASE 677 3HR MELTHRU, C.LNER FAIL, NO B.CLR, NO H2+02, PURGE
SUB.CAVITY WALLS. 700 FT2 OF 12-FT THICK MAG.CONCRETE. S.CAV.LF



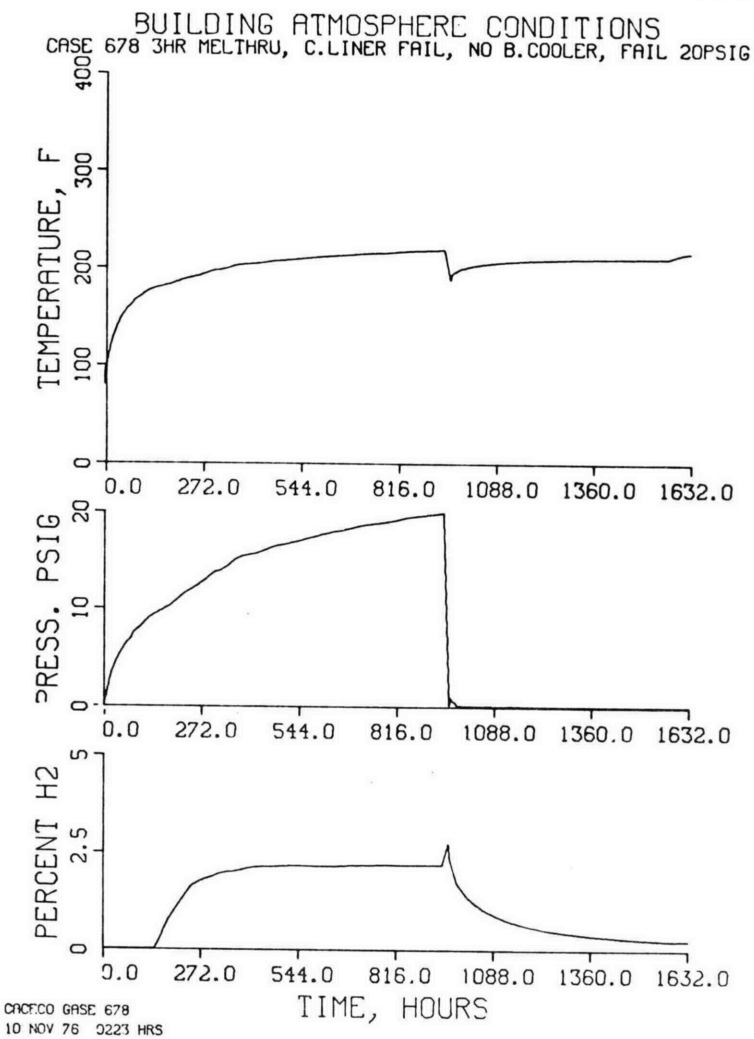
CACECO CASE 677
10 NOV 76 0908 HRS

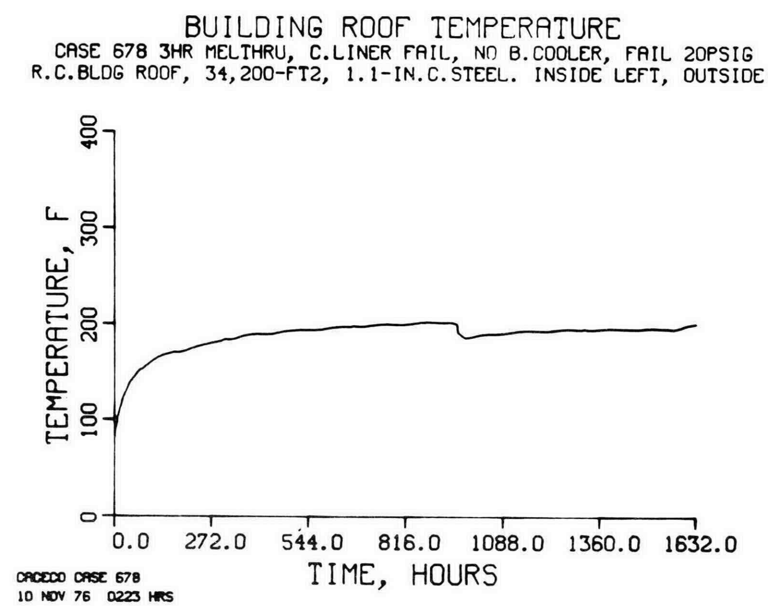
STRUCTURAL TEMPERATURES

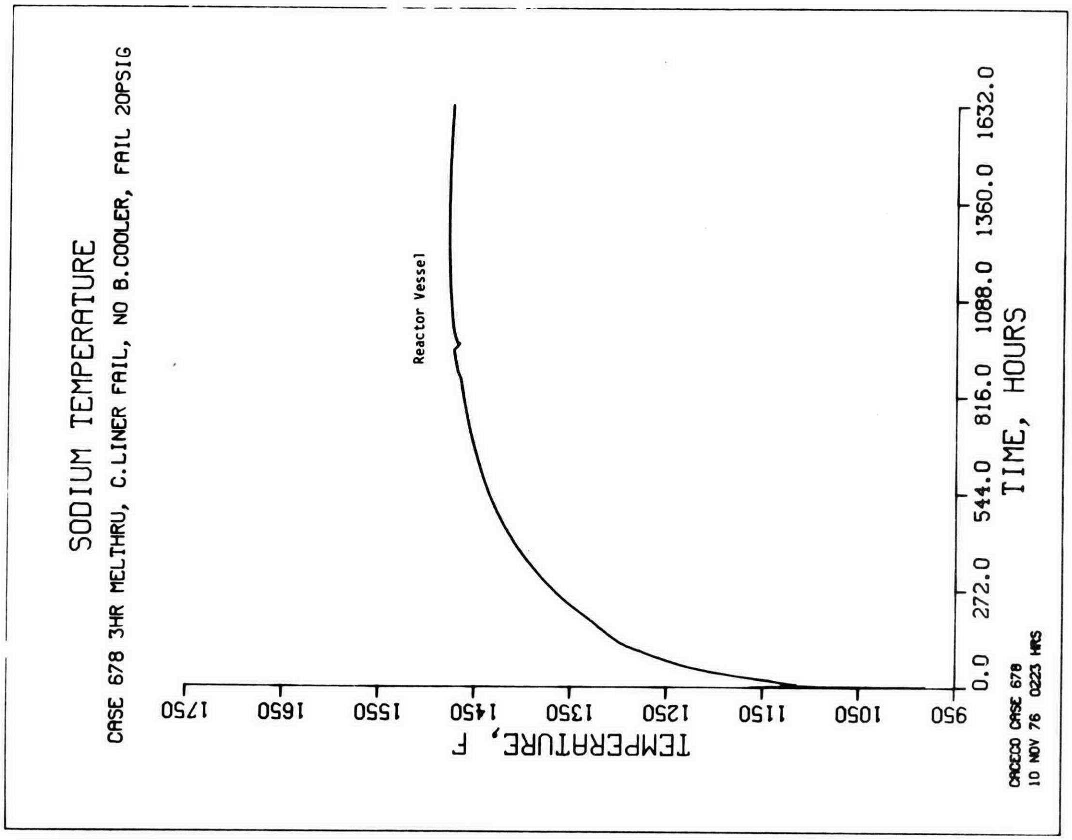
CASE 677 3HR MELTHRU, C.LNER FAIL, NO B.CLR, NO H2+02, PURGE
SUB.CAVITY FLOOR. 346 FT2 OF 6.8-FT BSL.CONCRETE. SUB.CAV. LEFT

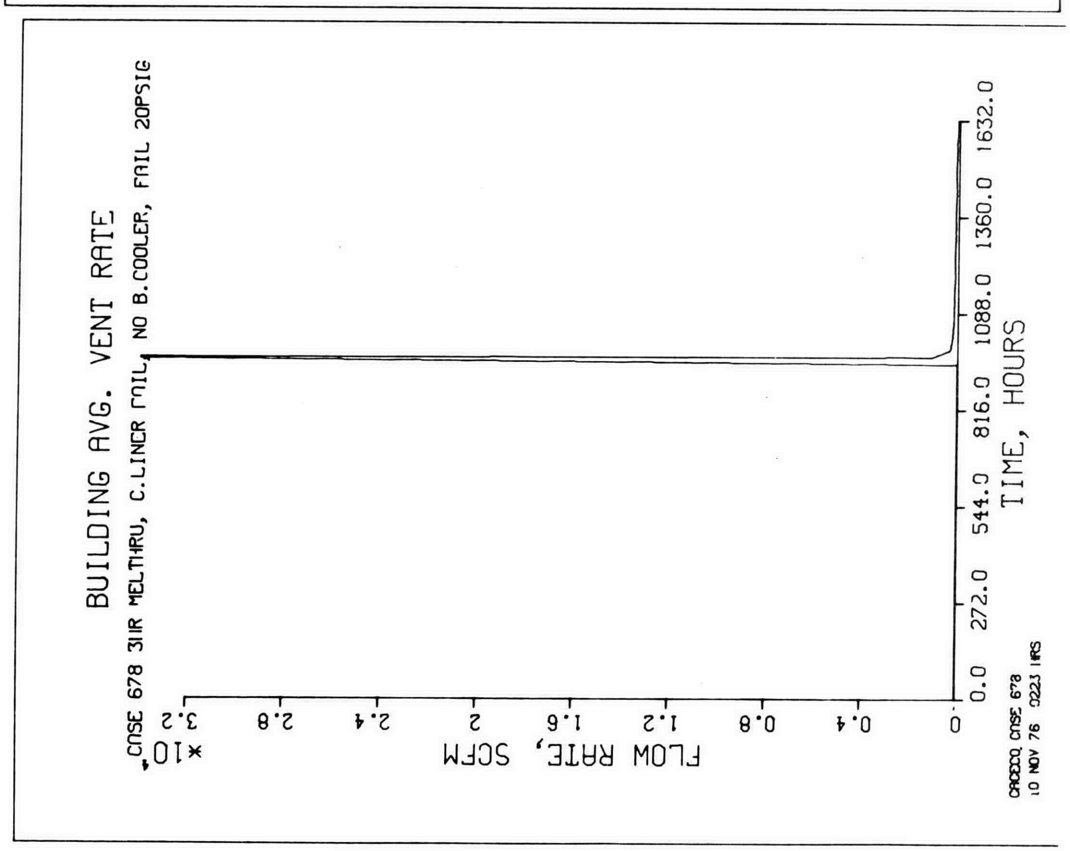


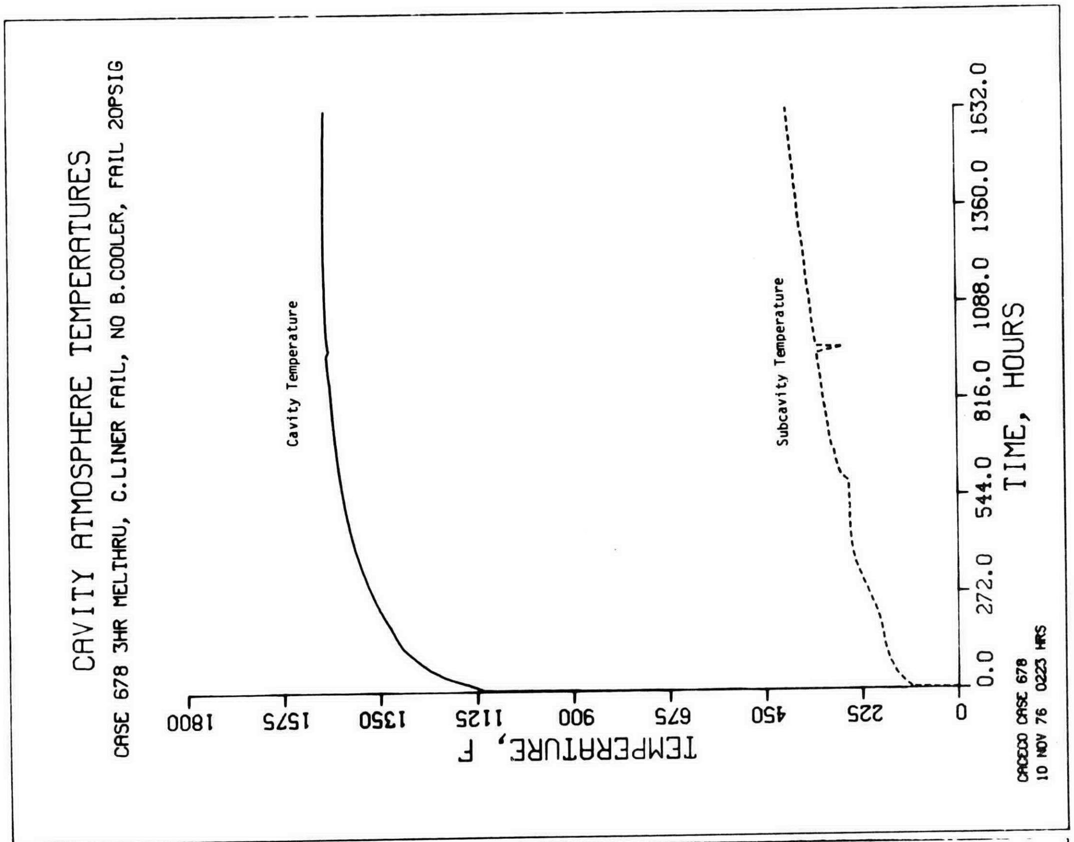
CACECO CASE 677
10 NOV 76 0908 HRS

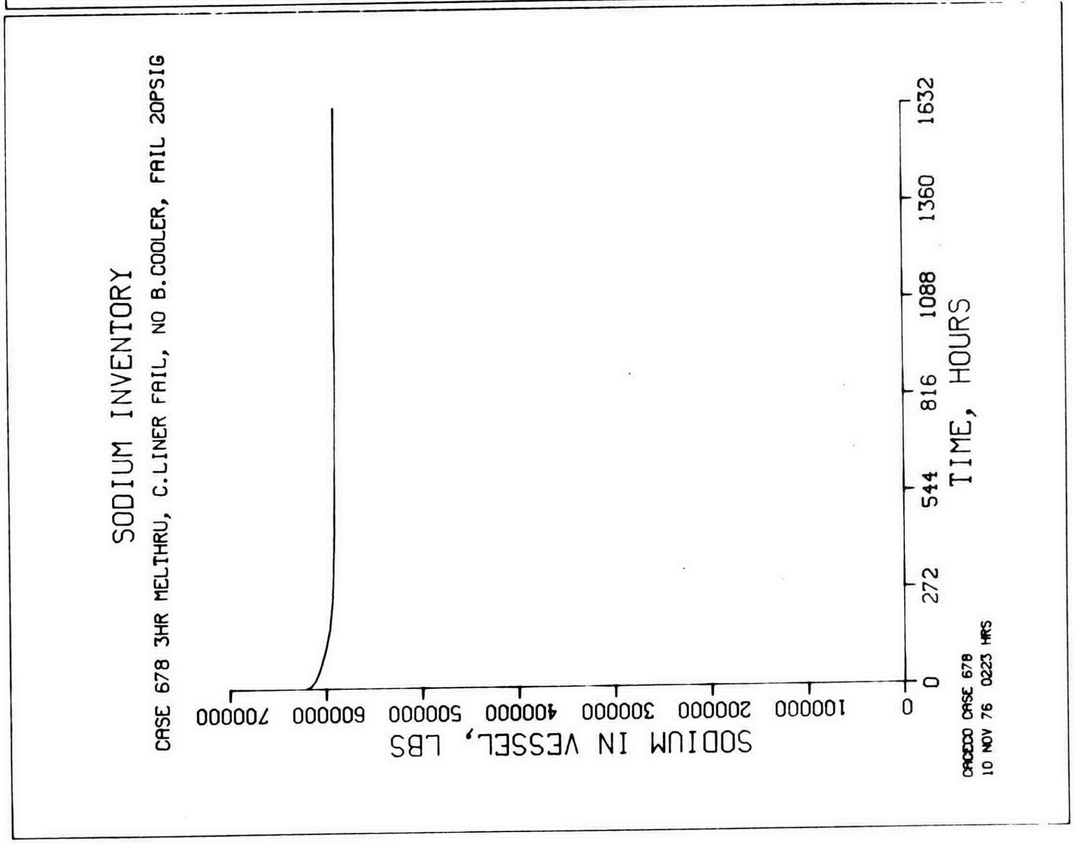

BUILDING ATMOSPHERE CONDITIONS
CASE 678 3HR MELTHRU, C.LINER FAIL, NO B.COOLER, FAIL 20PSIG
TEMPERATURE, F
PRESS. PSIG
PERCENT H2
TIME, HOURS
CACECO CASE 678
10 NOV 76 0223 HRS

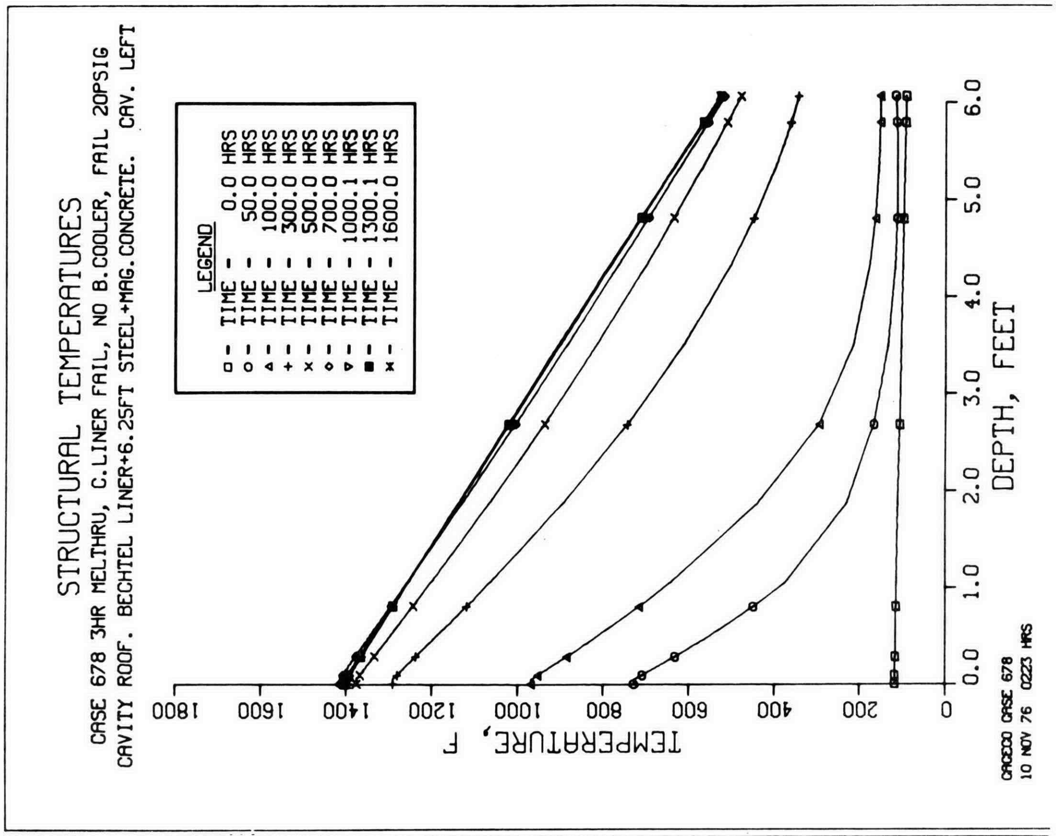

BUILDING ROOF TEMPERATURE
CASE 678 3HR MELTHRU, C.LINER FAIL, NO B.COOLER, FAIL 20PSIG
R.C.BLDG ROOF, 34,200-FT2, 1.1-IN.C.STEEL. INSIDE LEFT, OUTSIDE(
TEMPERATURE, F
TIME, HOURS
CACECO CASE 678
10 NOV 76 0223 HRS


SODIUM TEMPERATURE
CASE 678 3HR MELTHRU, C.LINER FAIL, NO B.COOLER, FAIL 20PSIG
Reactor Vessel
TEMPERATURE, F
950 1050 1150 1250 1350 1450 1550 1650 1750
TIME, HOURS
0.0 272.0 544.0 816.0 1088.0 1360.0 1632.0
CACECO CASE 678
10 NOV 76 0223 HRS

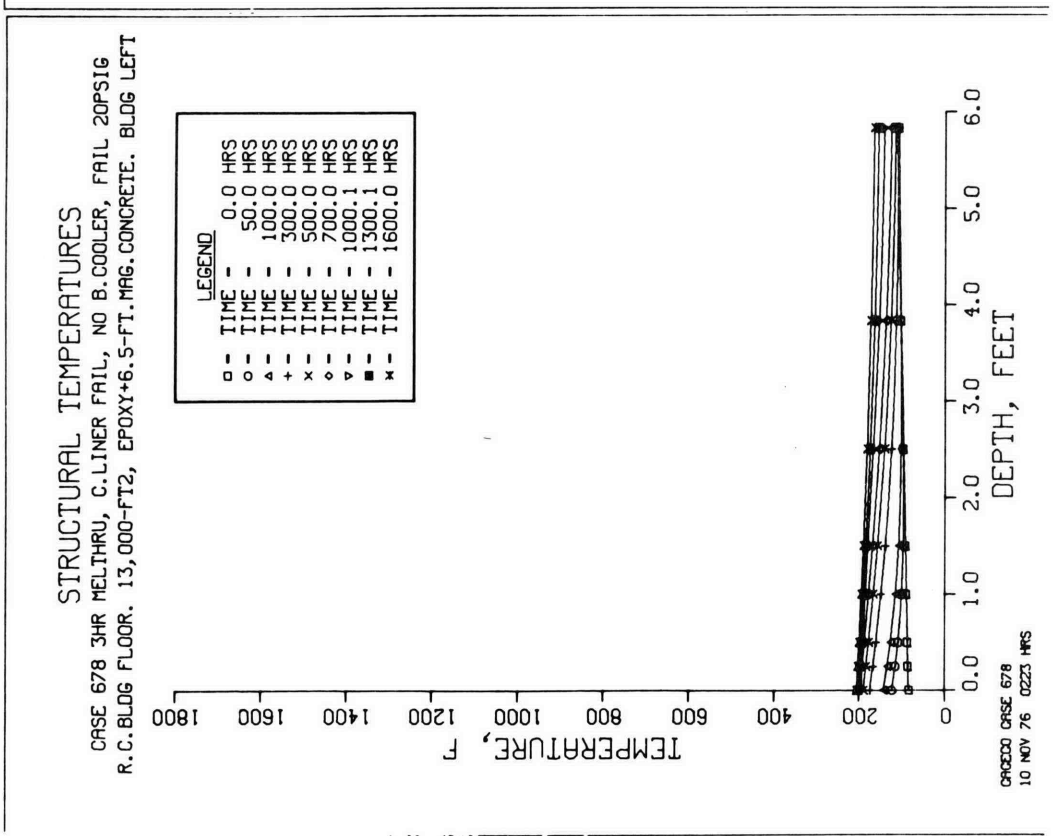

BUILDING AVG. VENT RATE
CASE 678 3HR MELTHRU, C.LINER FAIL, NO B.COOLER, FAIL 20PSIG
FLOW RATE, SCFM
*10⁴
0 0.4 0.8 1.2 1.6 2 2.4 2.8 3.2
TIME, HOURS
0.0 272.0 544.0 816.0 1088.0 1360.0 1632.0
CACECO CASE 678
10 NOV 76 0223 HRS


CAVITY ATMOSPHERE TEMPERATURES
CASE 678 3HR MELTHRU, C.LINER FAIL, NO B.COOLER, FAIL 20PSIG
Cavity Temperature
Subcavity Temperature
TEMPERATURE, F
0
225
450
675
900
1125
1350
1575
1800
TIME, HOURS
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
CACECO CASE 678
10 NOV 76 0223 HRS

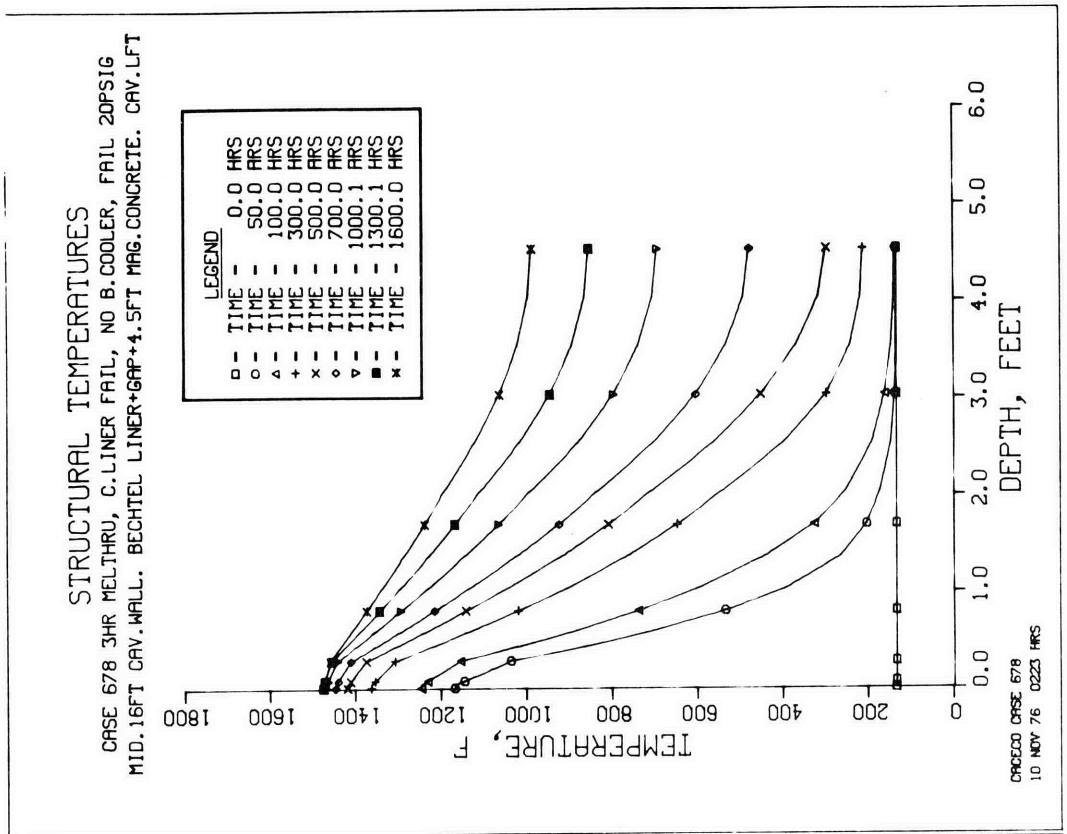

SODIUM INVENTORY
CASE 678 3HR MELTHRU, C.LINER FAIL, NO B.COOLER, FAIL 20PSIG
SODIUM IN VESSEL, LBS
0
100000
200000
300000
400000
500000
600000
700000
TIME, HOURS
0
272
544
816
1088
1360
1632
CACECO CASE 678
10 NOV 76 0223 HRS

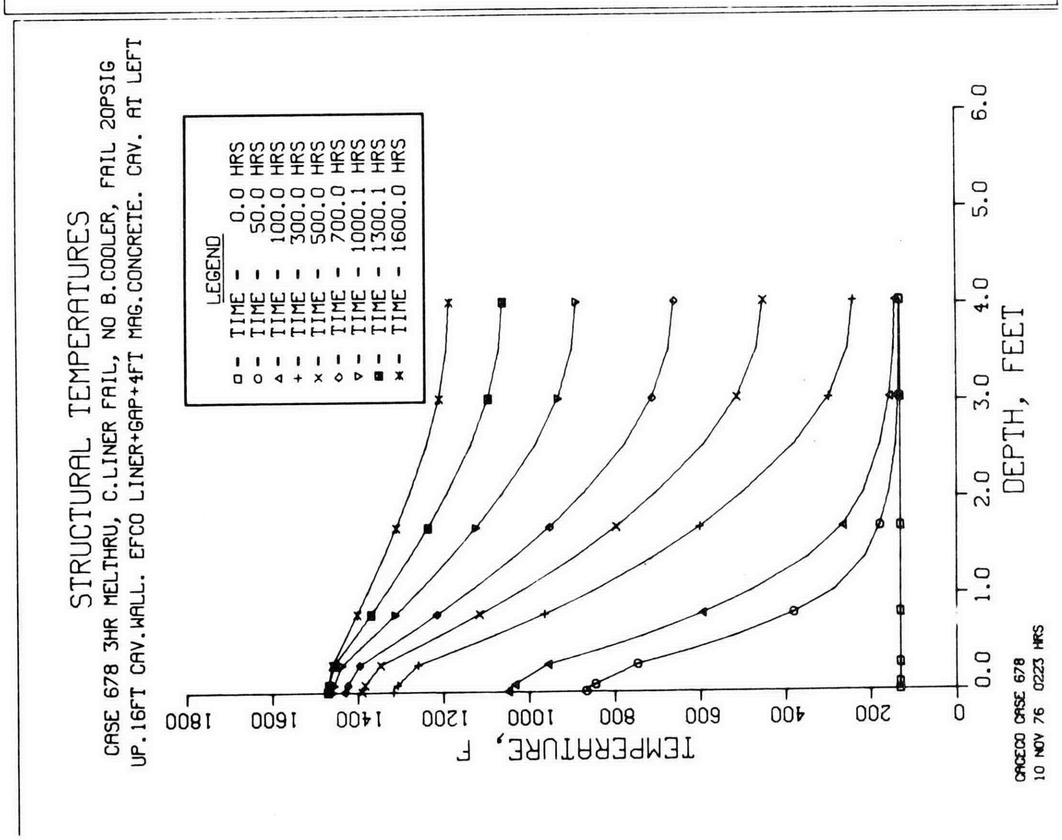


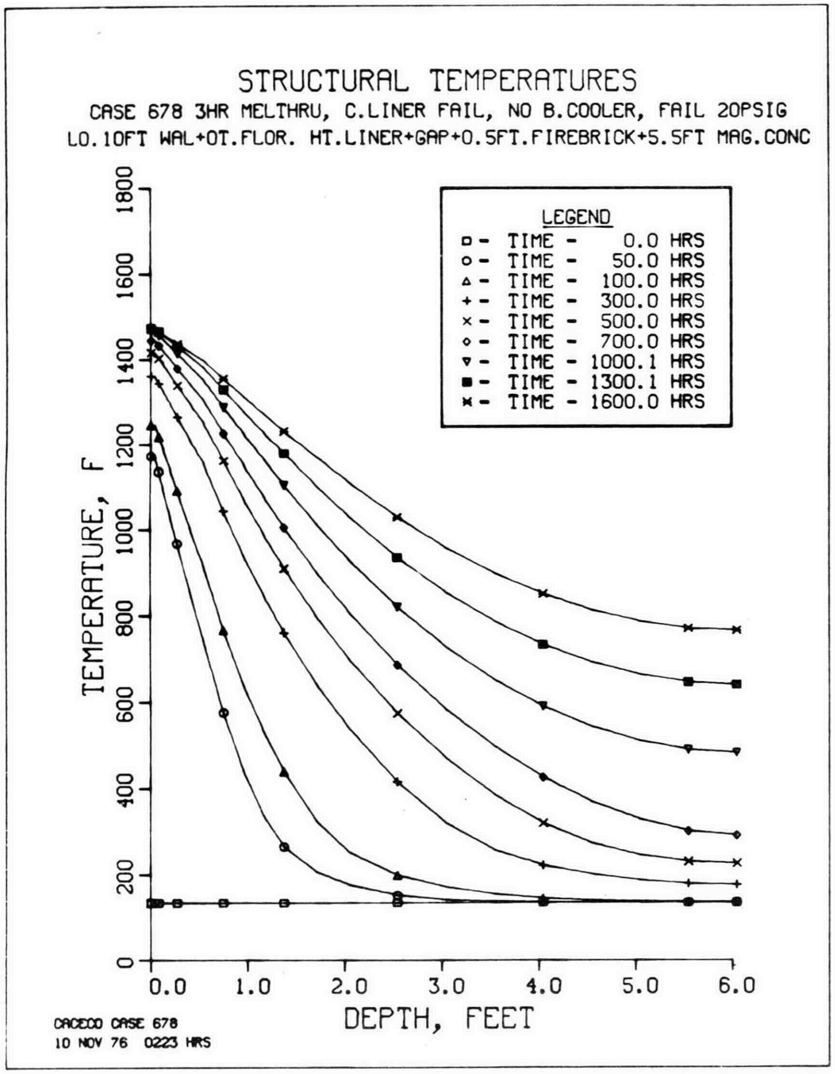
STRUCTURAL TEMPERATURES
CASE 678 3HR MELTHRU, C.LINER FAIL, NO B.COOLER, FAIL 20PSIG
CAVITY ROOF. BECHTEL LINER+6.25FT STEEL+MAG.CONCRETE. CAV. LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 678
10 NOV 76 0223 HRS

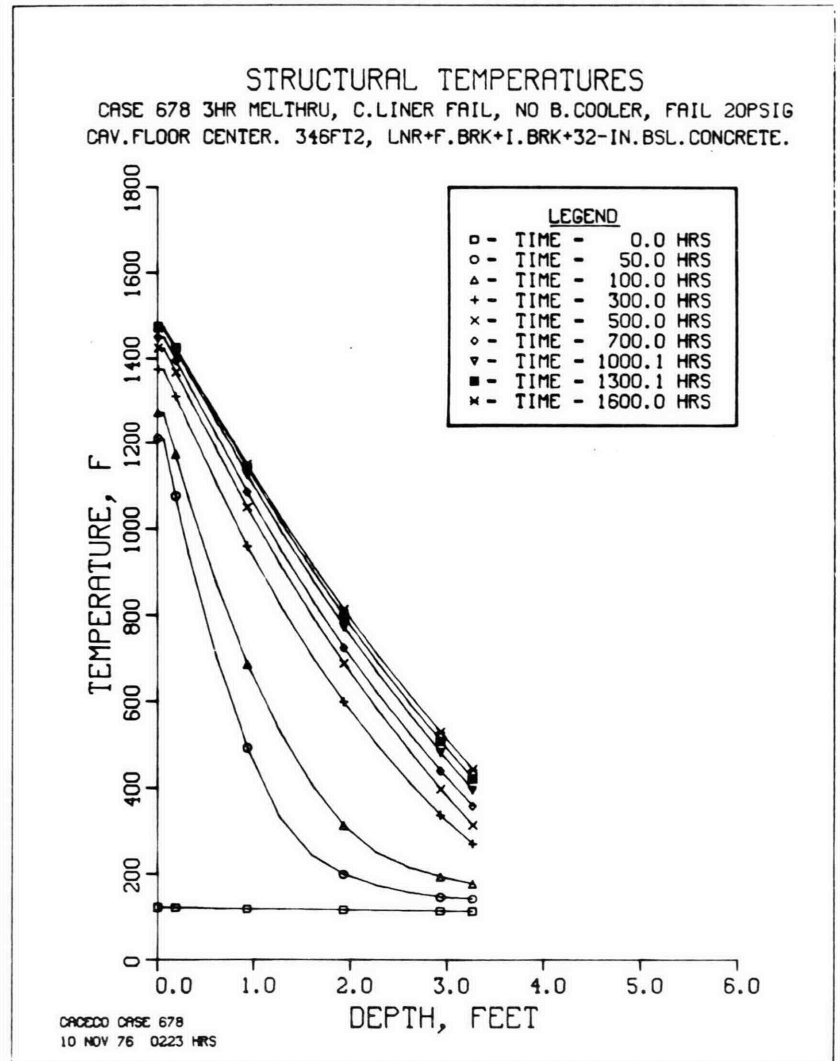


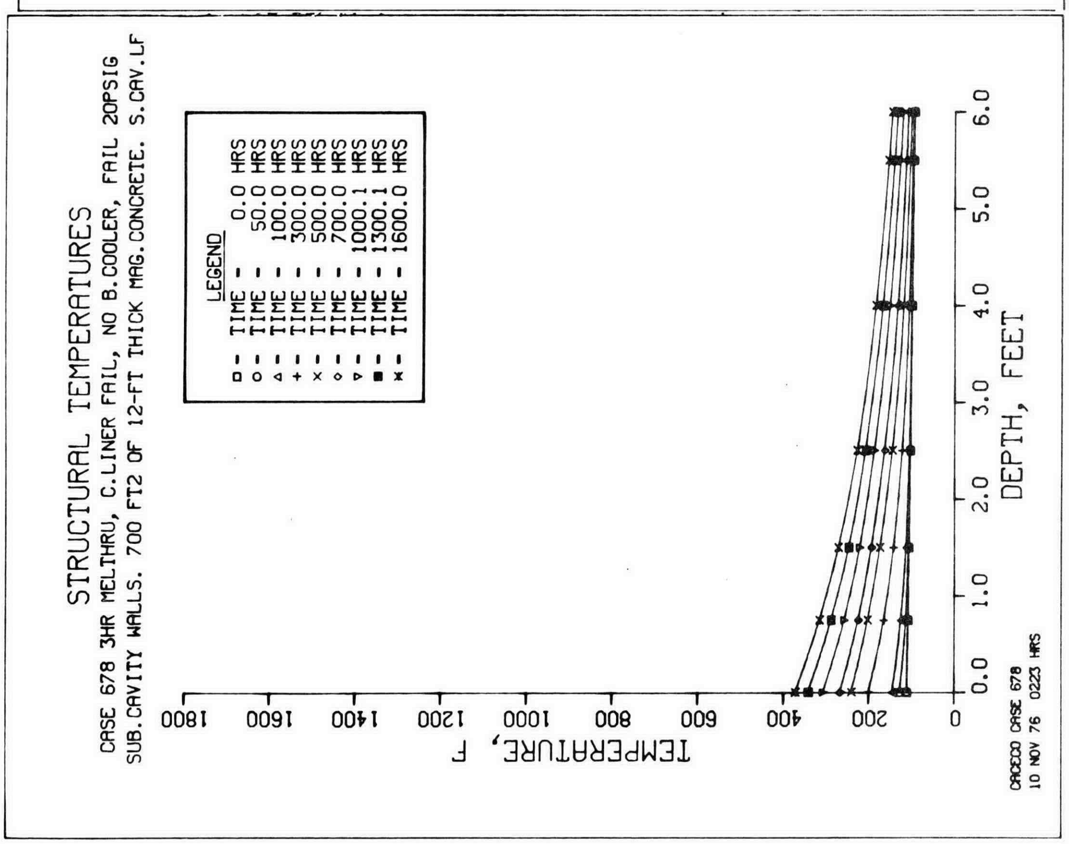
STRUCTURAL TEMPERATURES
CASE 678 3HR MELTHRU, C.LINER FAIL, NO B.COOLER, FAIL 20PSIG
R.C.BLDG FLOOR. 13,000-FT2, EPOXY+6.5-FT.MAG.CONCRETE. BLDG LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 678
10 NOV 76 0223 HRS


STRUCTURAL TEMPERATURES
CASE 678 3HR MELTHRU, C.LINER FAIL, NO B.COOLER, FAIL 20PSIG
MID.16FT CAV.WALL. BECHTEL LINER+GAP+4.5FT MAG.CONCRETE. CAV.LFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 678
10 NOV 76 0223 HRS

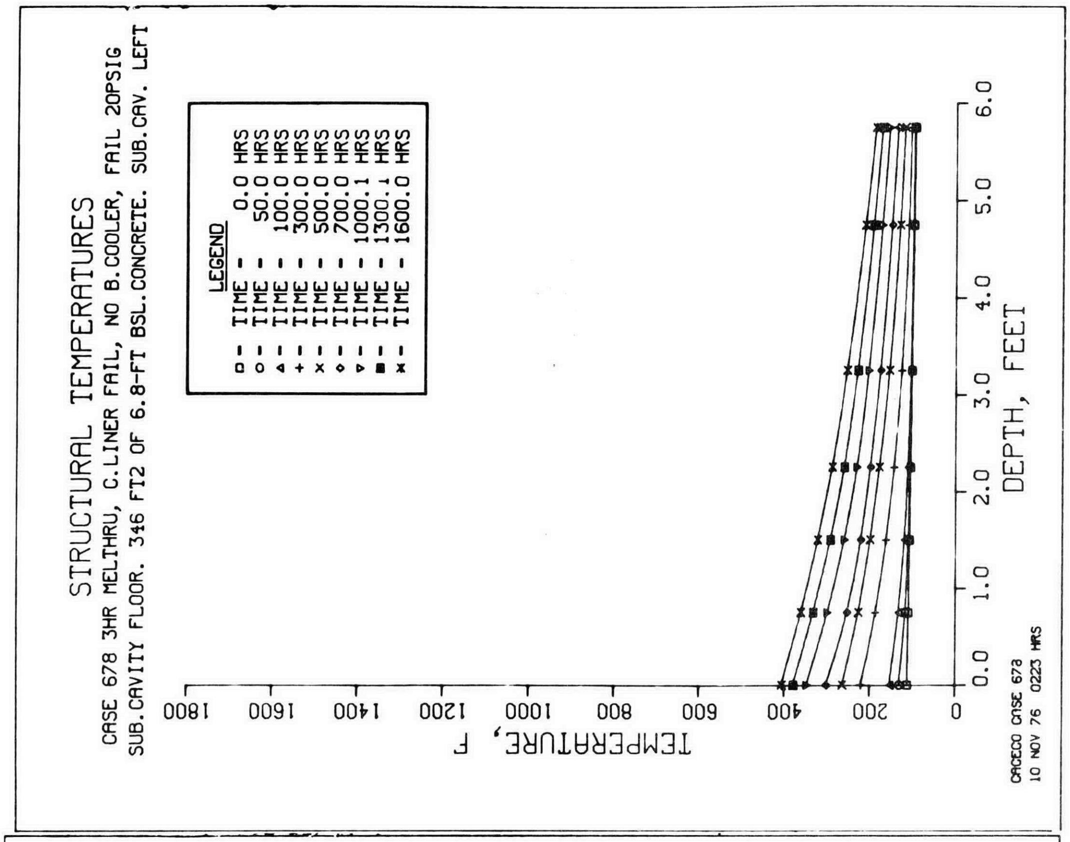

STRUCTURAL TEMPERATURES
CASE 678 3HR MELTHRU, C.LINER FAIL, NO B.COOLER, FAIL 20PSIG
UP.16FT CAV.WALL. EFCO LINER+GAP+4FT MAG.CONCRETE. CAV. AT LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 678
10 NOV 76 0223 HRS


STRUCTURAL TEMPERATURES
CASE 678 3HR MELTHRU, C.LINER FAIL, NO B.COOLER, FAIL 20PSIG
LO.10FT WAL+OT.FLOR. HT.LINER+GAP+0.5FT.FIREBRICK+5.5FT MAG.CONC
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 678
10 NOV 76 0223 HRS

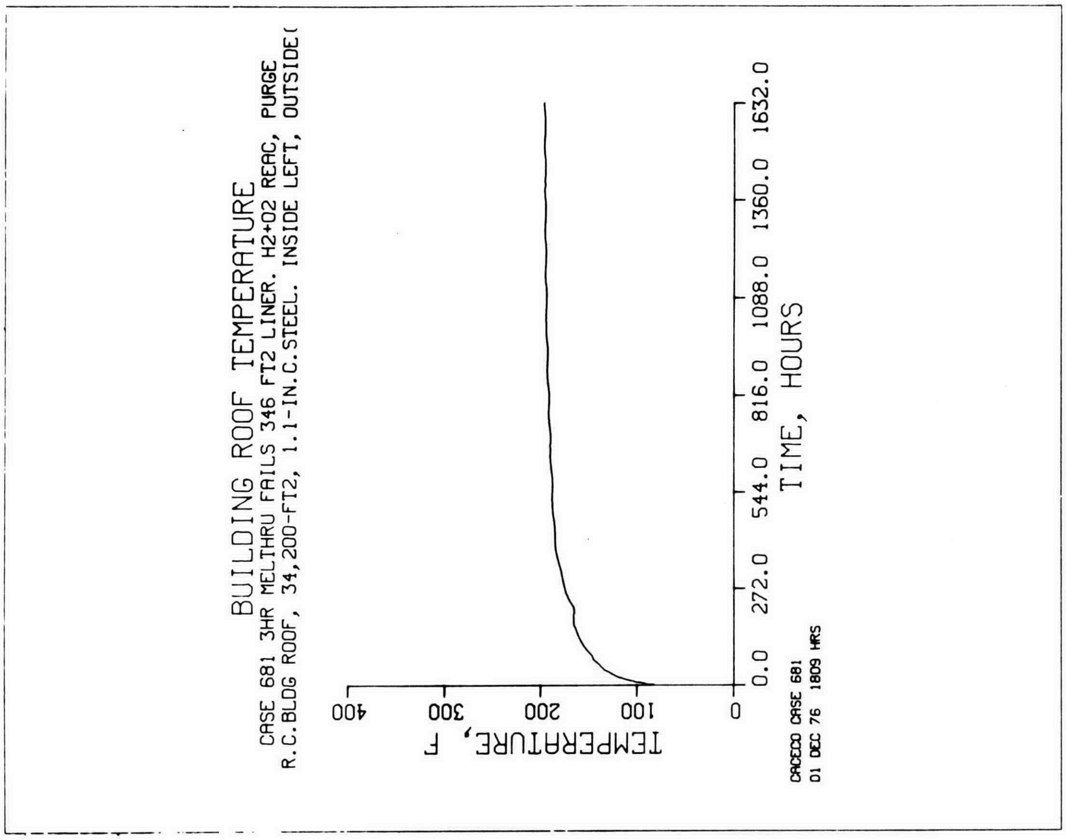

STRUCTURAL TEMPERATURES
CASE 678 3HR MELTHRU, C.LINER FAIL, NO B.COOLER, FAIL 20PSIG
CAV.FLOOR CENTER. 346FT2, LNR+F.BRK+I.BRK+32-IN.BSL.CONCRETE.
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 678
10 NOV 76 0223 HRS

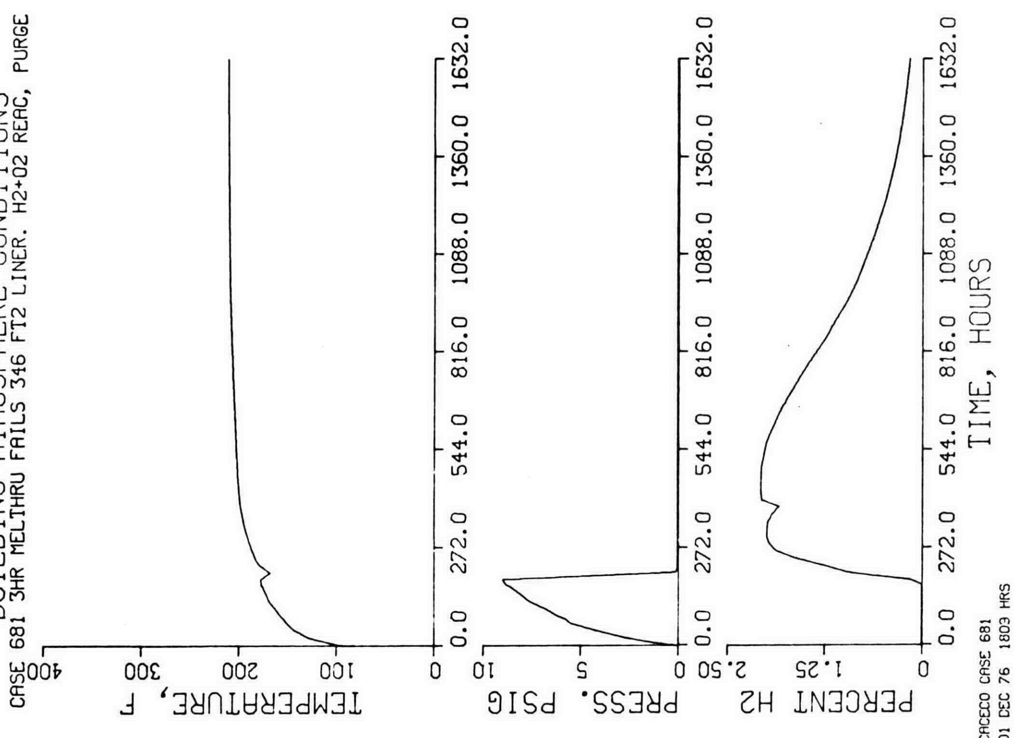


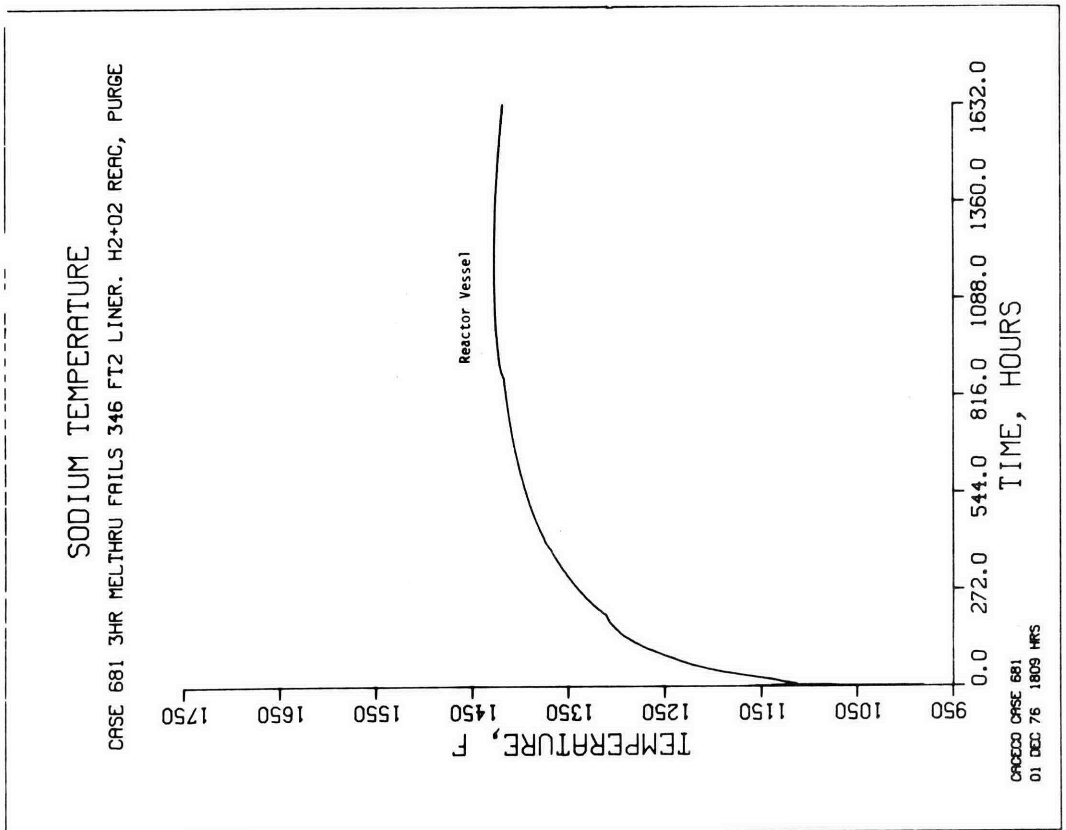
STRUCTURAL TEMPERATURES
CASE 678 3HR MELTHRU, C.LINER FAIL, NO B.COOLER, FAIL 20PSIG
SUB.CAVITY WALLS. 700 FT2 OF 12-FT THICK MAG.CONCRETE. S.CAV.LF
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CADECO CASE 678
10 NOV 76 0223 HRS



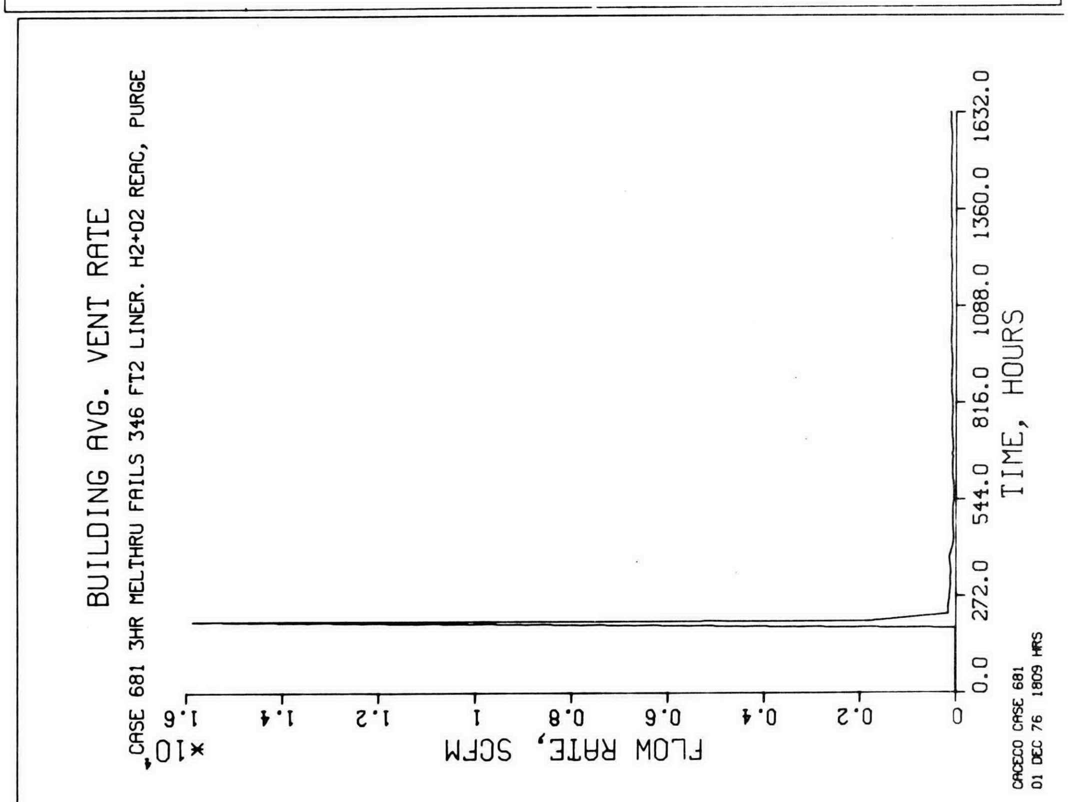
STRUCTURAL TEMPERATURES
CASE 678 3HR MELTHRU, C.LINER FAIL, NO B.COOLER, FAIL 20PSIG
SUB.CAVITY FLOOR. 346 FT2 OF 6.8-FT BSL.CONCRETE. SUB.CAV. LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CADECO CASE 678
10 NOV 76 0223 HRS


BUILDING ROOF TEMPERATURE
CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+02 REAC, PURGE
R.C.BLDG ROOF, 34,200-FT2, 1.1-IN.C.STEEL. INSIDE LEFT, OUTSIDE(
TEMPERATURE, F
0
100
200
300
400
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 681
01 DEC 76 1809 HRS

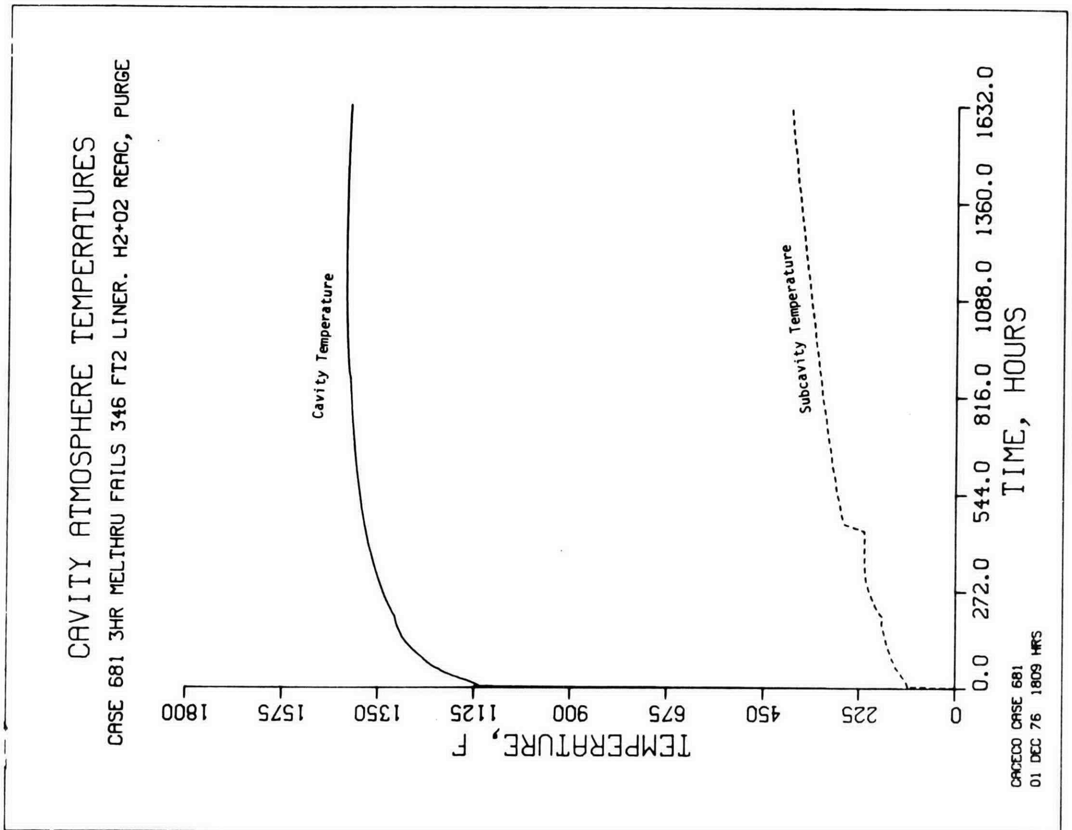

BUILDING ATMOSPHERE CONDITIONS
CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+02 REAC, PURGE
TEMPERATURE, F
0
100
200
300
400
PRESS. PSIG
0
5
10
PERCENT H2
0
1.25
2.50
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 681
01 DEC 76 1803 HRS

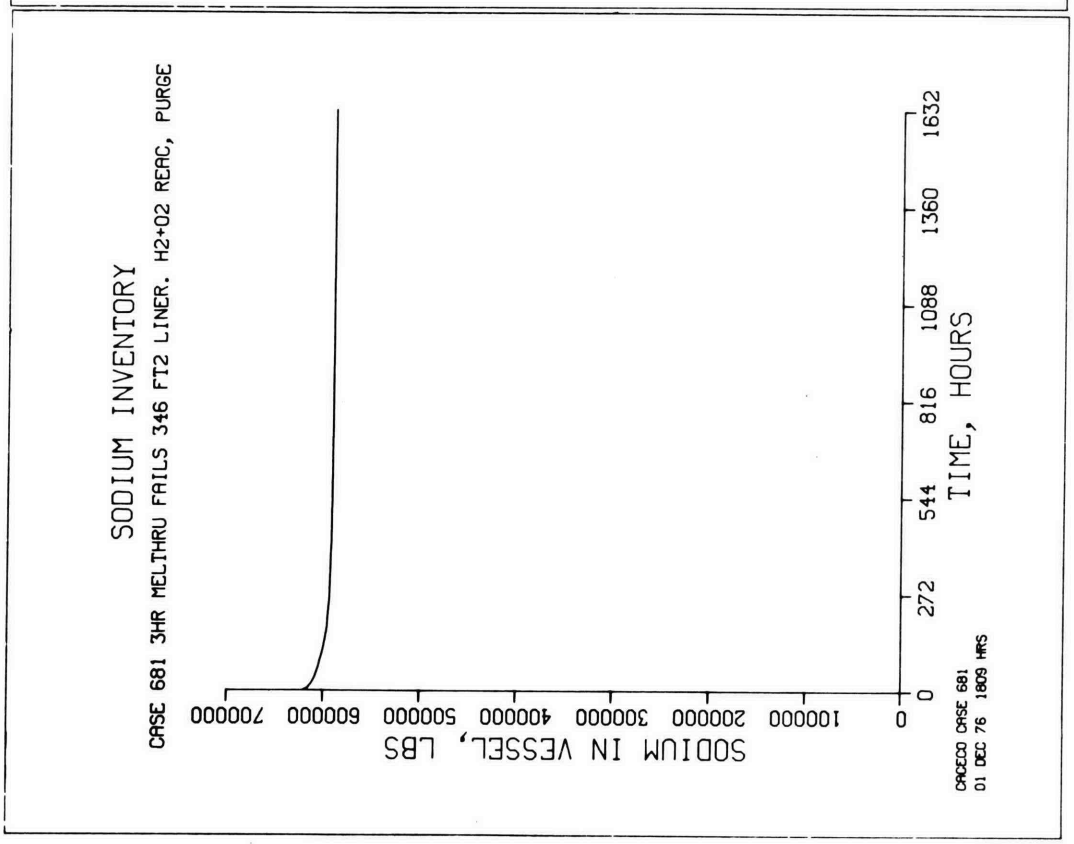


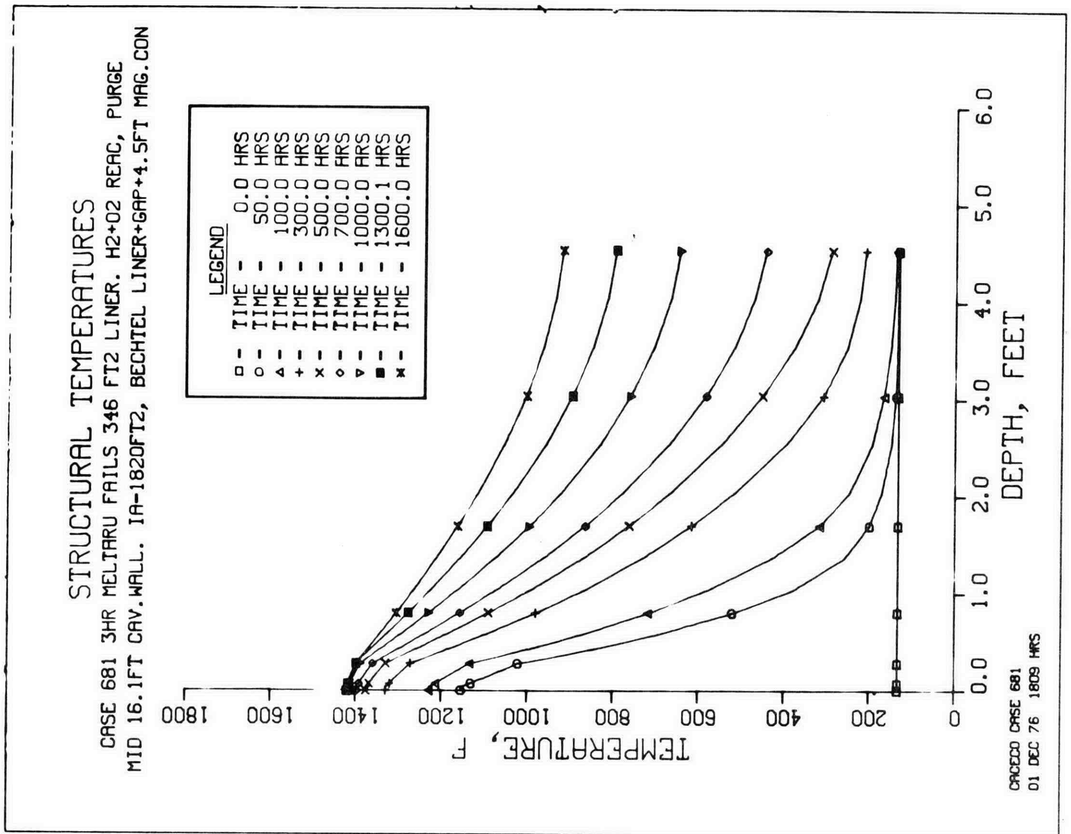
SODIUM TEMPERATURE
CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+O2 REAC, PURGE
TEMPERATURE, F
950 1050 1150 1250 1350 1450 1550 1650 1750
0.0 272.0 544.0 816.0 1088.0 1360.0 1632.0
TIME, HOURS
Reactor Vessel
CACECO CASE 681
01 DEC 76 1809 HRS



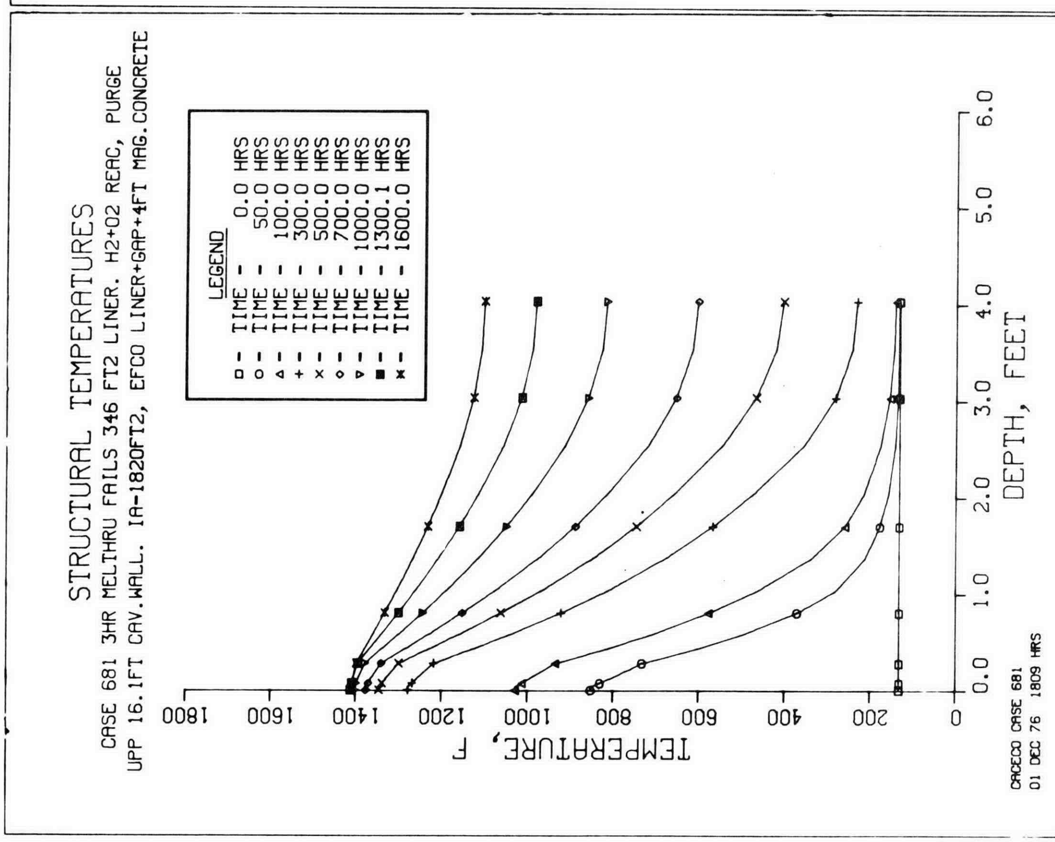
BUILDING AVG. VENT RATE
CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+O2 REAC, PURGE
FLOW RATE, SCFM
×10⁴
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6
0.0 272.0 544.0 816.0 1088.0 1360.0 1632.0
TIME, HOURS
CACECO CASE 681
01 DEC 76 1809 HRS


CAVITY ATMOSPHERE TEMPERATURES
CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+O2 REAC, PURGE
TEMPERATURE, F
1800
1575
1350
1125
900
675
450
225
0
Cavity Temperature
Subcavity Temperature
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 681
01 DEC 76 1809 HRS

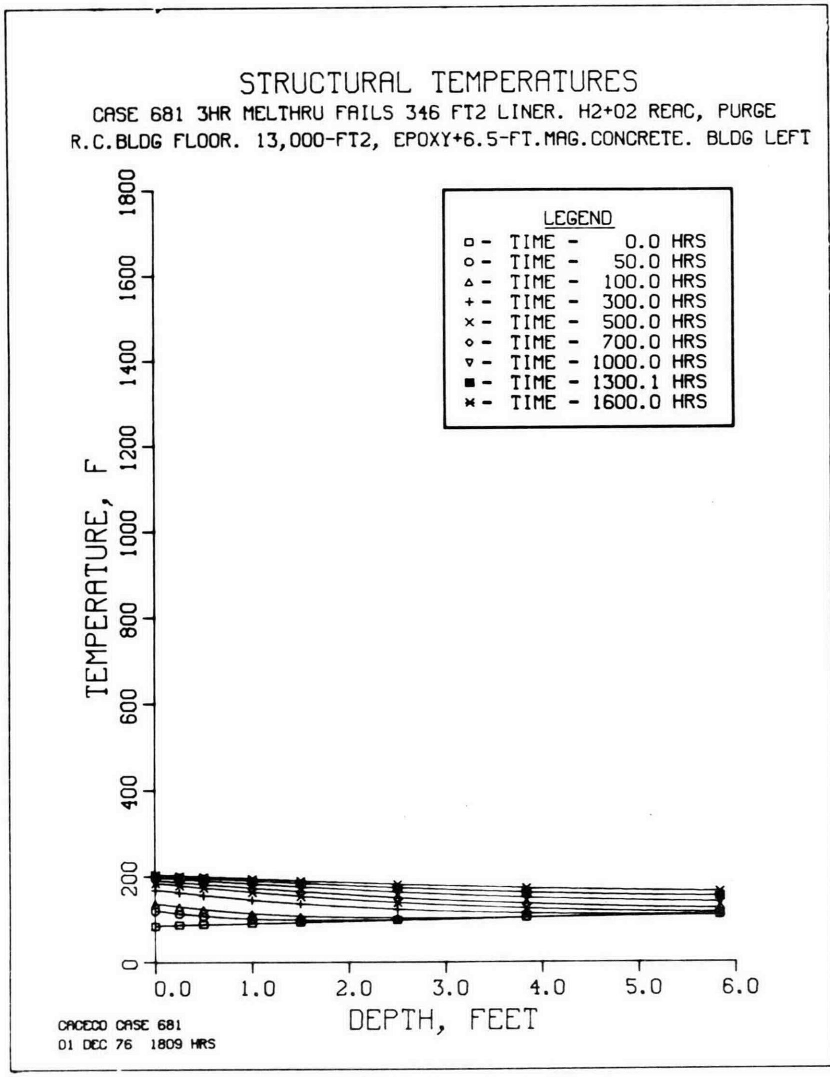

SODIUM INVENTORY
CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+O2 REAC, PURGE
SODIUM IN VESSEL, LBS
700000
600000
500000
400000
300000
200000
100000
0
0
272
544
816
1088
1360
1632
TIME, HOURS
CACECO CASE 681
01 DEC 76 1809 HRS

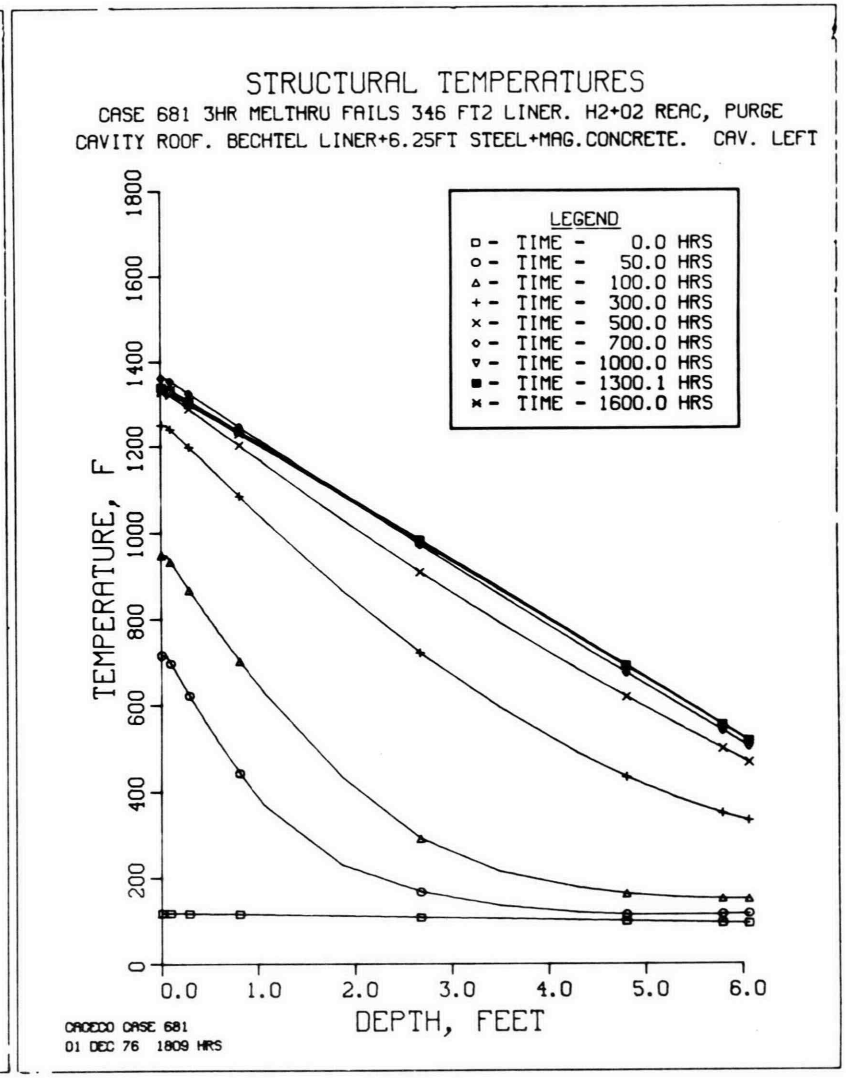


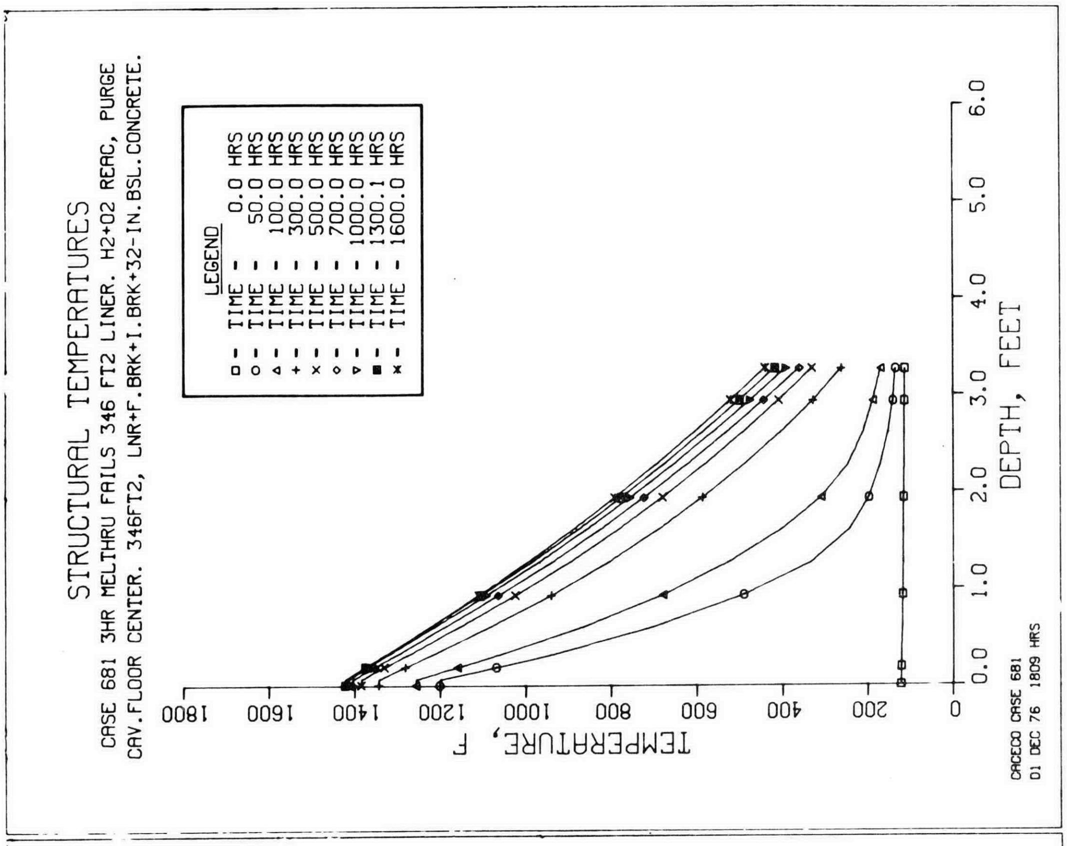
STRUCTURAL TEMPERATURES
CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+02 REAC, PURGE
MID 16.1FT CAV.WALL. IA-1820FT2, BECHTEL LINER+GAP+4.5FT MAG.CON
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✱ - TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 681
01 DEC 76 1809 HRS



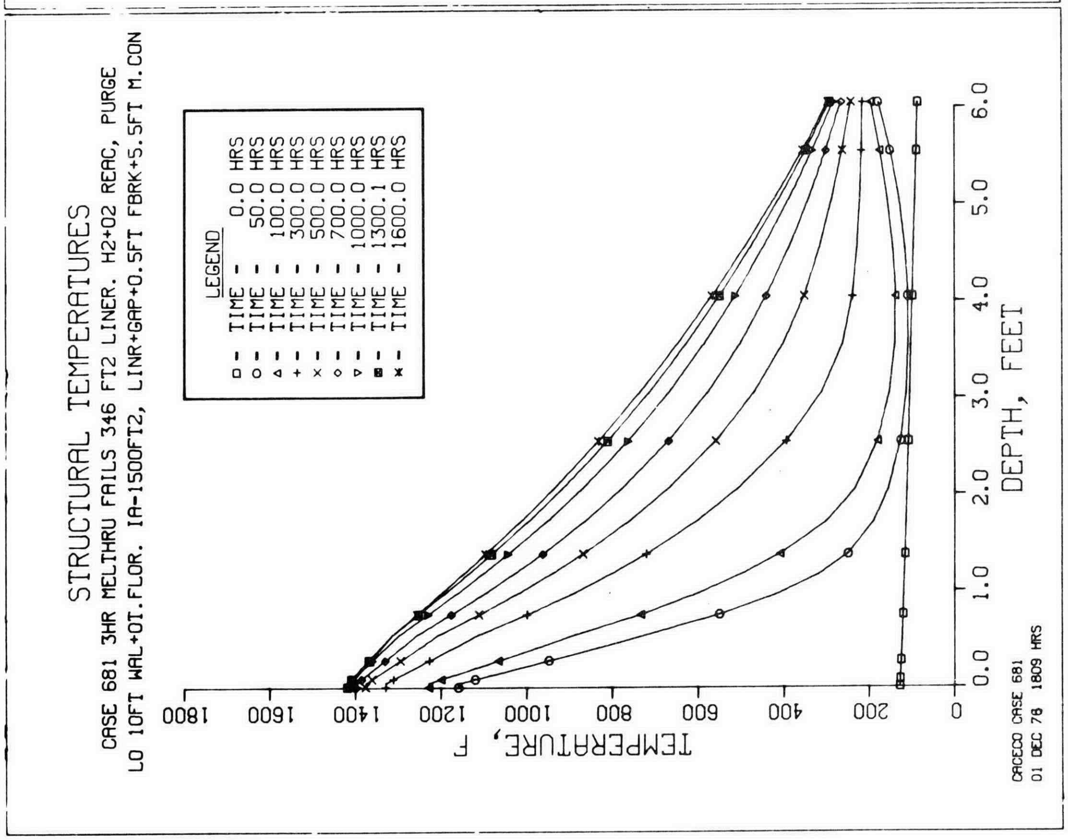
STRUCTURAL TEMPERATURES
CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+02 REAC, PURGE
UPP 16.1FT CAV.WALL. IA-1820FT2, EFCO LINER+GAP+4FT MAG.CONCRETE
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✱ - TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 681
01 DEC 76 1809 HRS


STRUCTURAL TEMPERATURES
CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+02 REAC, PURGE
R.C.BLDG FLOOR. 13,000-FT2, EPOXY+6.5-FT.MAG.CONCRETE. BLDG LEFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✱ - TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 681
01 DEC 76 1809 HRS

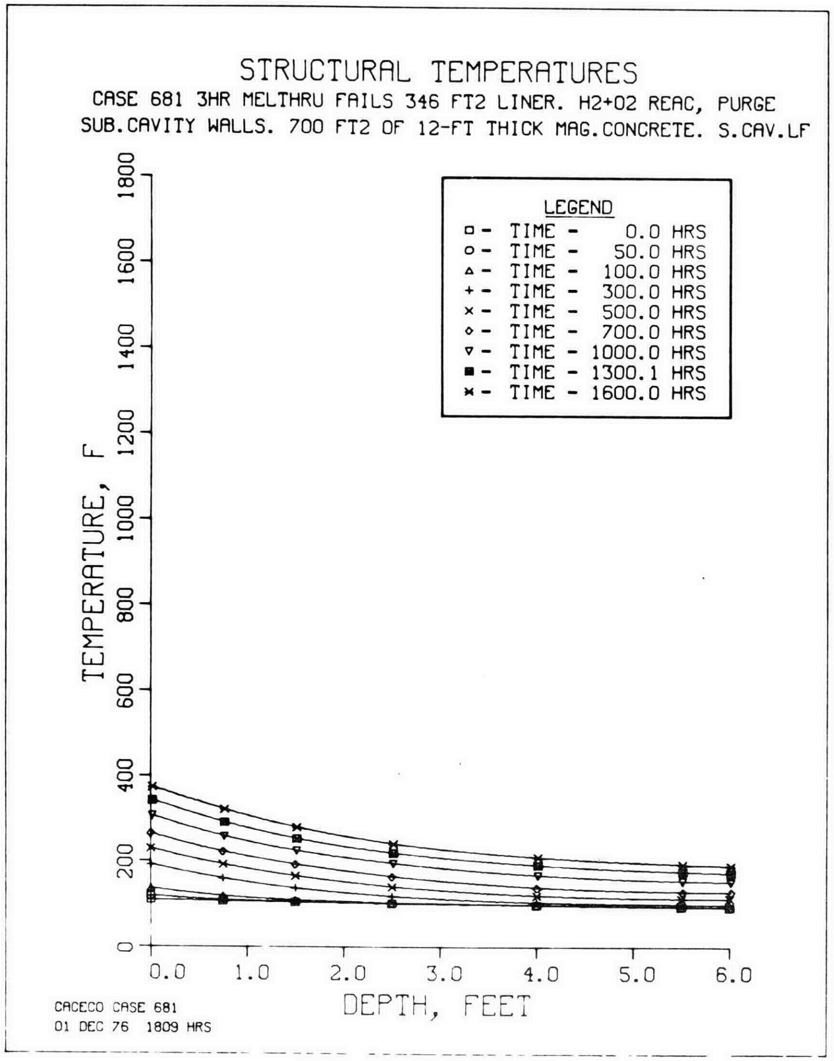

STRUCTURAL TEMPERATURES
CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+02 REAC, PURGE
CAVITY ROOF. BECHTEL LINER+6.25FT STEEL+MAG.CONCRETE. CAV. LEFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✱ - TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 681
01 DEC 76 1809 HRS

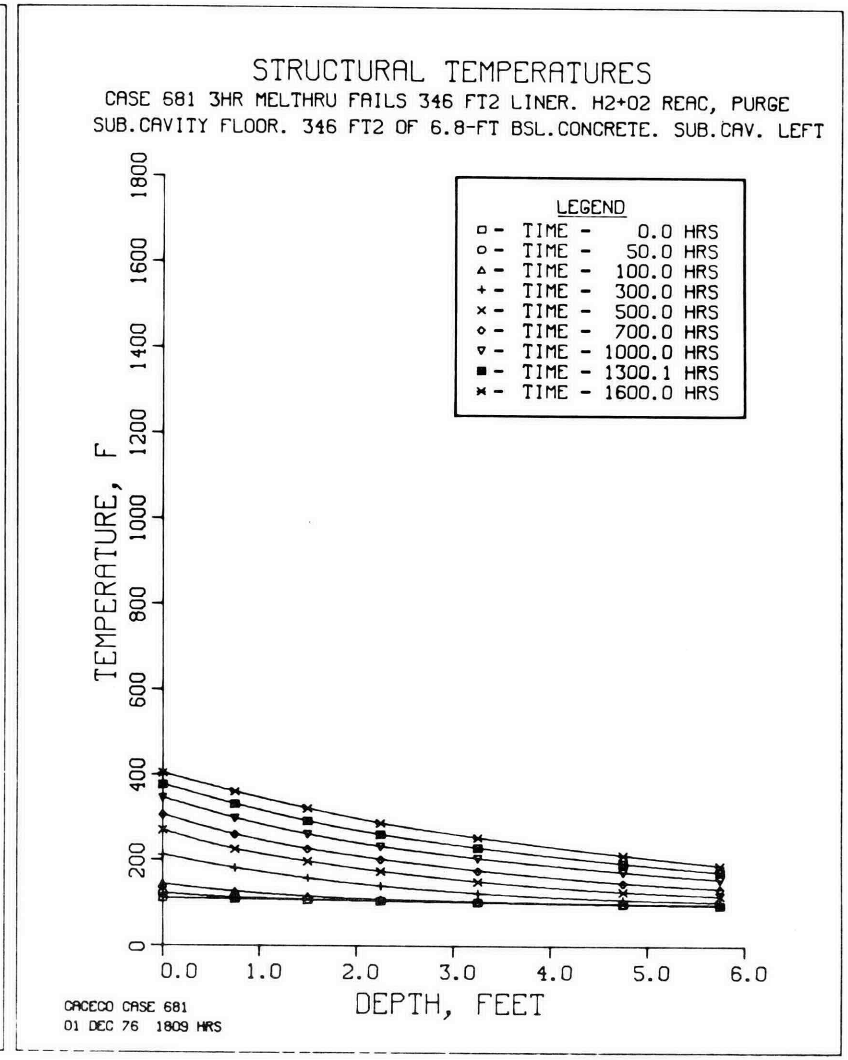


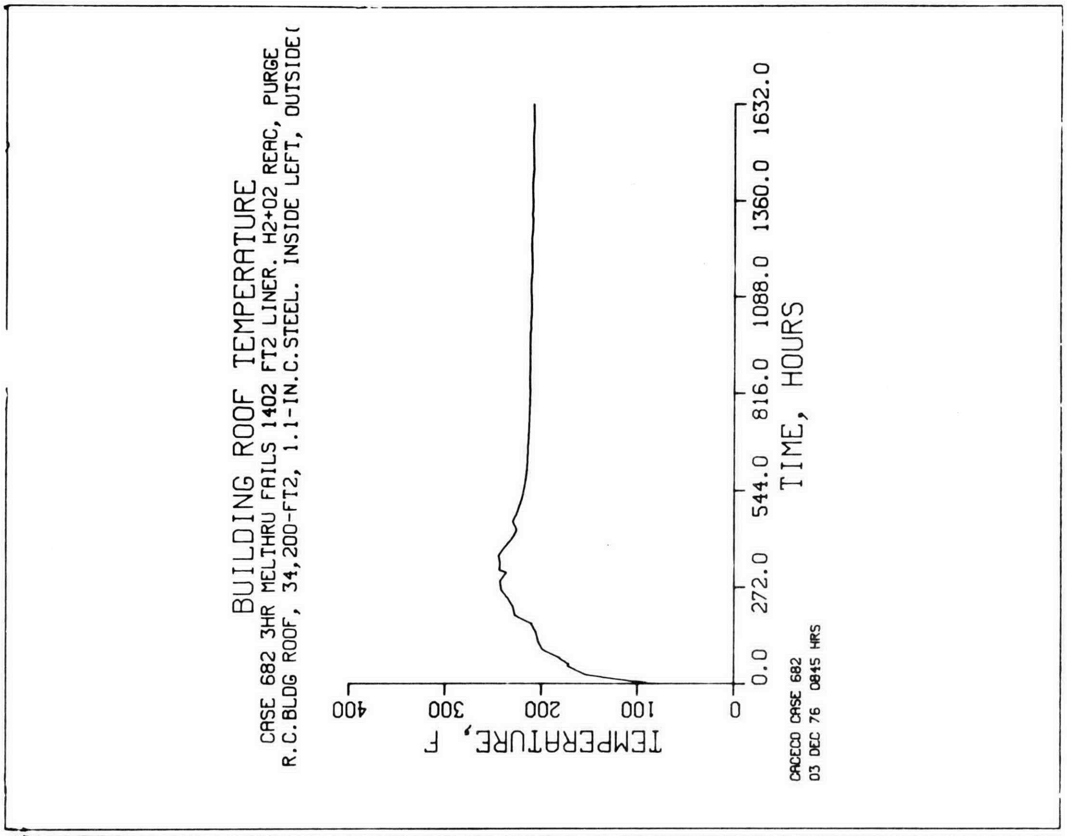
STRUCTURAL TEMPERATURES
CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+O2 REAC, PURGE
CAV.FLOOR CENTER. 346FT2, LNR+F.BRK+I.BRK+32-IN.BSL.CONCRETE.
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 681
01 DEC 76 1809 HRS

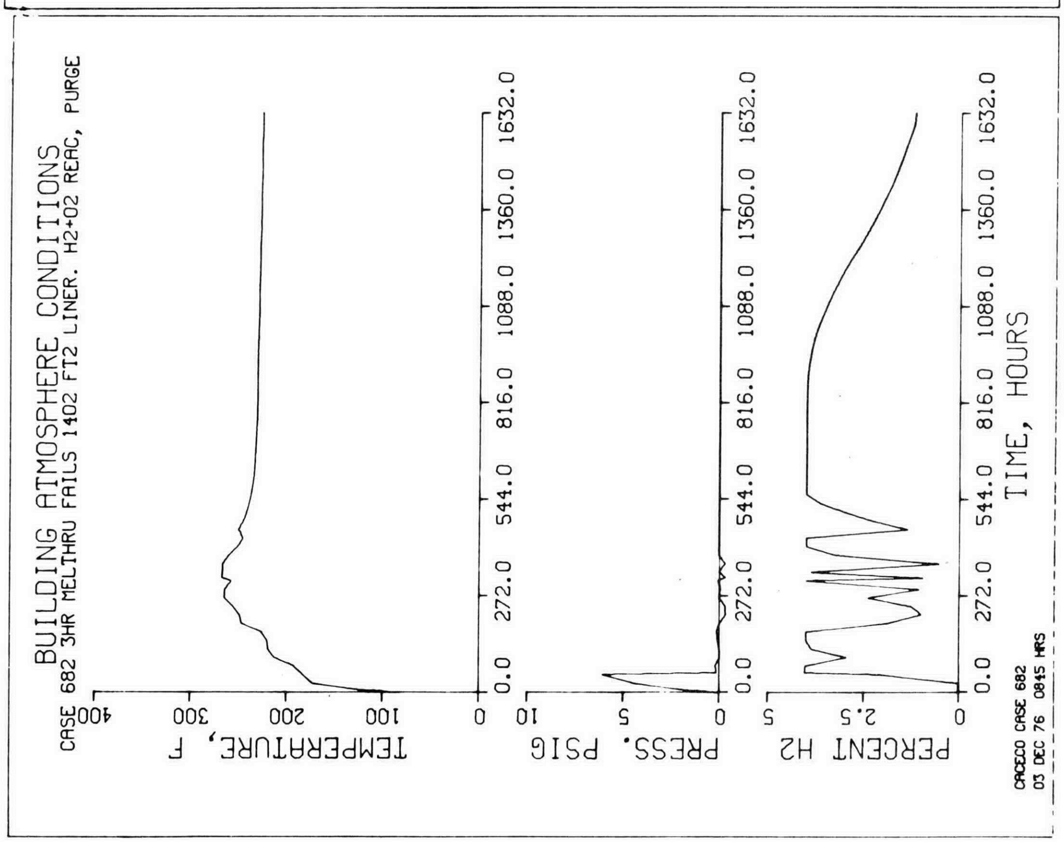


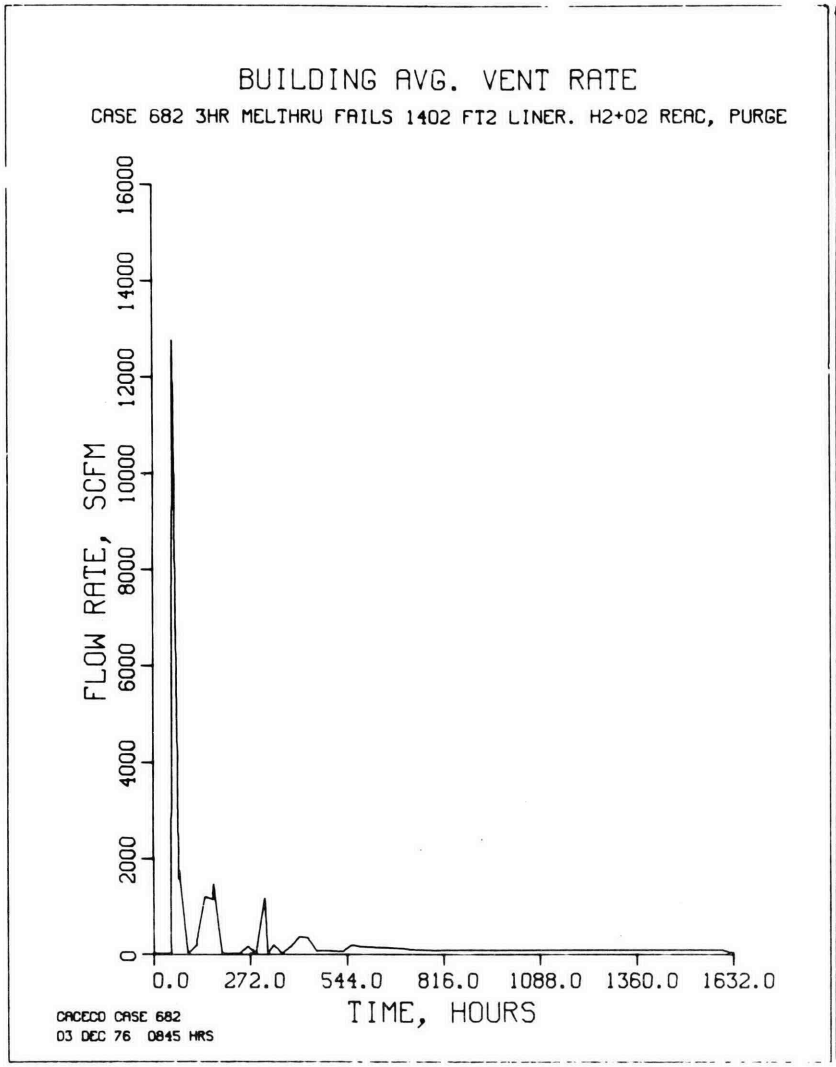
STRUCTURAL TEMPERATURES
CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+O2 REAC, PURGE
LO 10FT WAL+OT.FLOR. IA-1500FT2, LINR+GAP+0.5FT FBRK+5.5FT M.CON
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 681
01 DEC 78 1809 HRS


STRUCTURAL TEMPERATURES
CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+02 REAC, PURGE
SUB.CAVITY WALLS. 700 FT2 OF 12-FT THICK MAG.CONCRETE. S.CAV.LF
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 681
01 DEC 76 1809 HRS

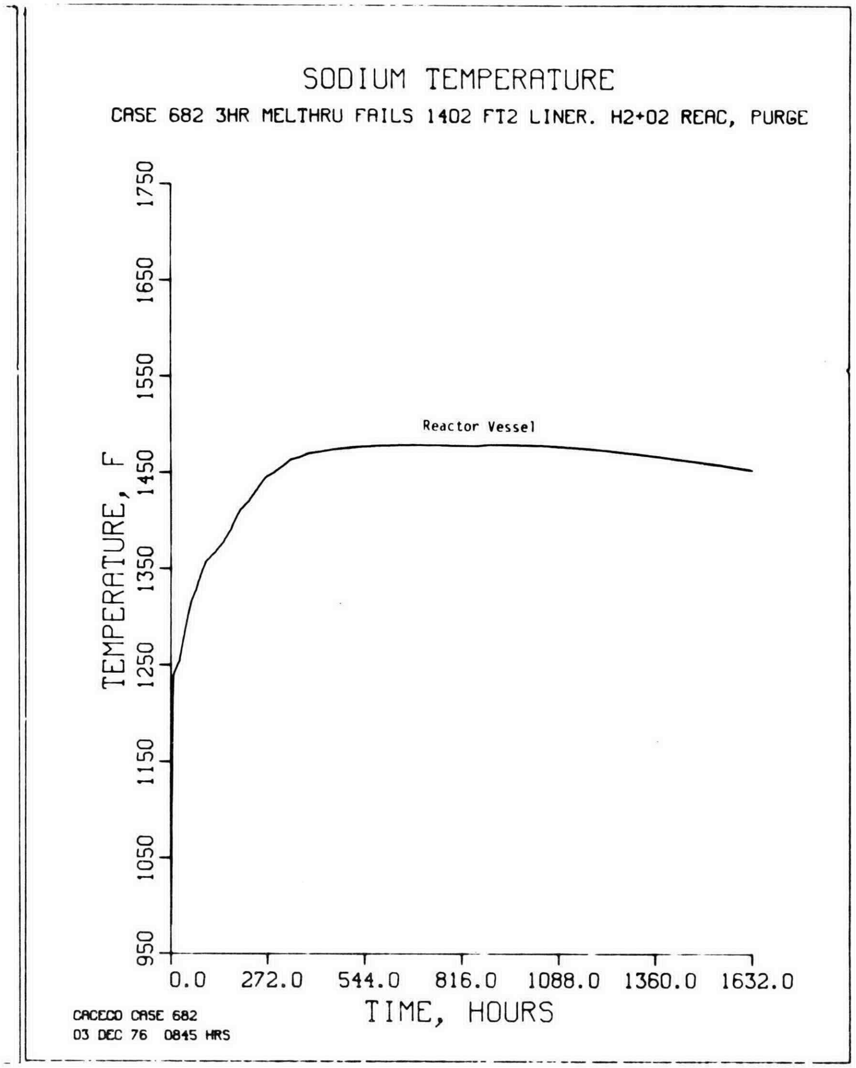

STRUCTURAL TEMPERATURES
CASE 681 3HR MELTHRU FAILS 346 FT2 LINER. H2+02 REAC, PURGE
SUB.CAVITY FLOOR. 346 FT2 OF 6.8-FT BSL.CONCRETE. SUB.CAV. LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 681
01 DEC 76 1809 HRS


BUILDING ROOF TEMPERATURE
CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
R.C.BLDG ROOF, 34,200-FT2, 1.1-IN.C.STEEL. INSIDE LEFT, OUTSIDE(
TEMPERATURE, F
0
100
200
300
400
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 682
03 DEC 76 0845 HRS

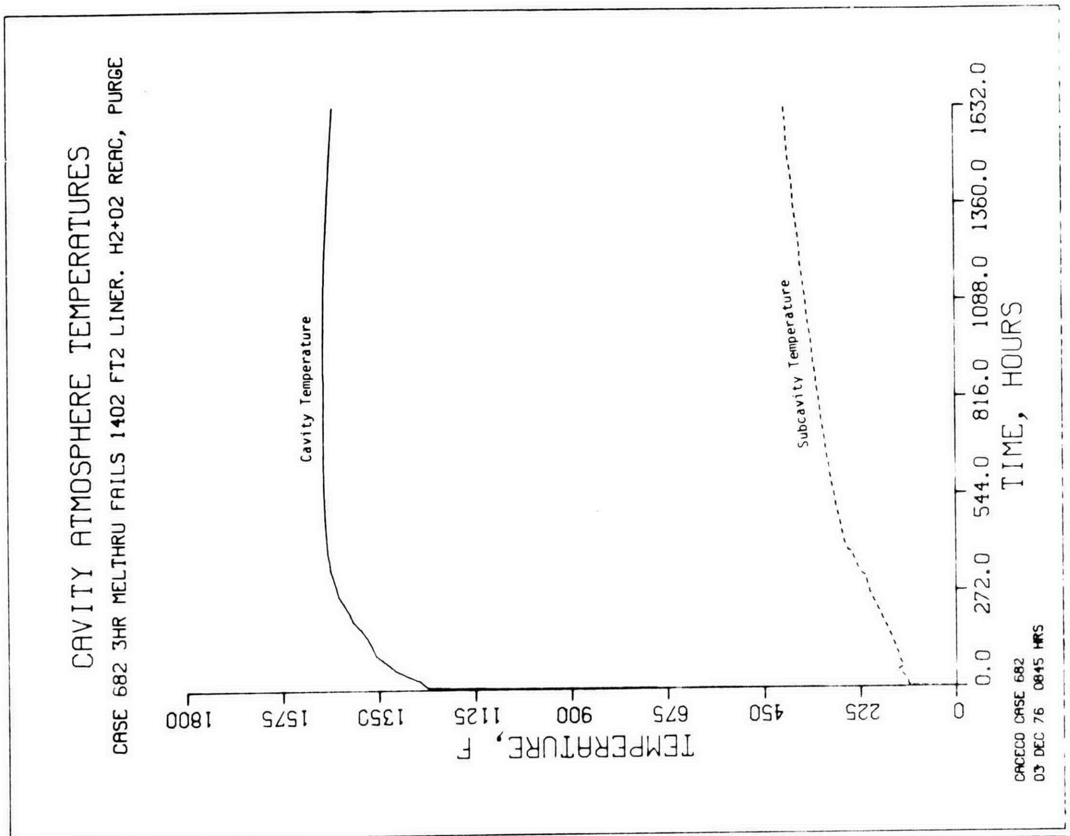

BUILDING ATMOSPHERE CONDITIONS
CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
TEMPERATURE, F
0
100
200
300
400
PRESS, PSIG
0
5
10
PERCENT H2
0
2.5
5
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 682
03 DEC 76 0845 HRS

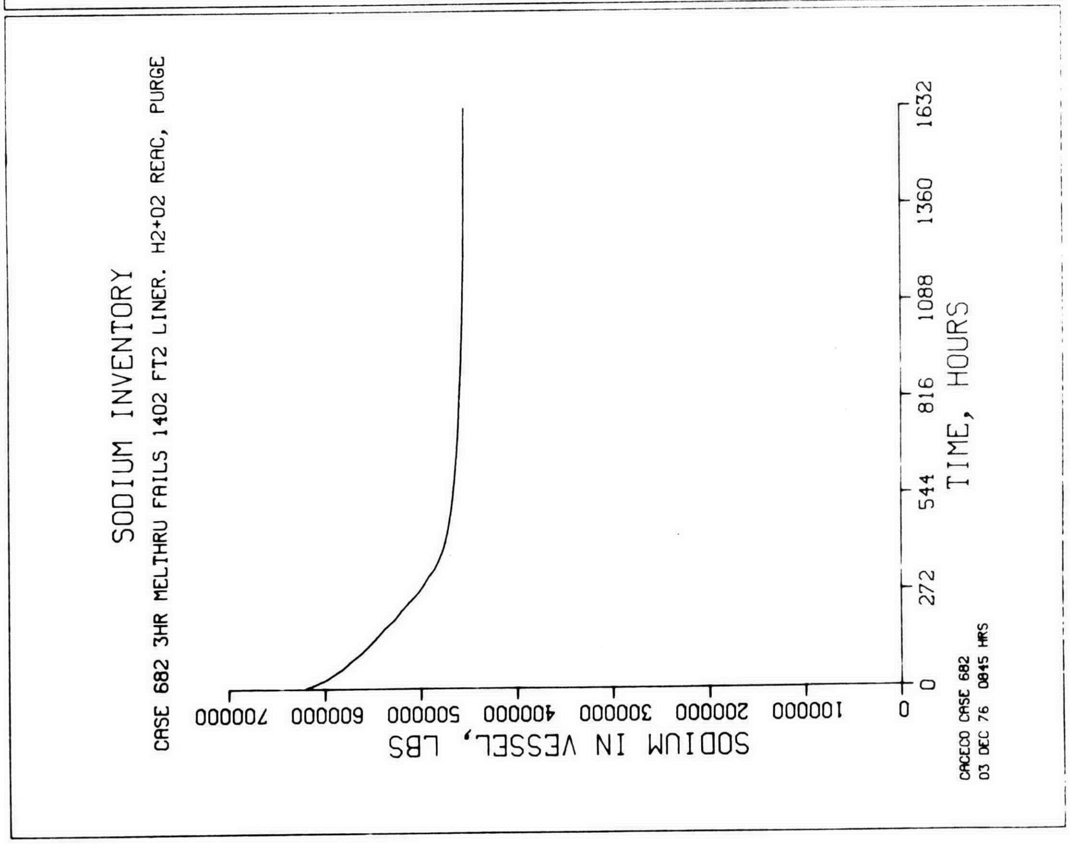


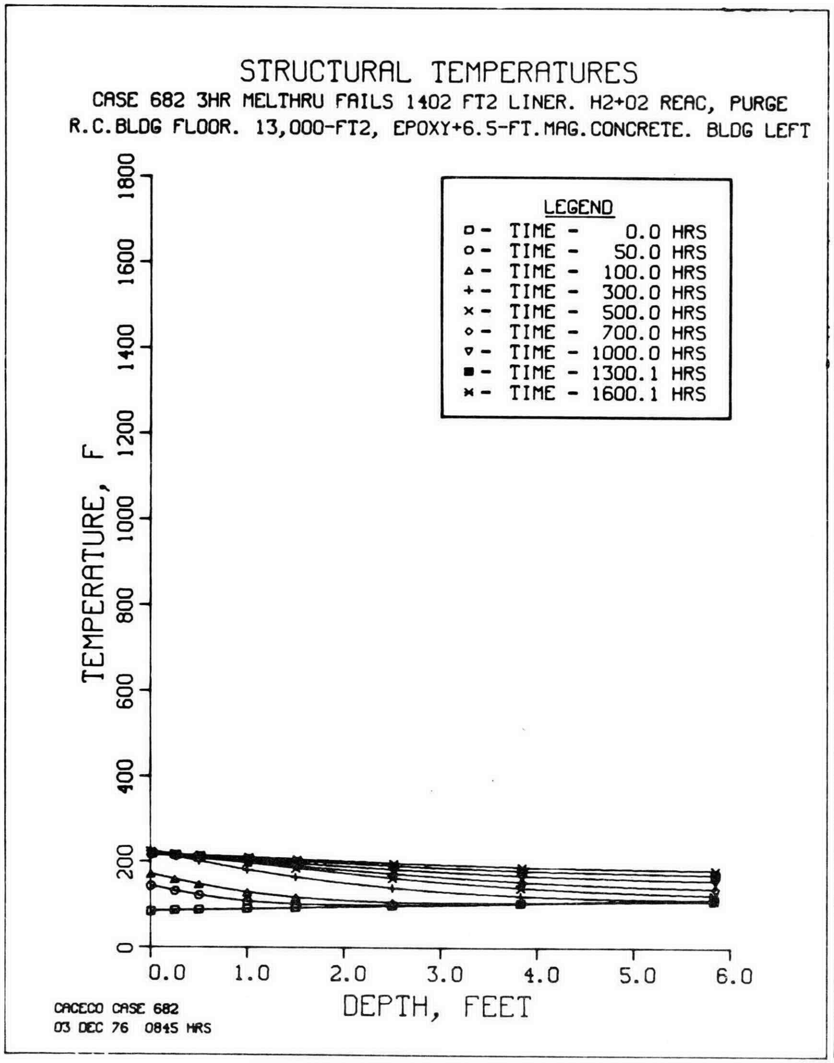
BUILDING AVG. VENT RATE
CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
FLOW RATE, SCFM
0
2000
4000
6000
8000
10000
12000
14000
16000
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 682
03 DEC 76 0845 HRS

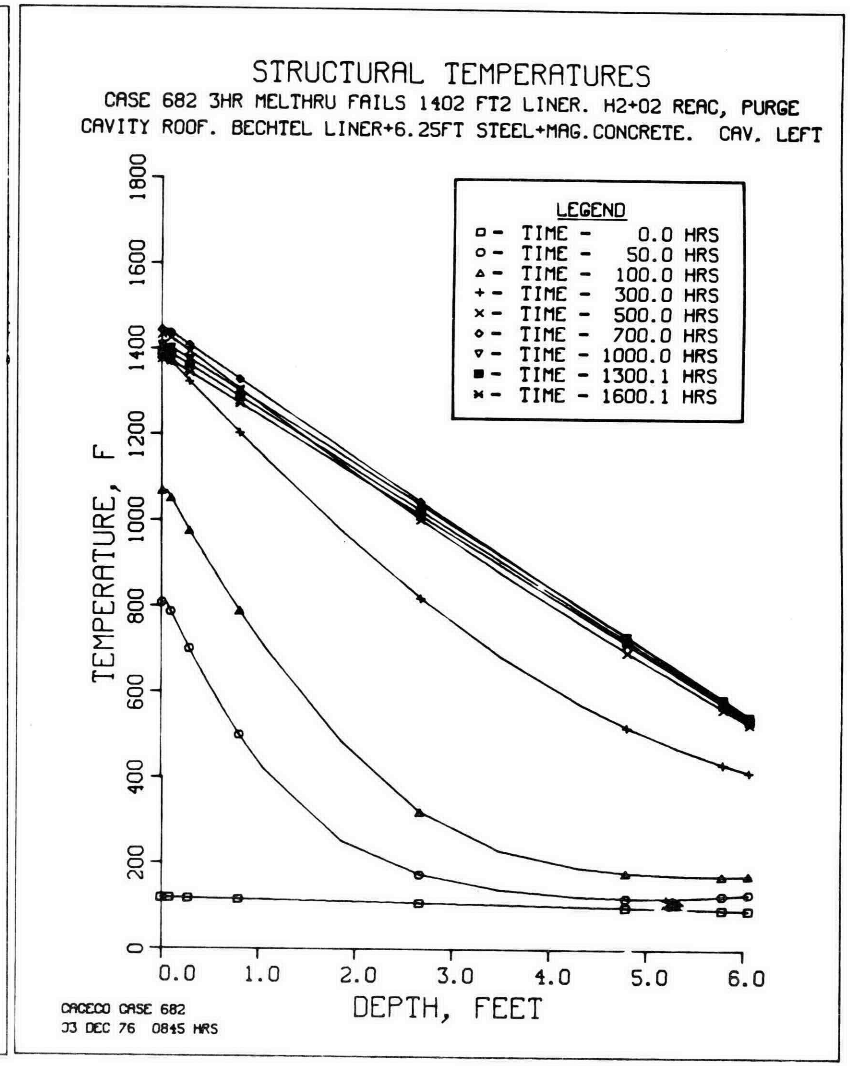


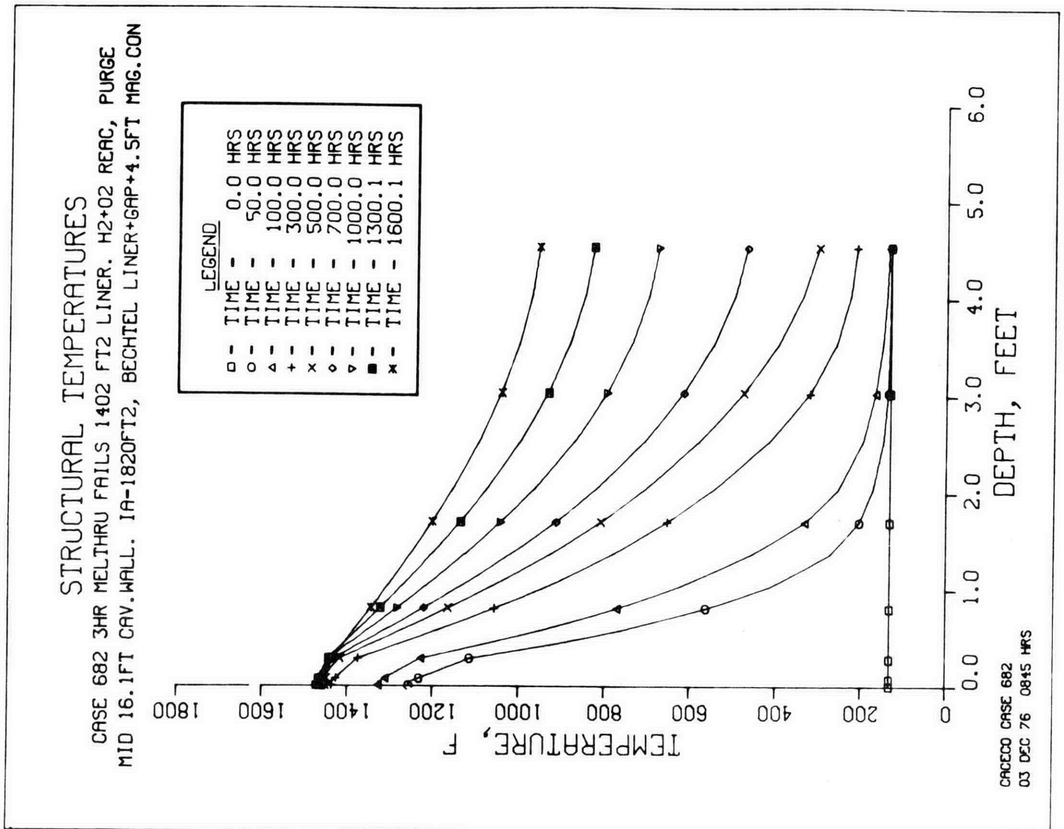
SODIUM TEMPERATURE
CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
TEMPERATURE, F
950
1050
1150
1250
1350
1450
1550
1650
1750
Reactor Vessel
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 682
03 DEC 76 0845 HRS


CAVITY ATMOSPHERE TEMPERATURES
CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
Cavity Temperature
Subcavity Temperature
TEMPERATURE, F
0
225
450
675
900
1125
1350
1575
1800
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 682
03 DEC 76 0845 HRS

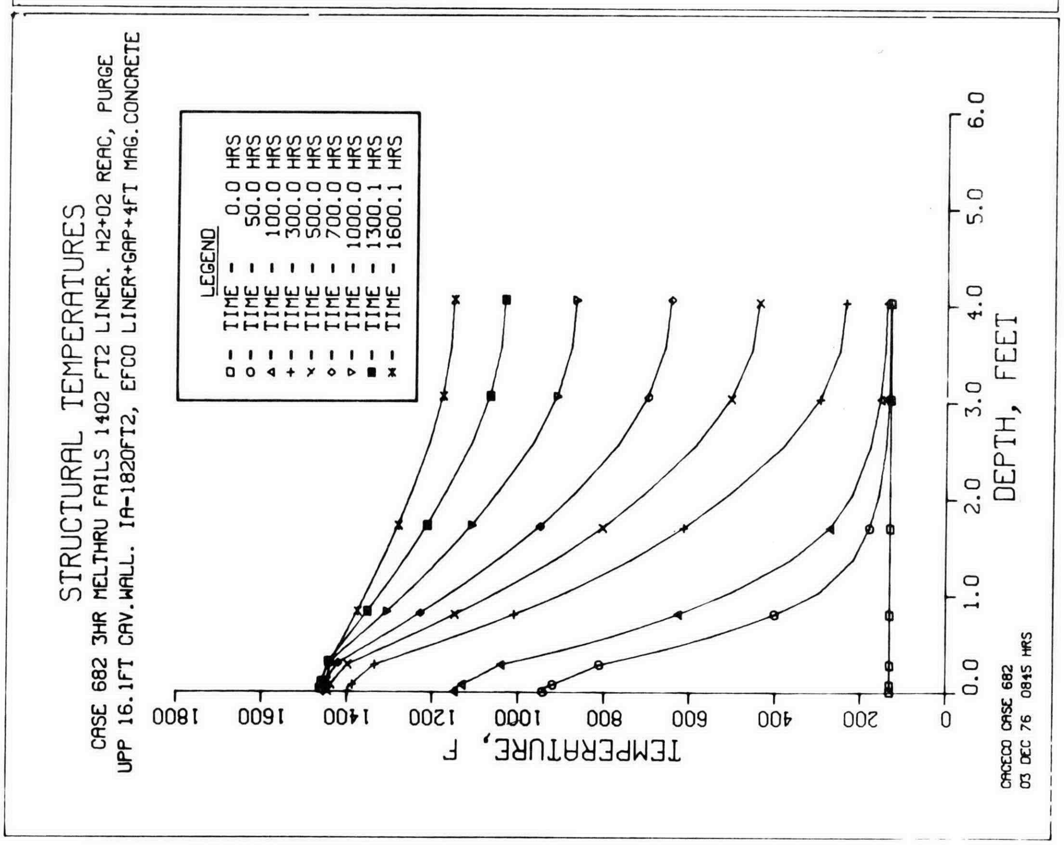

SODIUM INVENTORY
CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
SODIUM IN VESSEL, LBS
0
100000
200000
300000
400000
500000
600000
700000
0
272
544
816
1088
1360
1632
TIME, HOURS
CACECO CASE 682
03 DEC 76 0845 HRS


STRUCTURAL TEMPERATURES
CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
R.C.BLDG FLOOR. 13,000-FT2, EPOXY+6.5-FT.MAG.CONCRETE. BLDG LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 682
03 DEC 76 0845 HRS

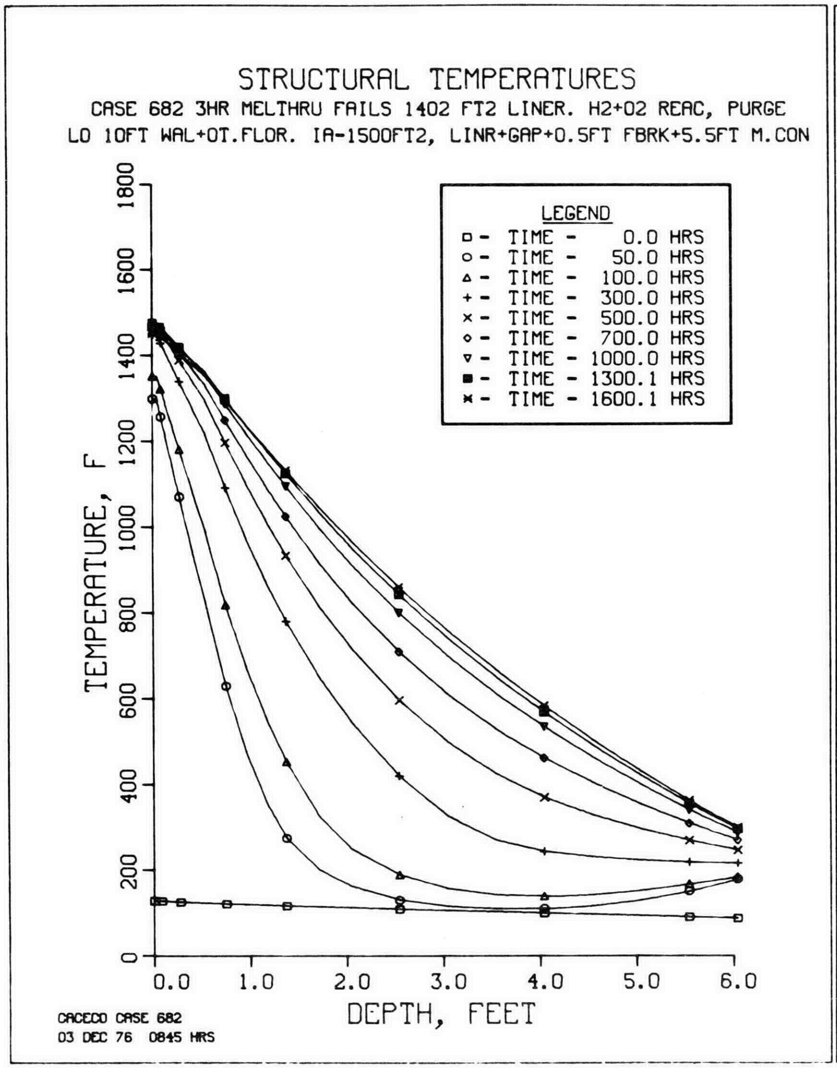

STRUCTURAL TEMPERATURES
CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
CAVITY ROOF. BECHTEL LINER+6.25FT STEEL+MAG.CONCRETE. CAV. LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 682
03 DEC 76 0845 HRS

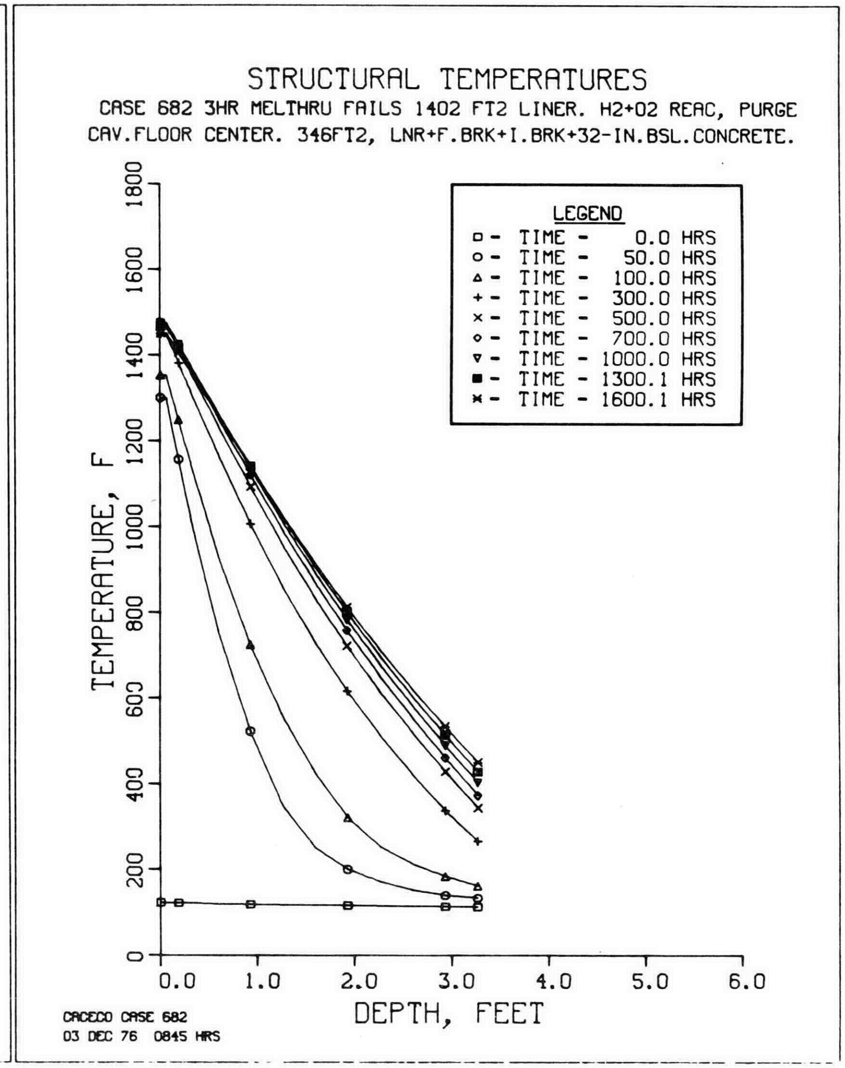


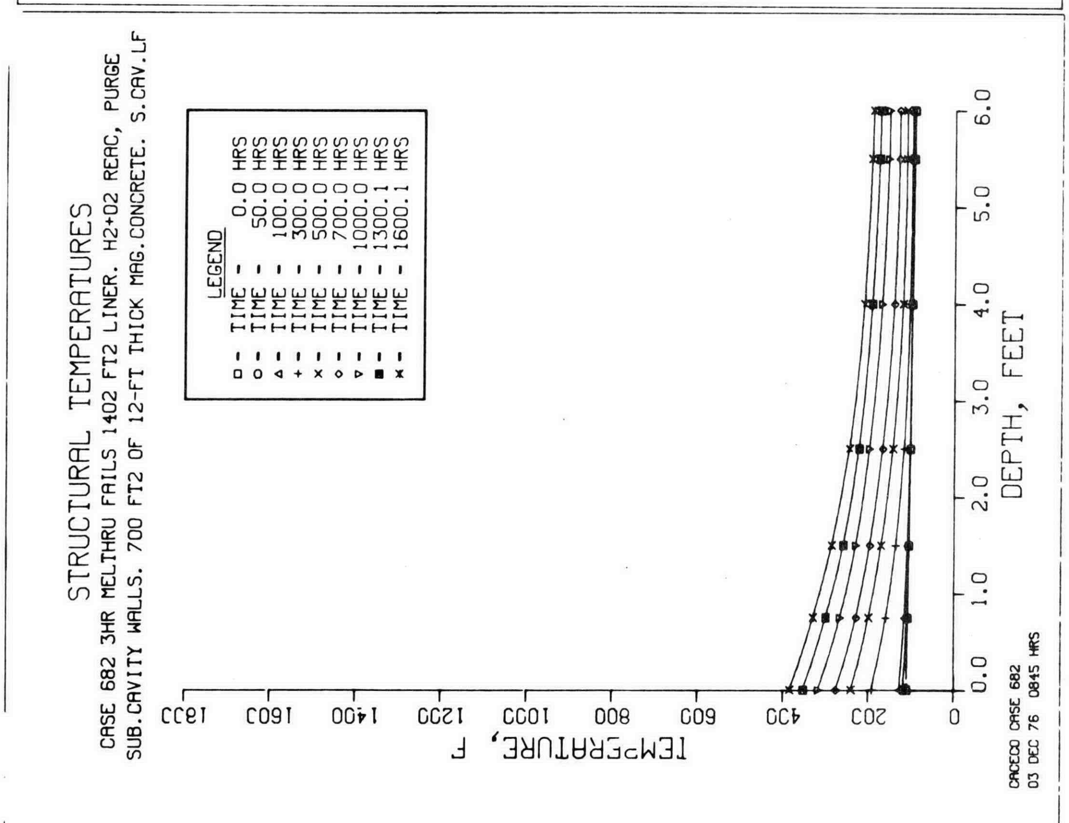
STRUCTURAL TEMPERATURES
CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
MID 16.1FT CAV.WALL. IA-1820FT2, BECHTEL LINER+GAP+4.5FT MAG.CON
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 682
03 DEC 76 0845 HRS

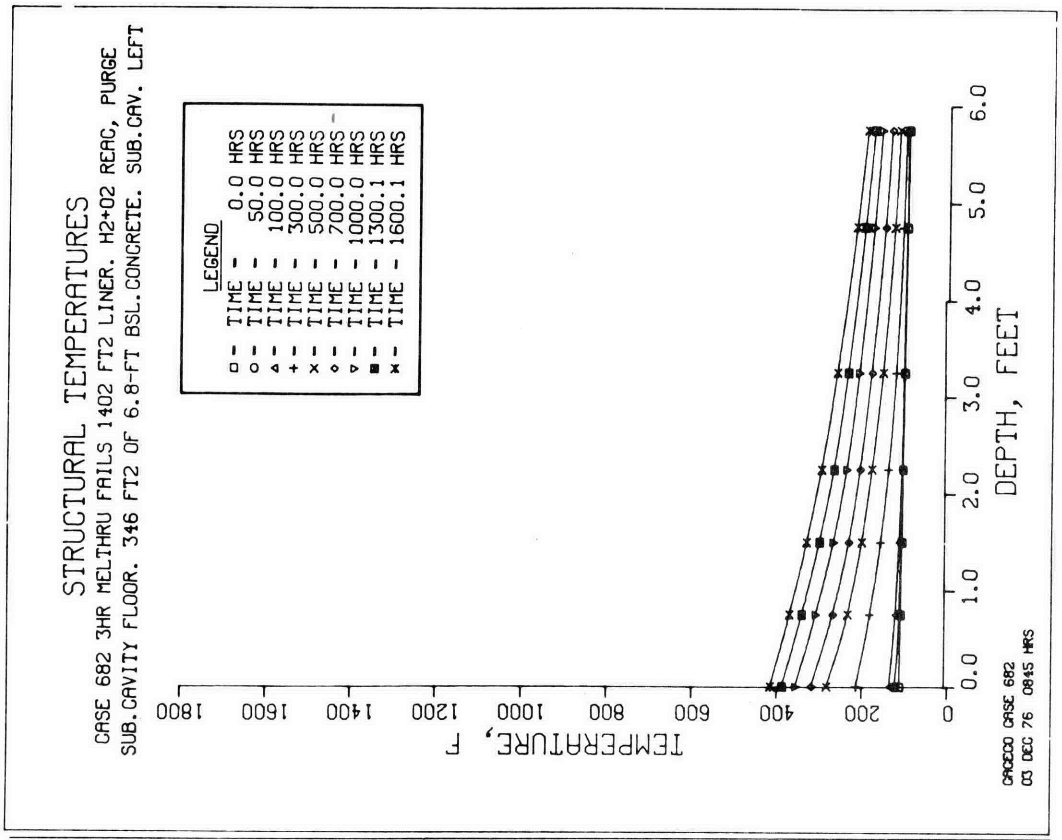


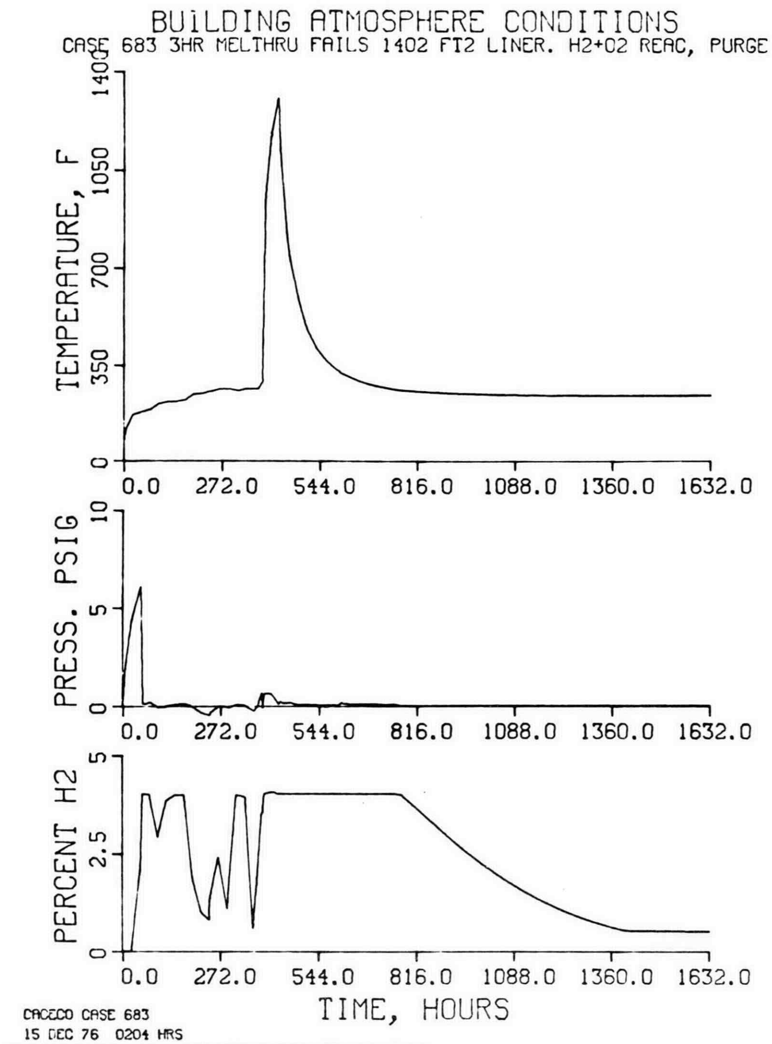
STRUCTURAL TEMPERATURES
CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
UPP 16.1FT CAV.WALL. IA-1820FT2, EFCO LINER+GAP+4FT MAG.CONCRETE
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 682
03 DEC 76 0845 HRS

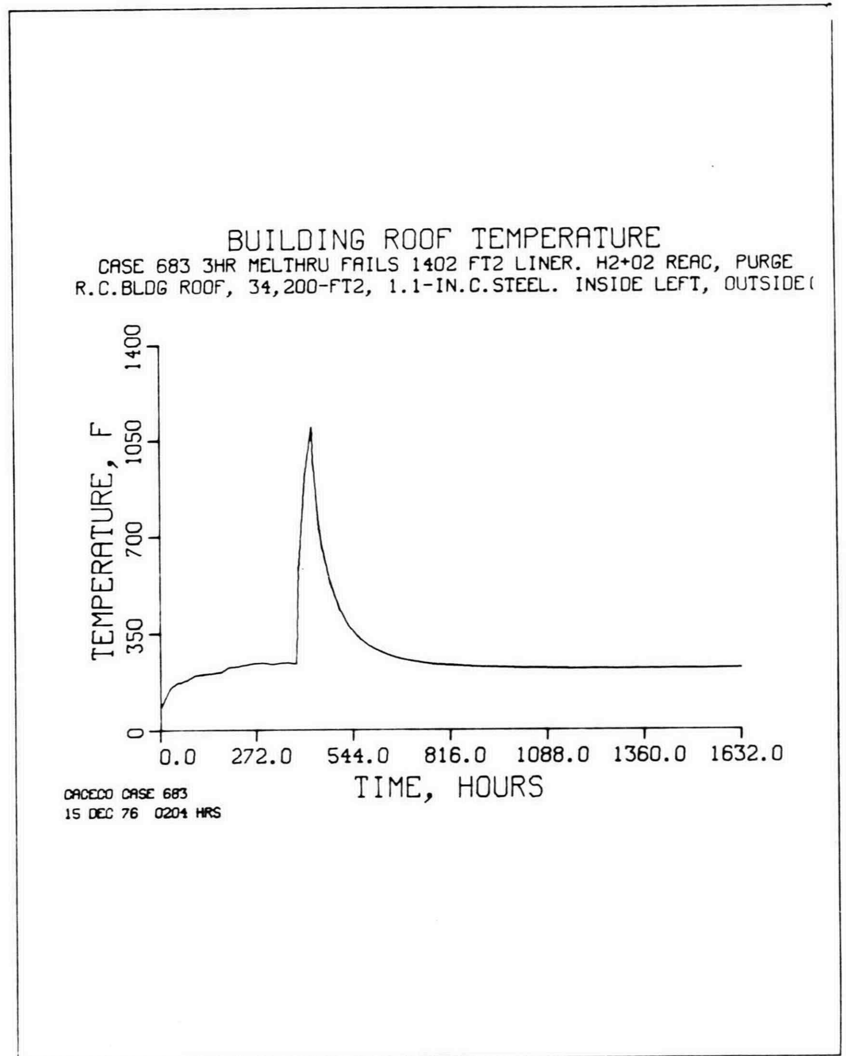

STRUCTURAL TEMPERATURES
CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
LO 10FT WAL+OT.FLOR. IA-1500FT2, LINR+GAP+0.5FT FBRK+5.5FT M.CON
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 682
03 DEC 76 0845 HRS

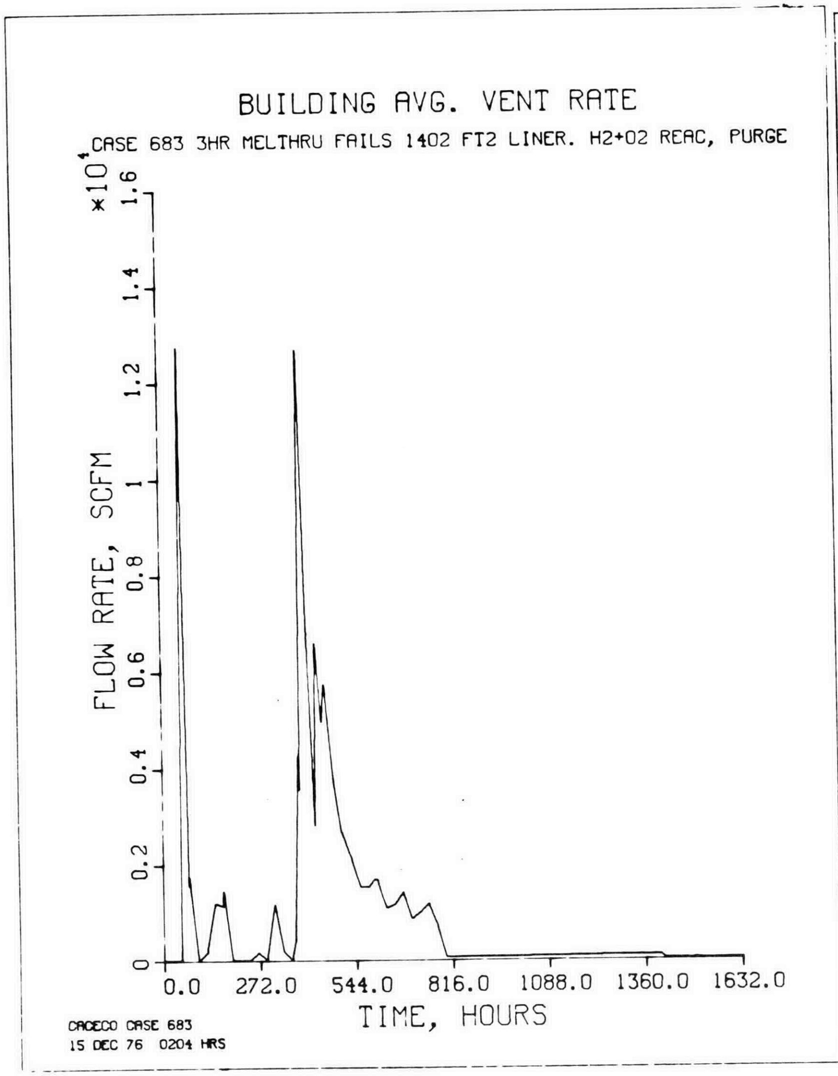

STRUCTURAL TEMPERATURES
CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
CAV.FLOOR CENTER. 346FT2, LNR+F.BRK+I.BRK+32-IN.BSL.CONCRETE.
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.0 HRS
TIME - 1300.1 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 682
03 DEC 76 0845 HRS

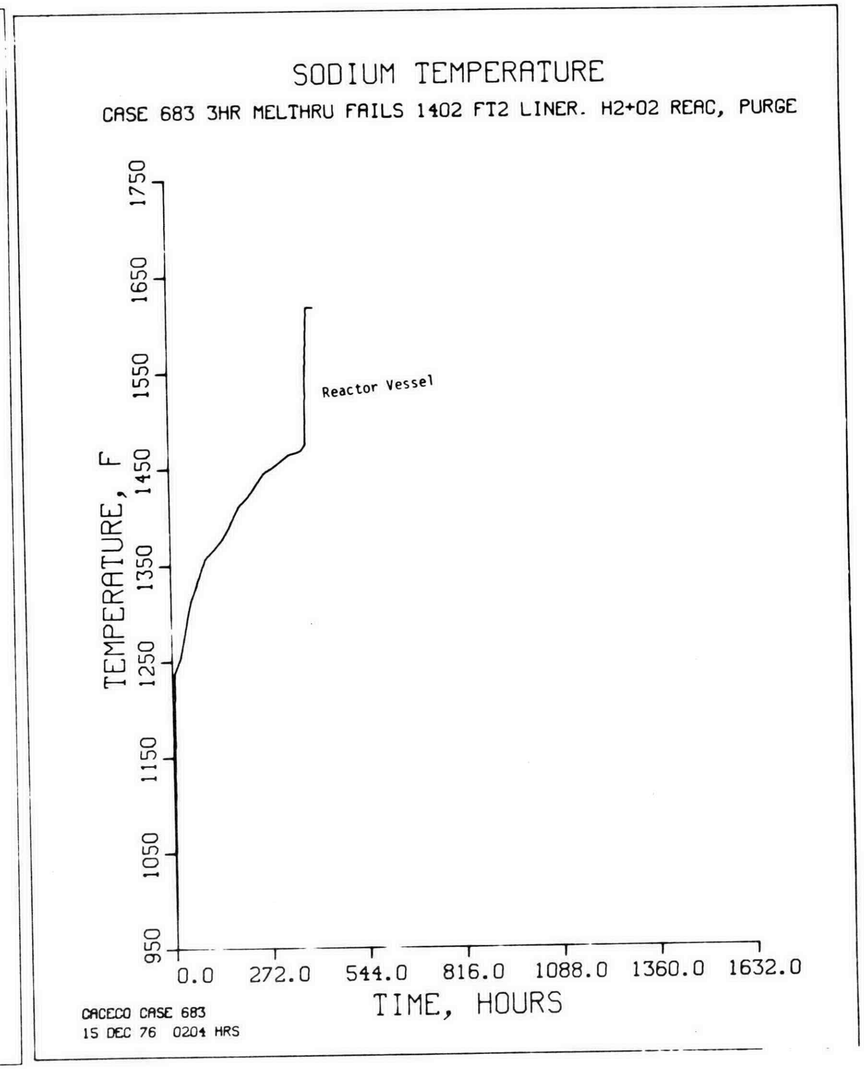

STRUCTURAL TEMPERATURES
CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
SUB.CAVITY WALLS. 700 FT2 OF 12-FT THICK MAG.CONCRETE. S.CAV.LF
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✖ - TIME - 1600.1 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 682
03 DEC 76 0845 HRS

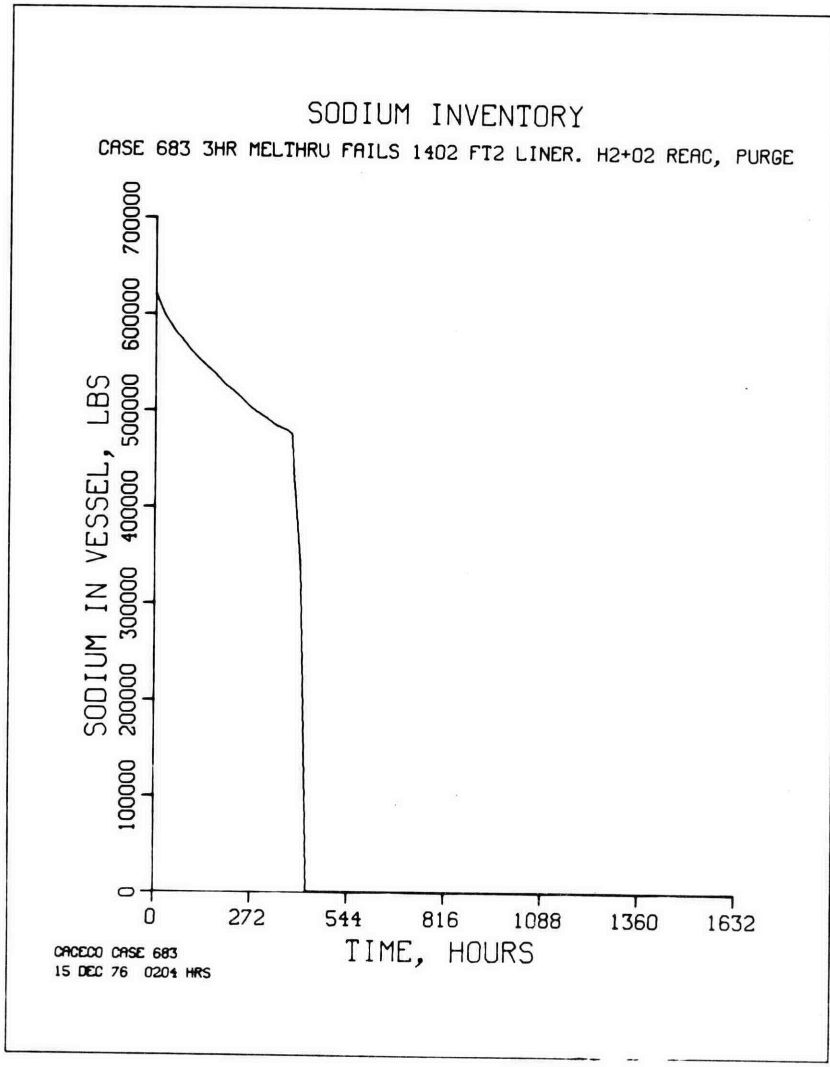

STRUCTURAL TEMPERATURES
CASE 682 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
SUB.CAVITY FLOOR. 346 FT2 OF 6.8-FT BSL.CONCRETE. SUB.CAV. LEFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.0 HRS
■ - TIME - 1300.1 HRS
✖ - TIME - 1600.1 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 682
03 DEC 76 0845 HRS

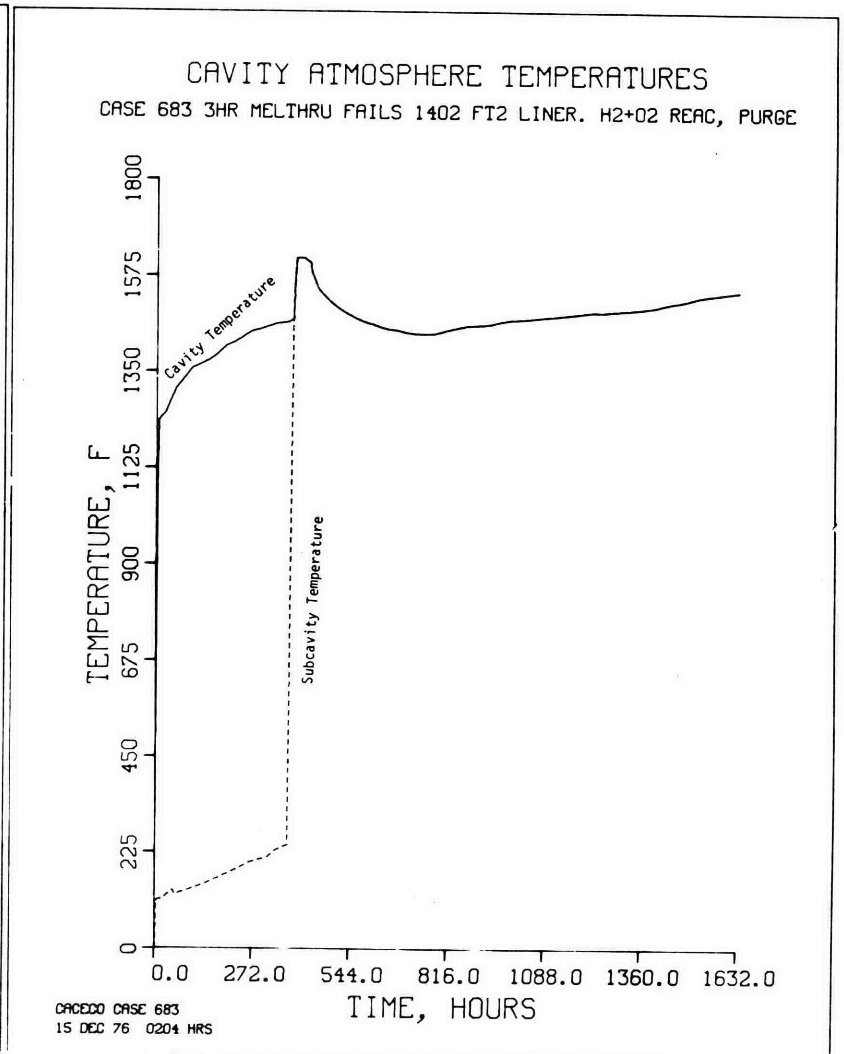

BUILDING ATMOSPHERE CONDITIONS
CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
TEMPERATURE, F
0
350
700
1050
1400
PRESS. PSIG
0
5
10
PERCENT H2
0
2.5
5
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 683
15 DEC 76 0204 HRS

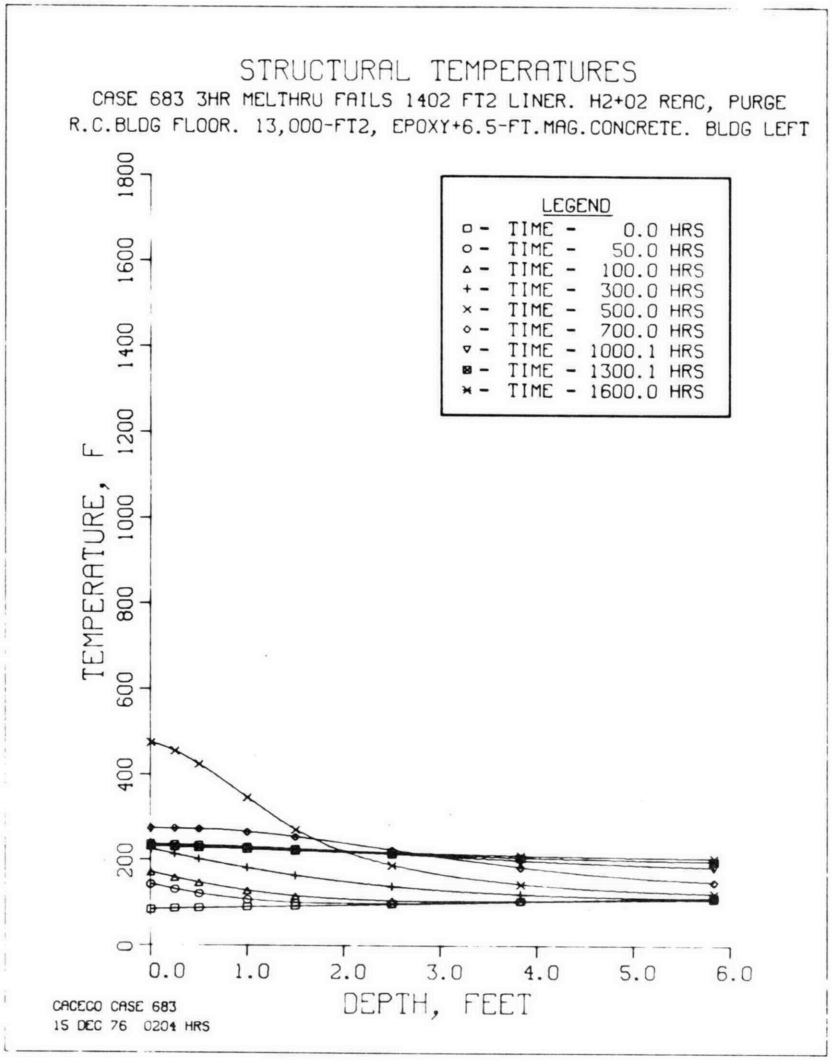

BUILDING ROOF TEMPERATURE
CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
R.C.BLDG ROOF, 34,200-FT2, 1.1-IN.C.STEEL. INSIDE LEFT, OUTSIDE(
TEMPERATURE, F
0
350
700
1050
1400
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 683
15 DEC 76 0204 HRS

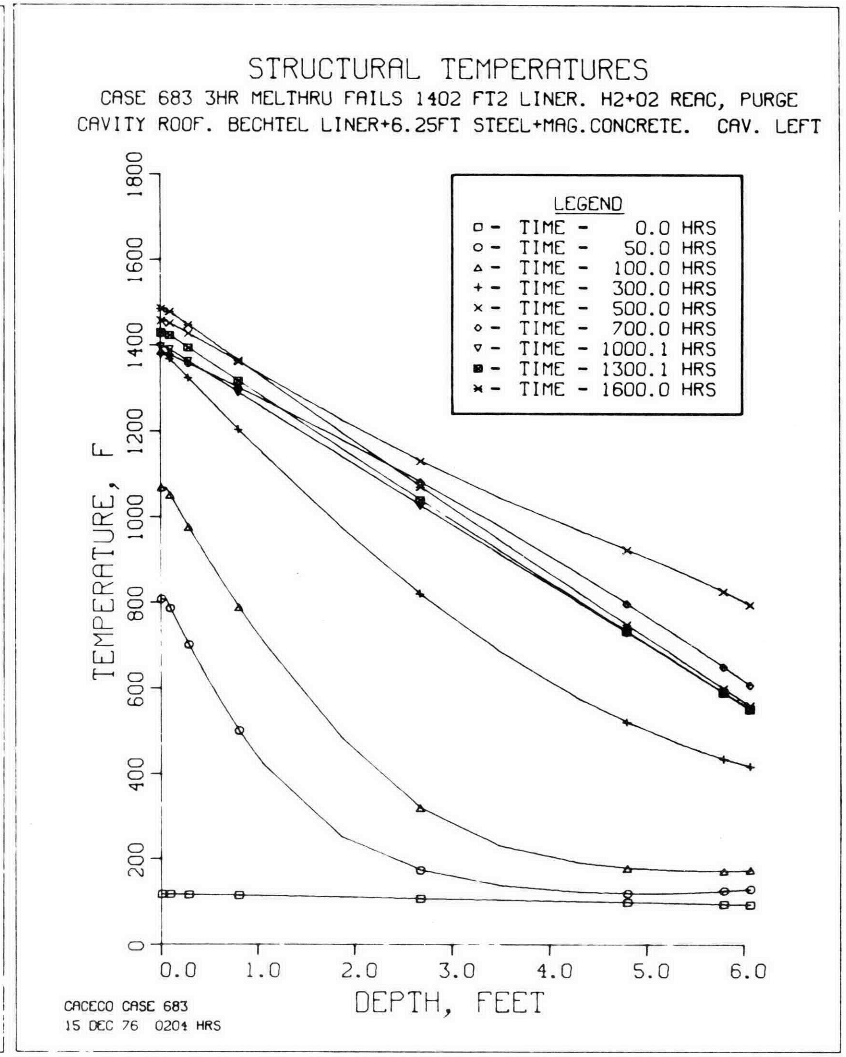

BUILDING AVG. VENT RATE
CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
×10⁴
FLOW RATE, SCFM
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 683
15 DEC 76 0204 HRS

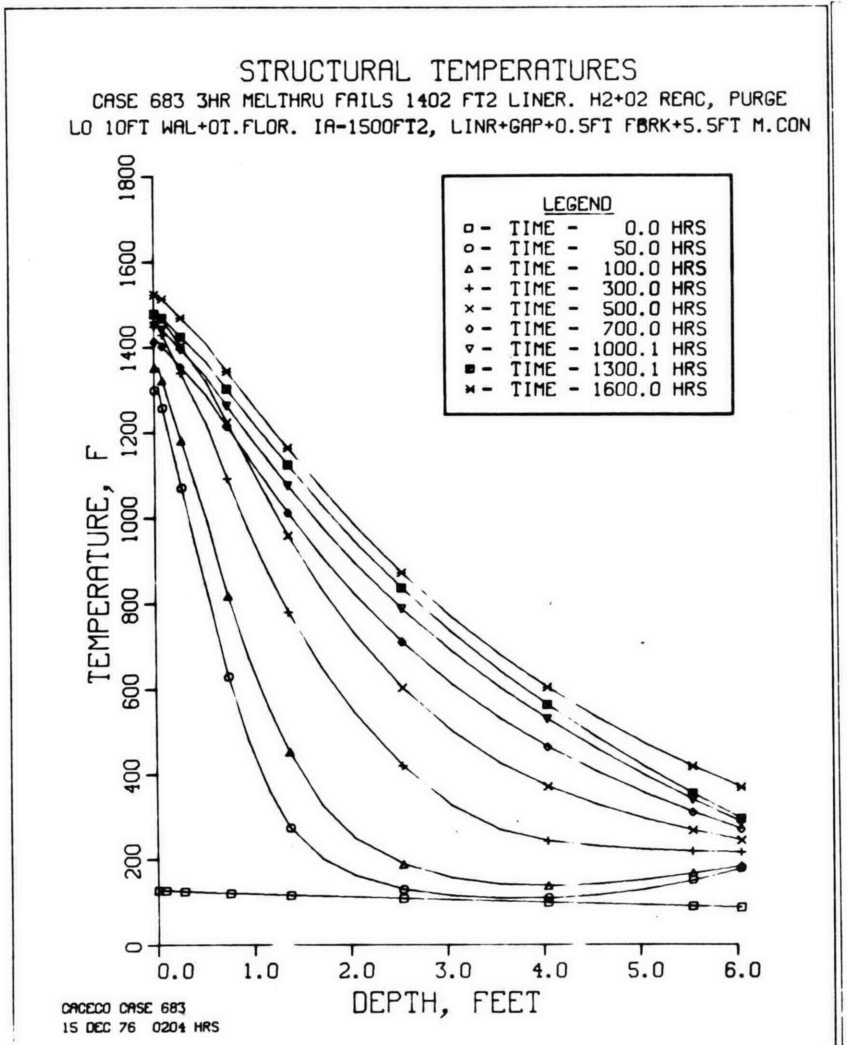

SODIUM TEMPERATURE
CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
TEMPERATURE, F
950
1050
1150
1250
1350
1450
1550
1650
1750
Reactor Vessel
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 683
15 DEC 76 0204 HRS

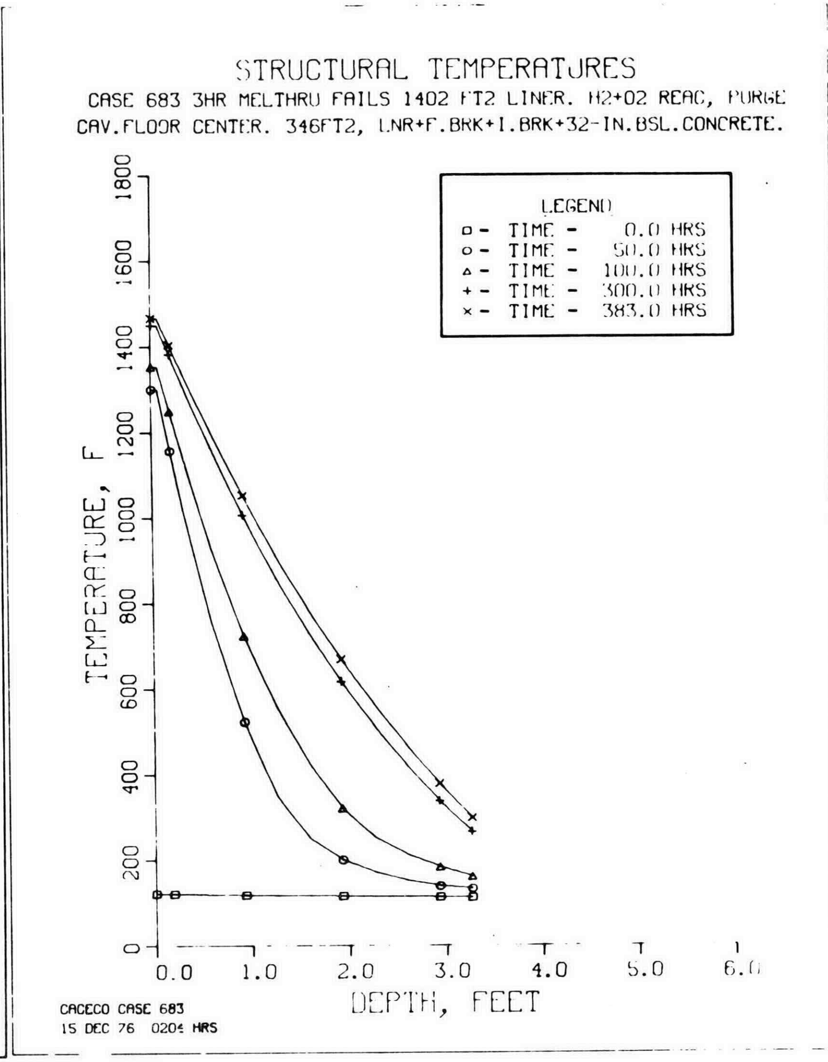

SODIUM INVENTORY
CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
SODIUM IN VESSEL, LBS
0
100000
200000
300000
400000
500000
600000
700000
0
272
544
816
1088
1360
1632
TIME, HOURS
CACECO CASE 683
15 DEC 76 0204 HRS

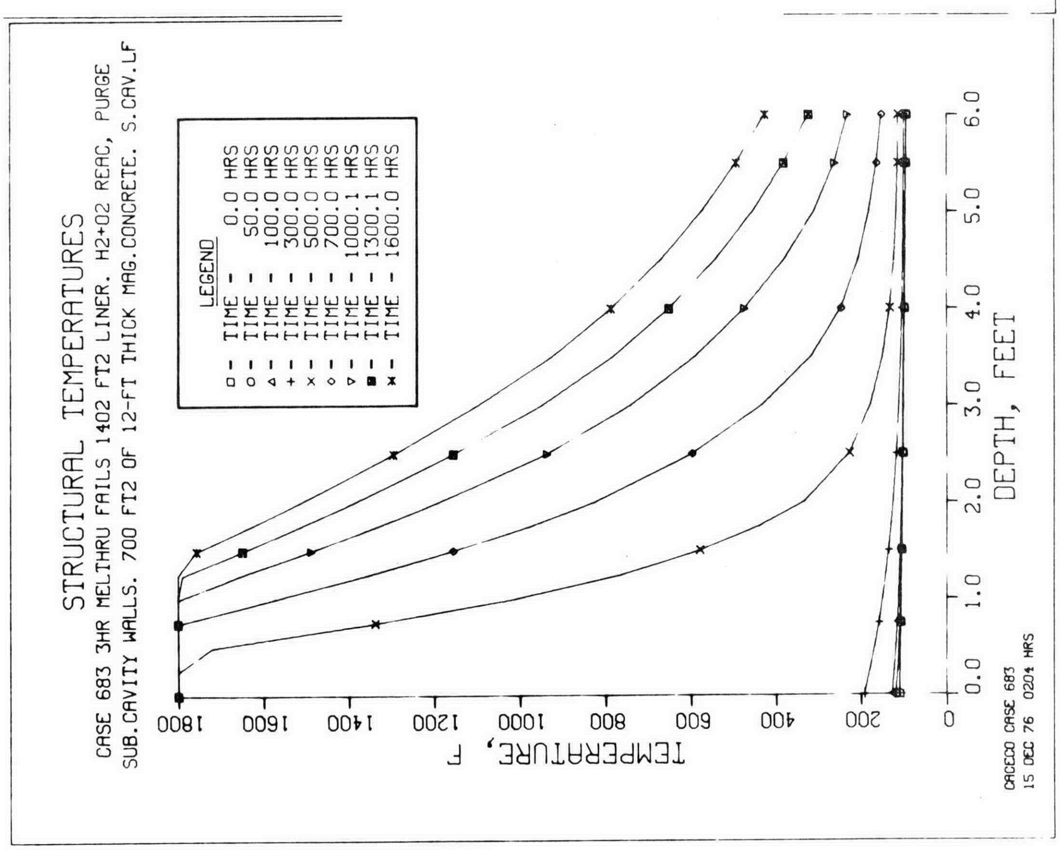

CAVITY ATMOSPHERE TEMPERATURES
CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
TEMPERATURE, F
0
225
450
675
900
1125
1350
1575
1800
Cavity Temperature
Subcavity Temperature
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 683
15 DEC 76 0204 HRS

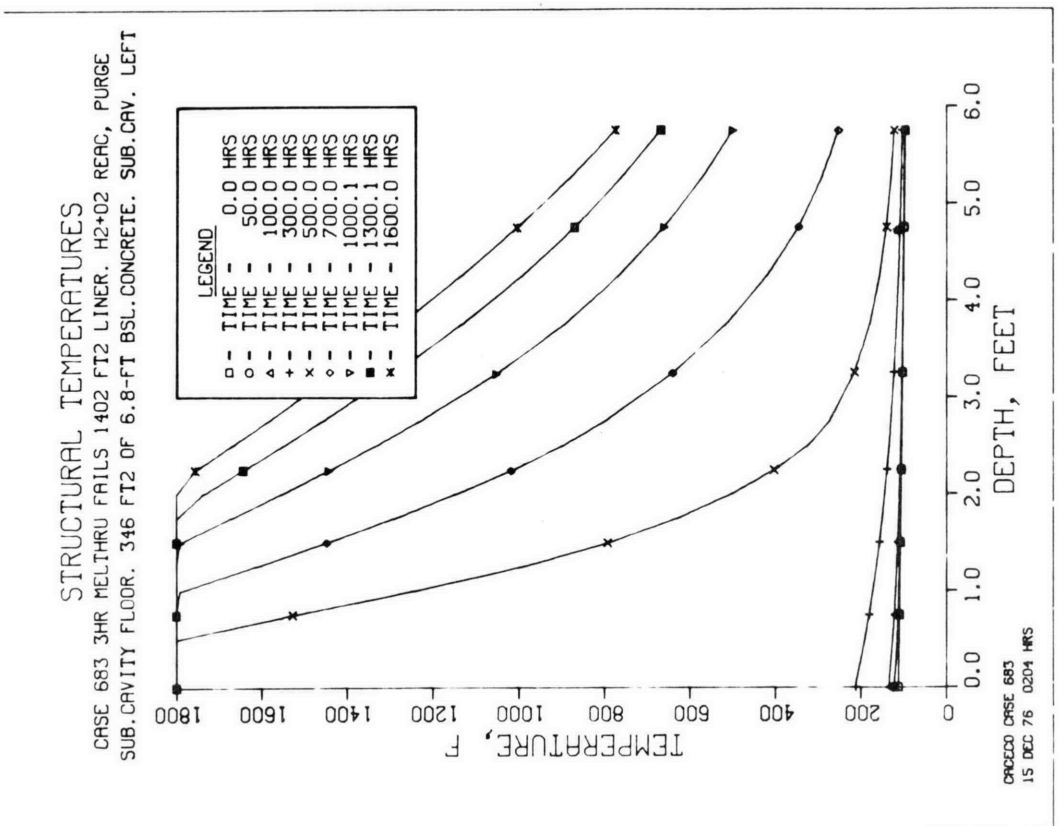

STRUCTURAL TEMPERATURES
CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
R.C.BLDG FLOOR. 13,000-FT2, EPOXY+6.5-FT.MAG.CONCRETE. BLDG LEFT
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
CACECO CASE 683
15 DEC 76 0204 HRS


STRUCTURAL TEMPERATURES
CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
CAVITY ROOF. BECHTEL LINER+6.25FT STEEL+MAG.CONCRETE. CAV. LEFT
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
CACECO CASE 683
15 DEC 76 0204 HRS


STRUCTURAL TEMPERATURES
CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
LO 10FT WAL+OT.FLOR. IA-1500FT2, LINR+GAP+0.5FT FBRK+5.5FT M.CON
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 683
15 DEC 76 0204 HRS

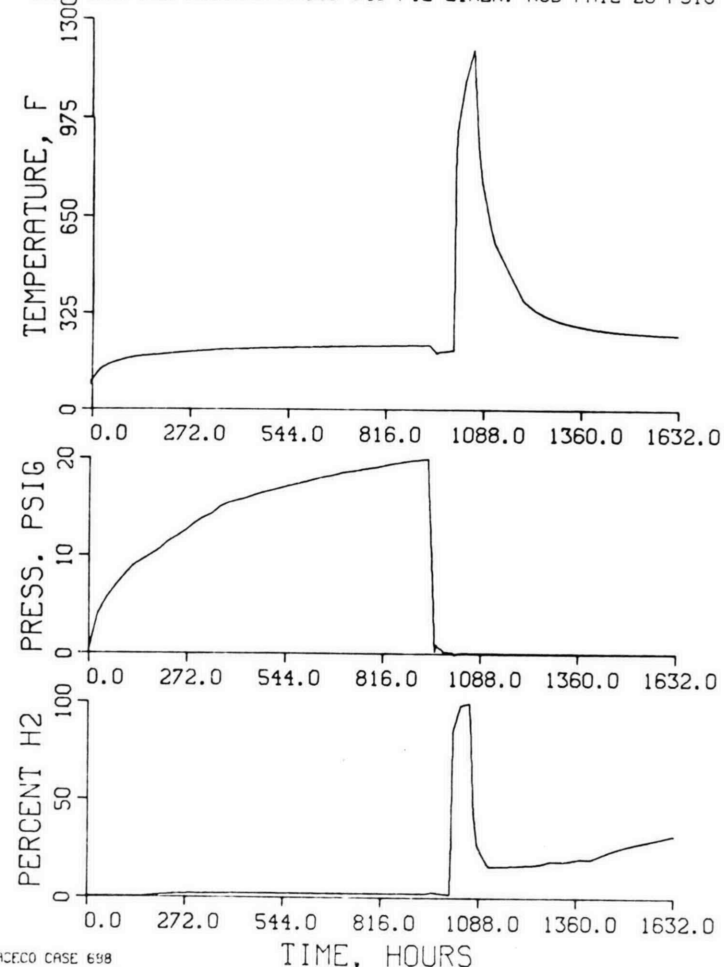

STRUCTURAL TEMPERATURES
CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
CAV.FLOOR CENTER. 346FT2, LNR+F.BRK+I.BRK+32-IN.BSL.CONCRETE.
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 383.0 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 683
15 DEC 76 0204 HRS


STRUCTURAL TEMPERATURES
CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
SUB.CAVITY WALLS. 700 FT2 OF 12-FT THICK MAG.CONCRETE. S.CAV.LF
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.1 HRS
■ - TIME - 1300.1 HRS
✱ - TIME - 1600.0 HRS
TEMPERATURE, F
1800
1600
1400
1200
1000
800
600
400
200
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 683
15 DEC 76 0204 HRS


STRUCTURAL TEMPERATURES
CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+02 REAC, PURGE
SUB.CAVITY FLOOR. 346 FT2 OF 6.8-FT BSL.CONCRETE. SUB.CAV. LEFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.1 HRS
■ - TIME - 1300.1 HRS
✱ - TIME - 1600.0 HRS
TEMPERATURE, F
1800
1600
1400
1200
1000
800
600
400
200
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 683
15 DEC 76 0204 HRS

BUILDING ATMOSPHERE CONDITIONS

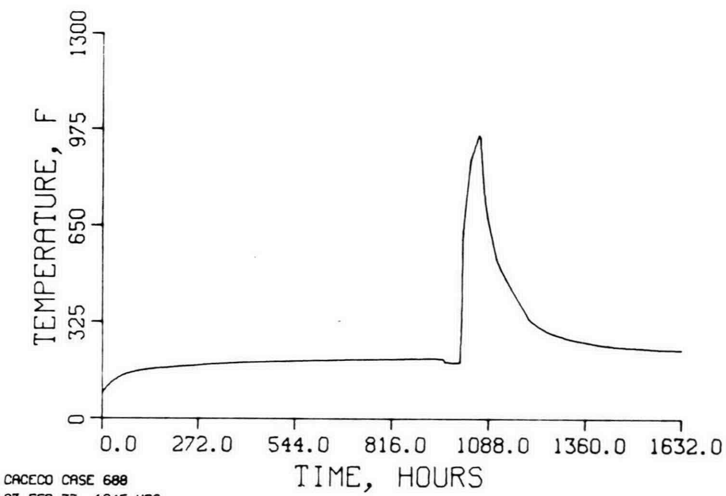
CASE 688 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG



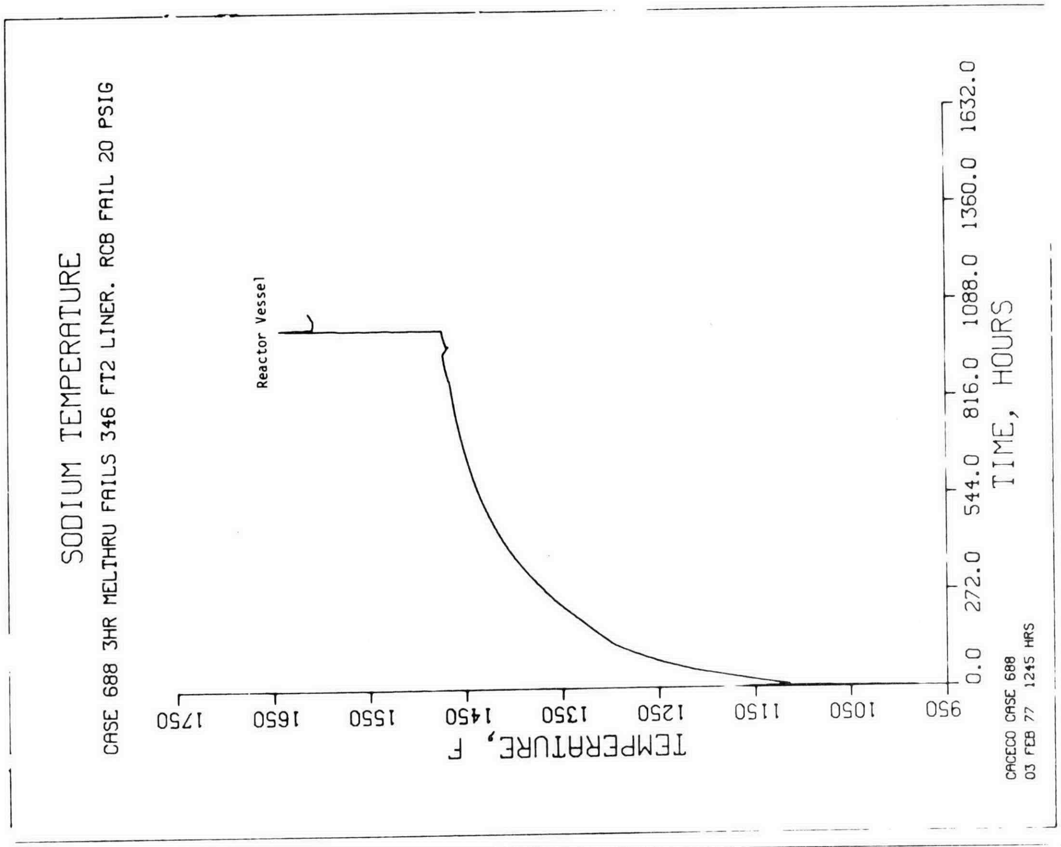
CACECO CASE 698
03 FEB 77 1245 HRS

BUILDING ROOF TEMPERATURE

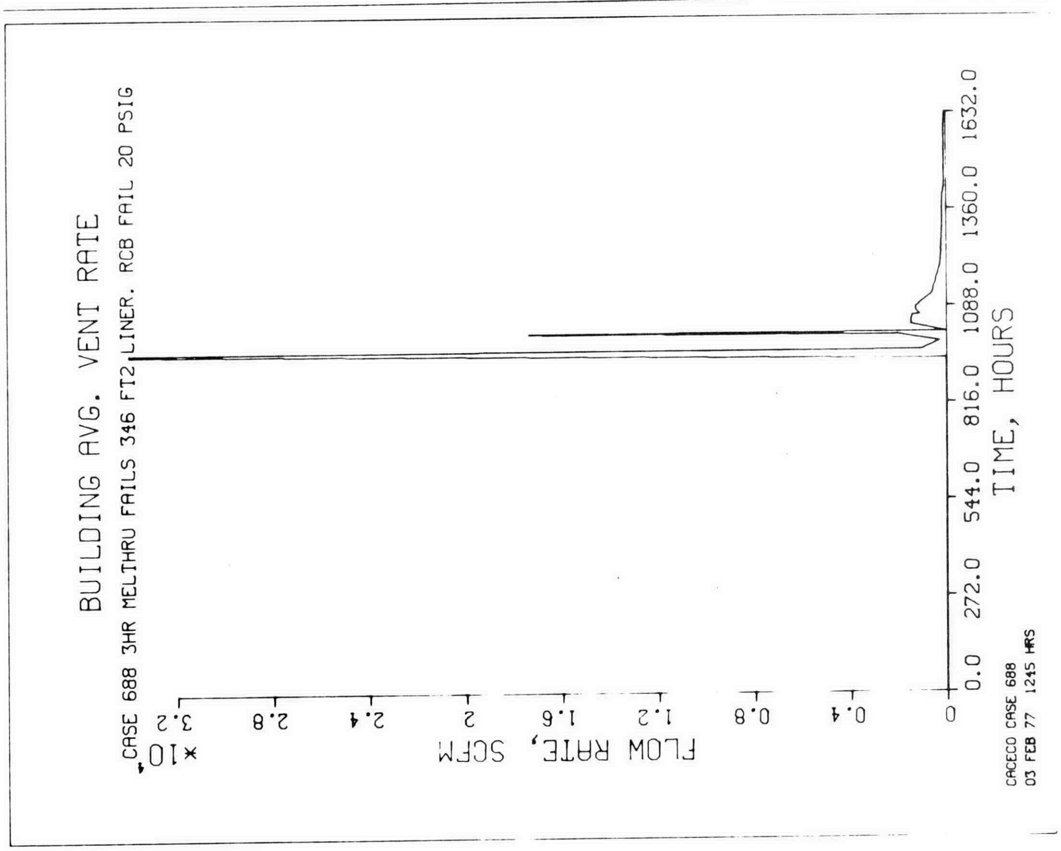
CASE 688 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG
R.C.BLDG ROOF, 34,200-FT2, 1.1-IN.C.STEEL. INSIDE LEFT, OUTSIDE(



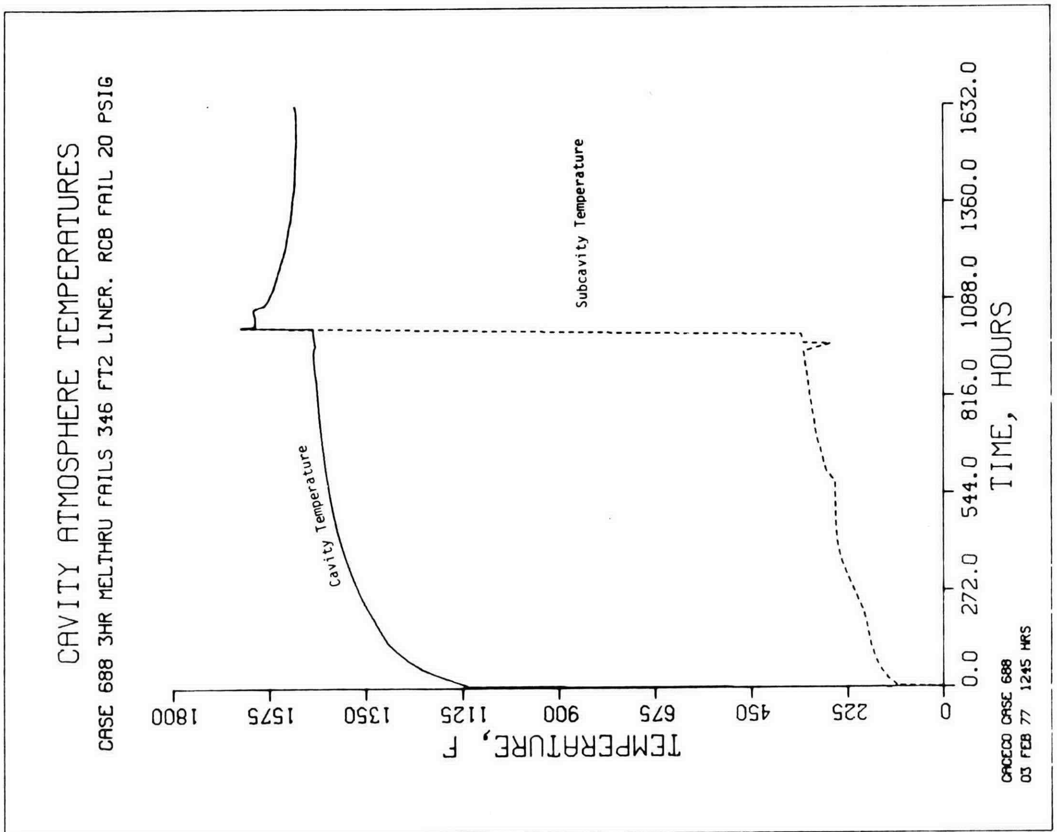
CACECO CASE 688
03 FEB 77 1245 HRS

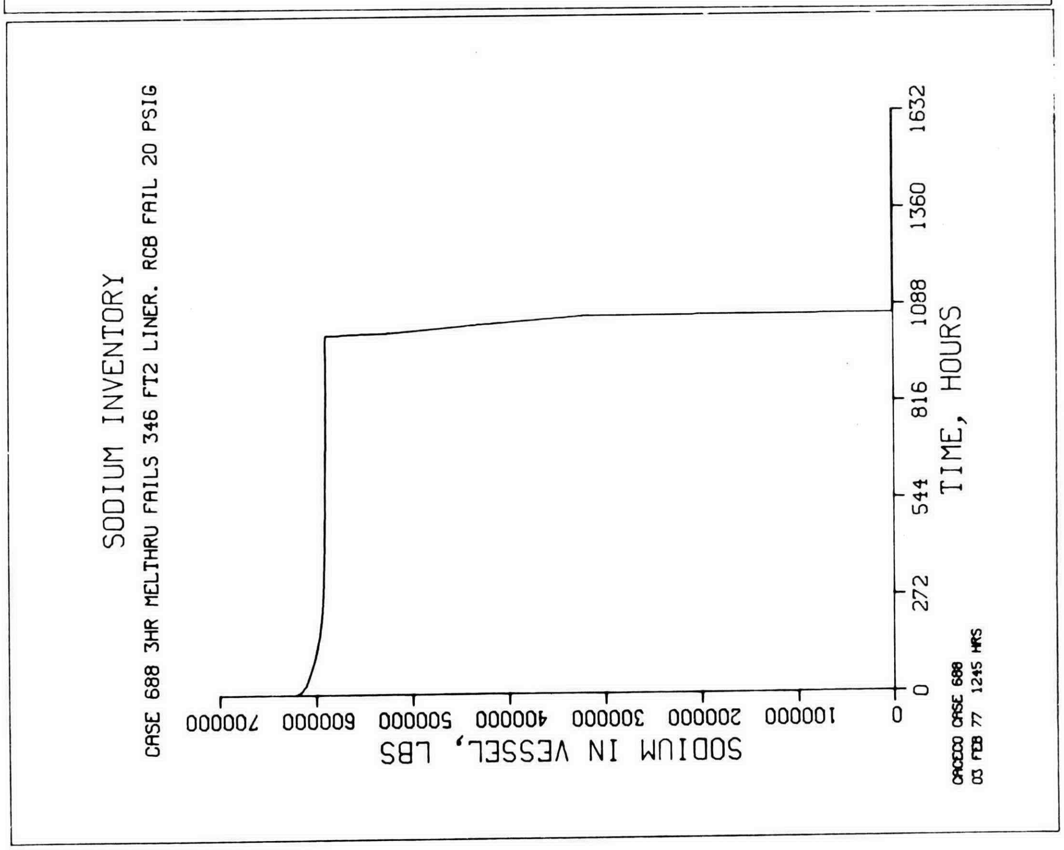


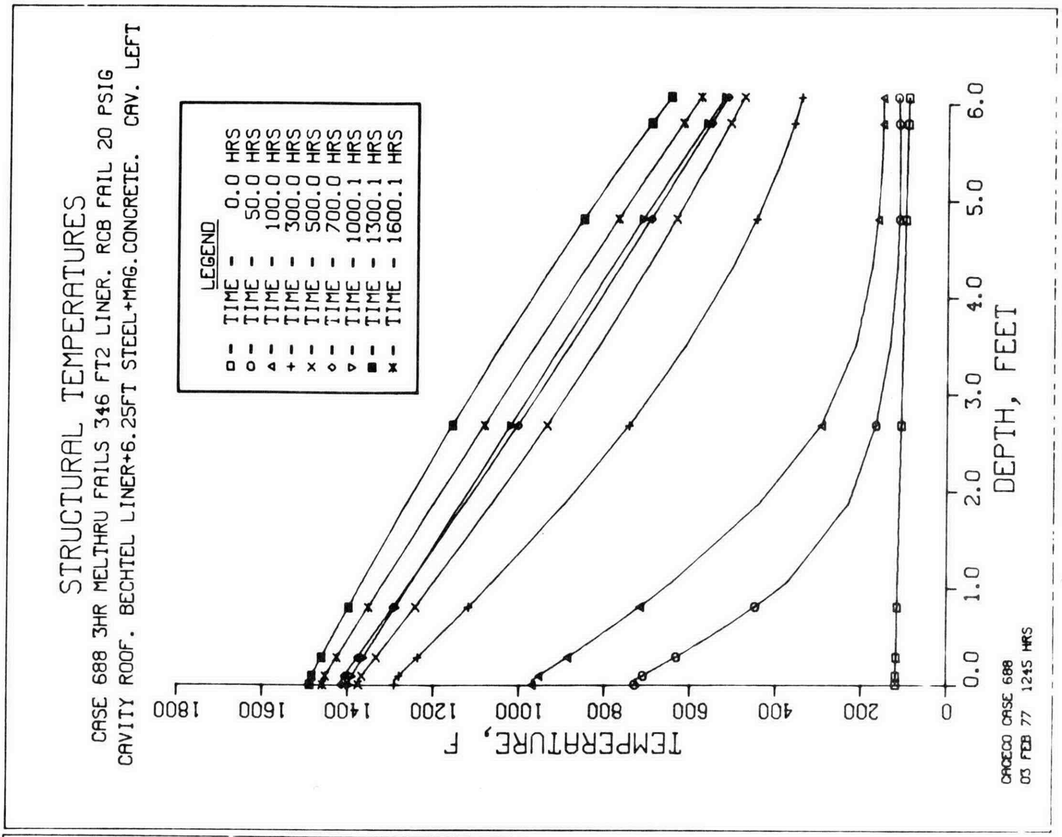
SODIUM TEMPERATURE
CASE 688 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG
Reactor Vessel
TEMPERATURE, F
950
1050
1150
1250
1350
1450
1550
1650
1750
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 688
03 FEB 77 1245 HRS



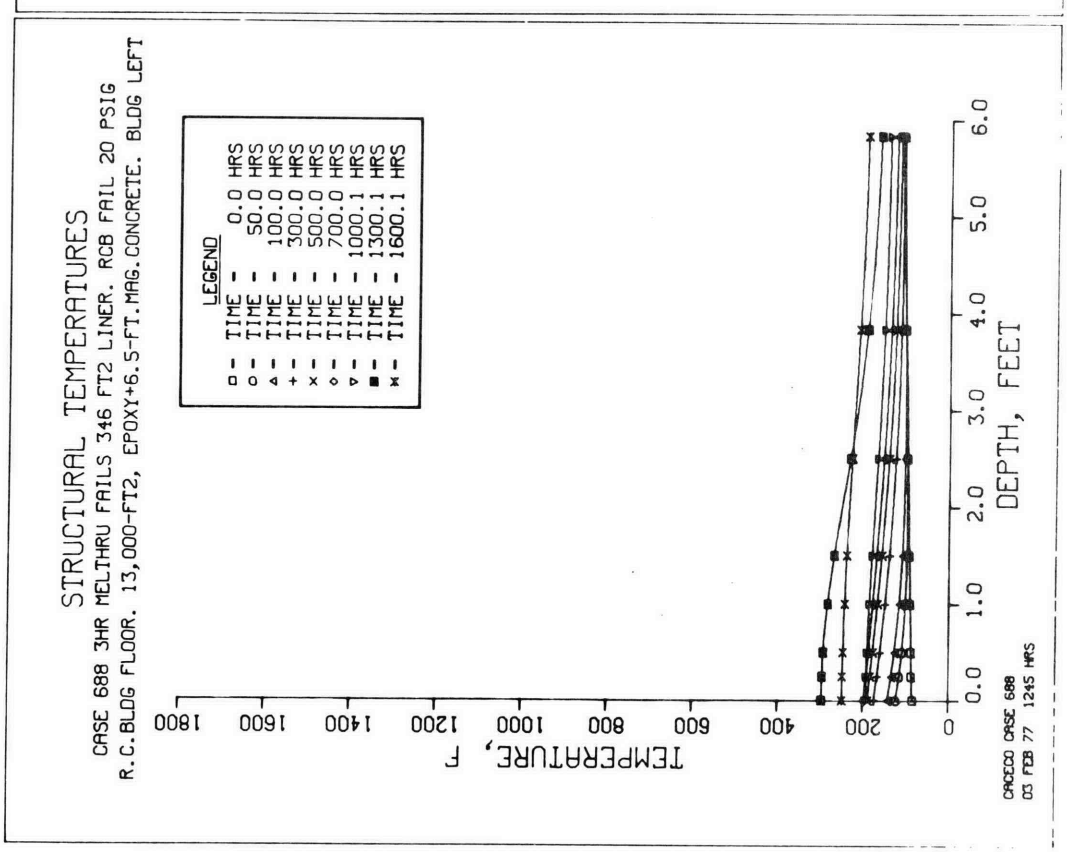
BUILDING AVG. VENT RATE
CASE 688 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG
FLOW RATE, SCFM
×10⁴
0
0.4
0.8
1.2
1.6
2
2.4
2.8
3.2
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
TIME, HOURS
CACECO CASE 688
03 FEB 77 1245 HRS


CAVITY ATMOSPHERE TEMPERATURES
CASE 688 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG
TEMPERATURE, F
0
225
450
675
900
1125
1350
1575
1800
TIME, HOURS
0.0
272.0
544.0
816.0
1088.0
1360.0
1632.0
Cavity Temperature
Subcavity Temperature
CACECO CASE 688
03 FEB 77 1245 HRS

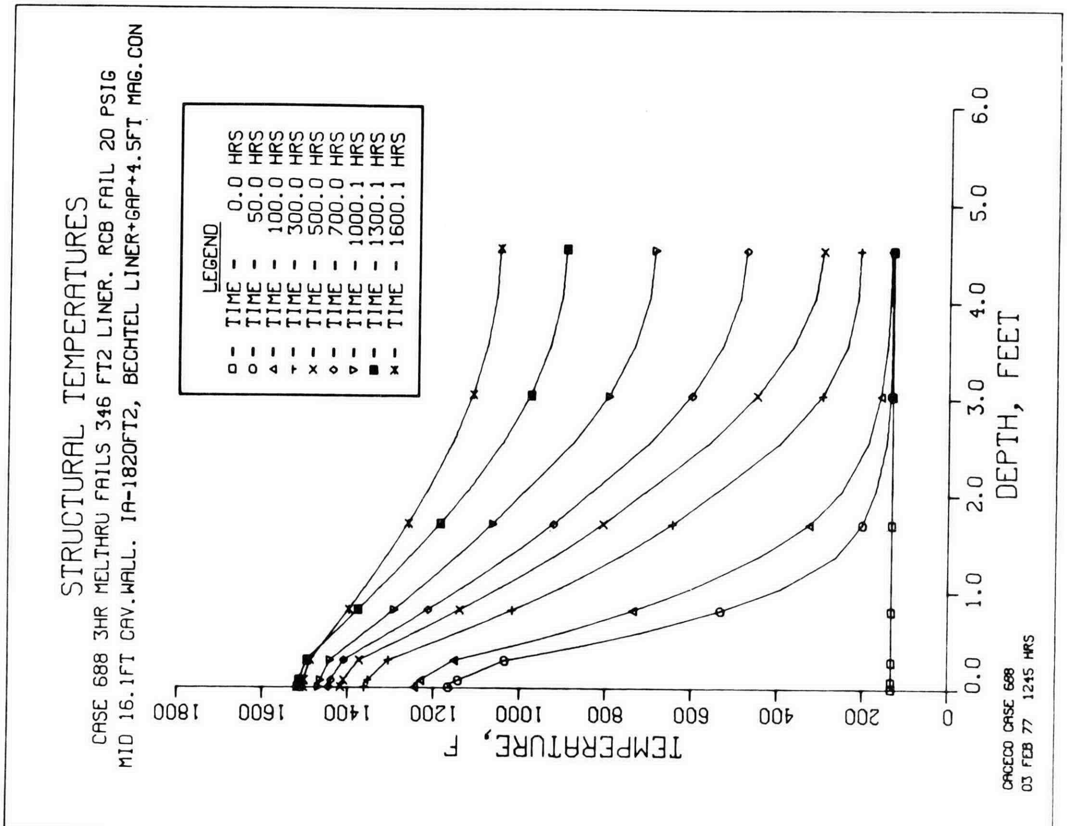

SODIUM INVENTORY
CASE 688 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG
SODIUM IN VESSEL, LBS
0
100000
200000
300000
400000
500000
600000
700000
TIME, HOURS
0
272
544
816
1088
1360
1632
CACECO CASE 688
03 FEB 77 1245 HRS

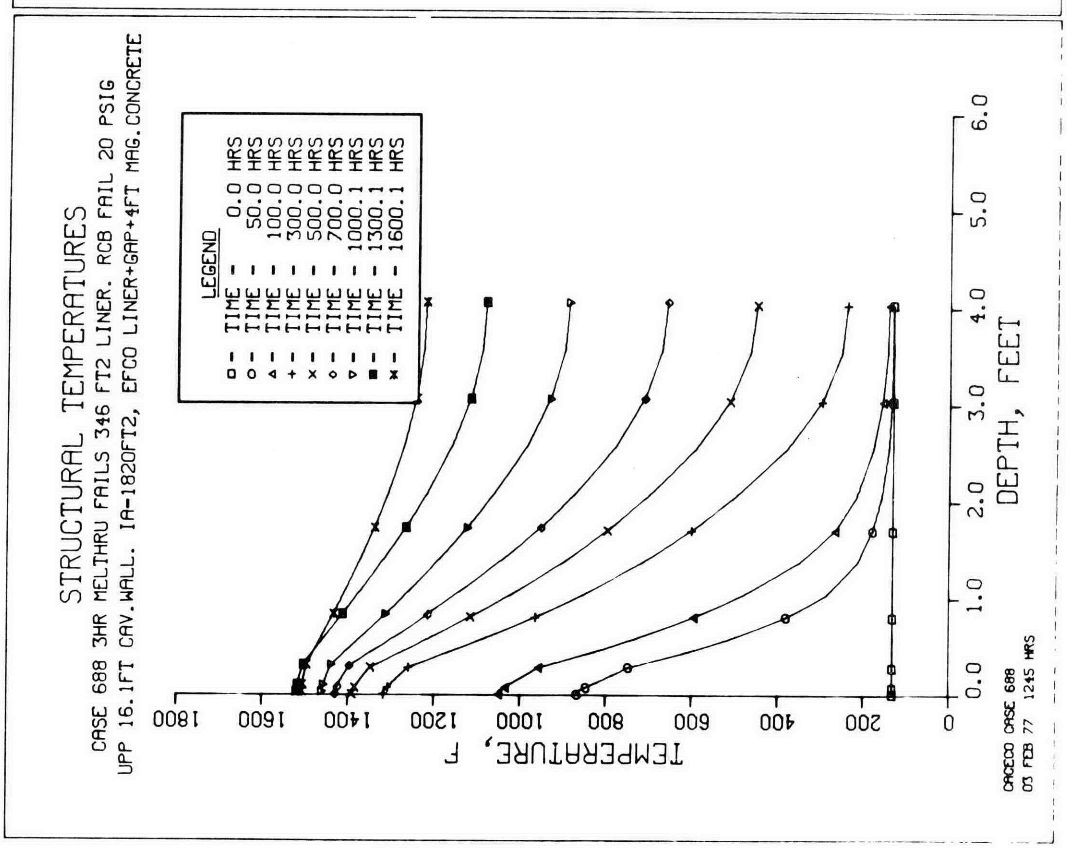


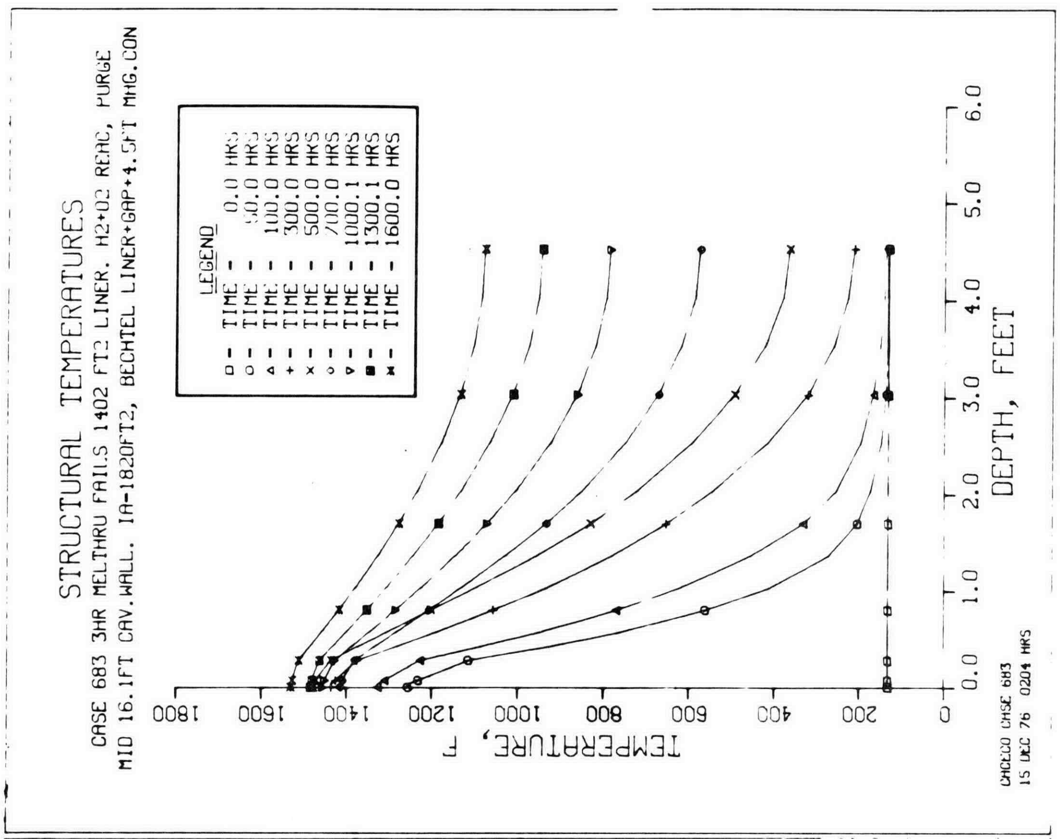
STRUCTURAL TEMPERATURES
CASE 688 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG
CAVITY ROOF. BECHTEL LINER+6.25FT STEEL+MAG.CONCRETE. CAV. LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 688
03 FEB 77 1245 HRS



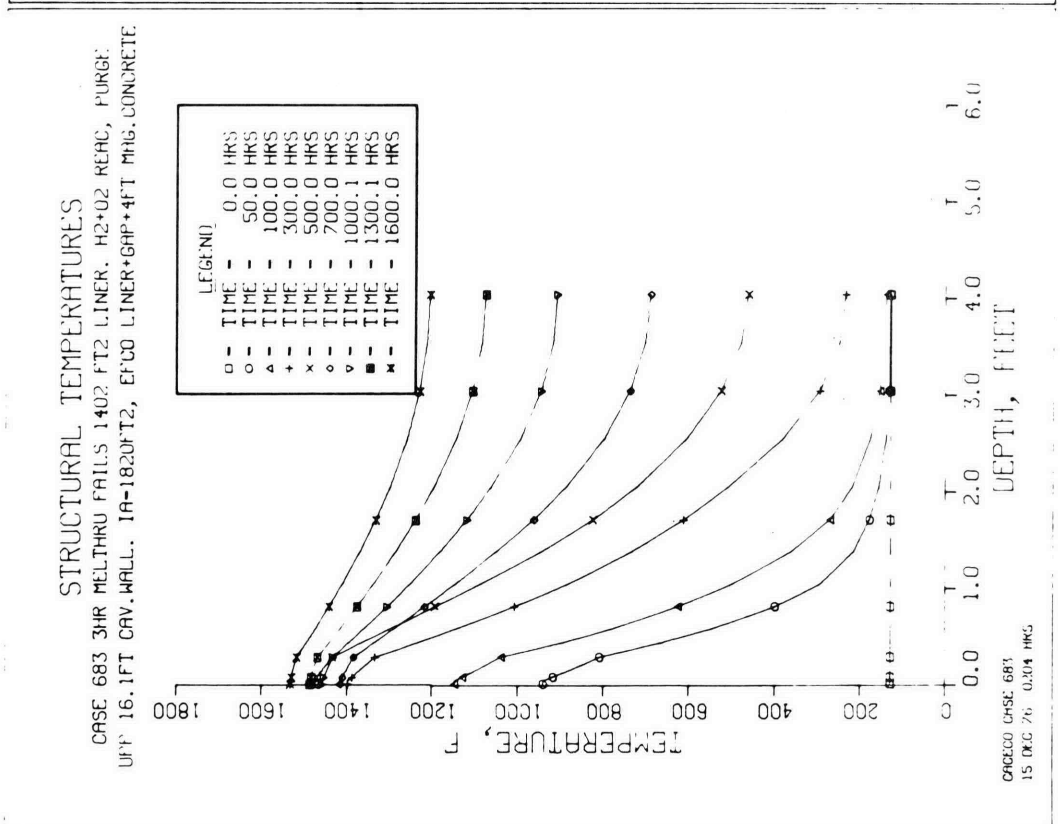
STRUCTURAL TEMPERATURES
CASE 688 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG
R.C.BLDG FLOOR. 13,000-FT2, EPOXY+6.5-FT.MAG.CONCRETE. BLDG LEFT
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 688
03 FEB 77 1245 HRS


STRUCTURAL TEMPERATURES
CASE 688 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG
MID 16.1FT CAV.WALL. IA-1820FT2, BECHTEL LINER+GAP+4.5FT MAG.CON
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 688
03 FEB 77 1245 HRS

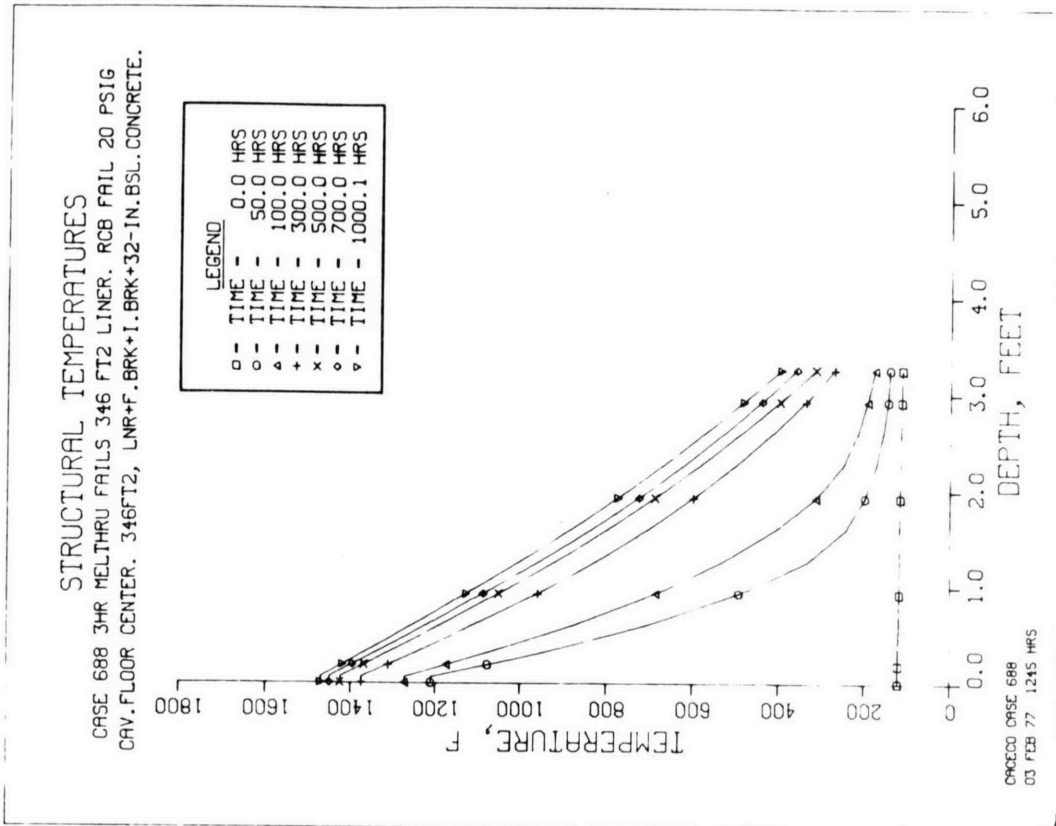

STRUCTURAL TEMPERATURES
CASE 688 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG
UPP 16.1FT CAV.WALL. IA-1820FT2, EFCO LINER+GAP+4FT MAG.CONCRETE
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
0
200
400
600
800
1000
1200
1400
1600
1800
DEPTH, FEET
0.0
1.0
2.0
3.0
4.0
5.0
6.0
CACECO CASE 688
03 FEB 77 1245 HRS

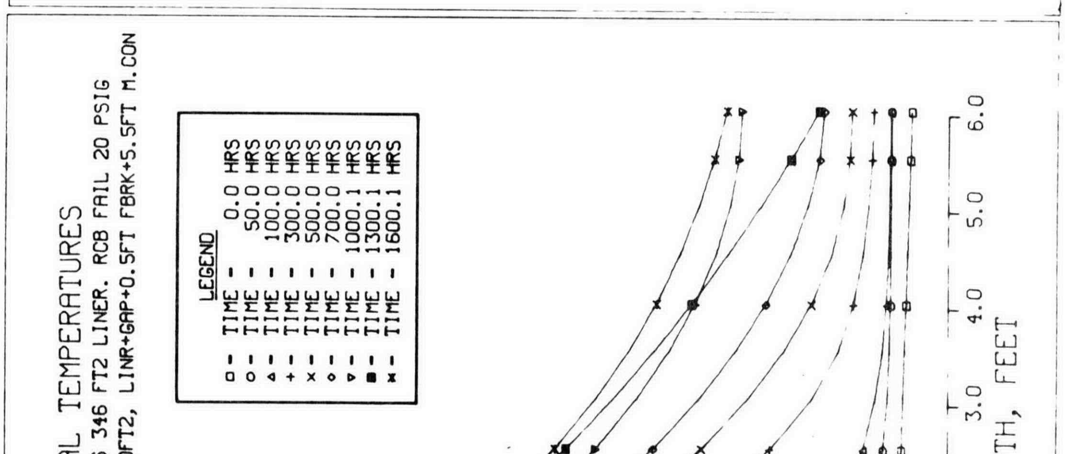


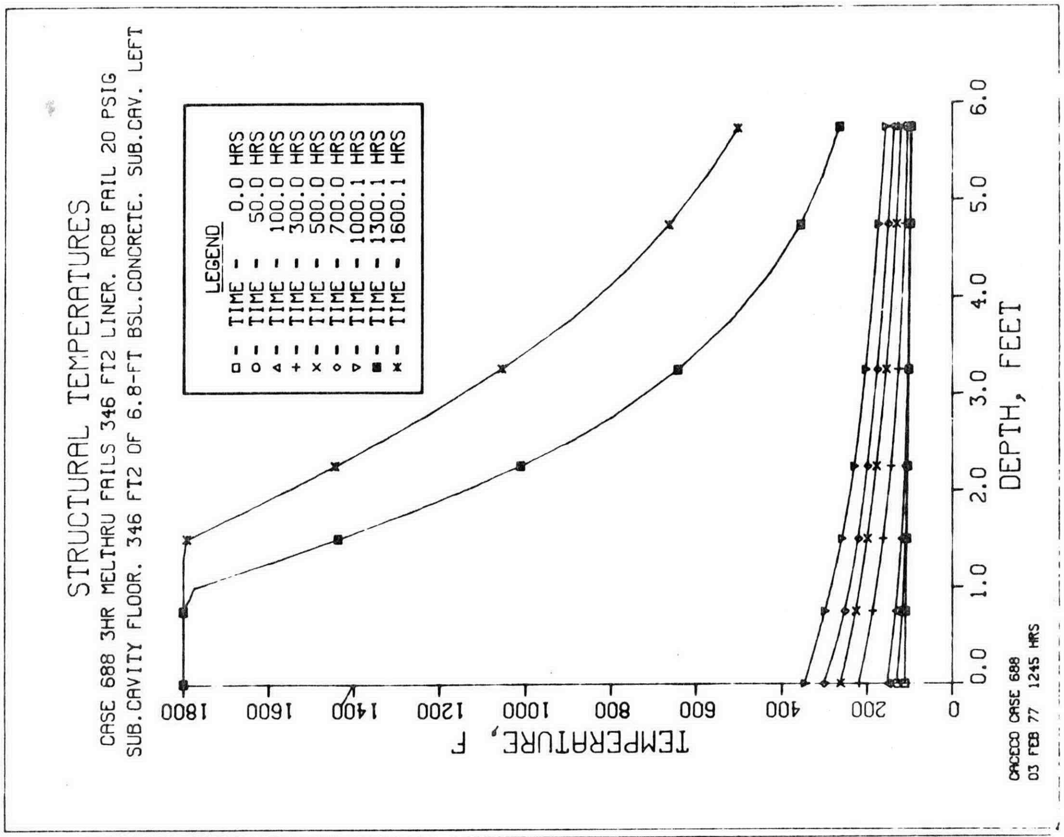
STRUCTURAL TEMPERATURES
CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
MID 16.1FT CAV.WALL. IA-1820FT2, BECHTEL LINER+GAP+4.5FT MAG.CON
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 683
15 DEC 76 0204 HRS



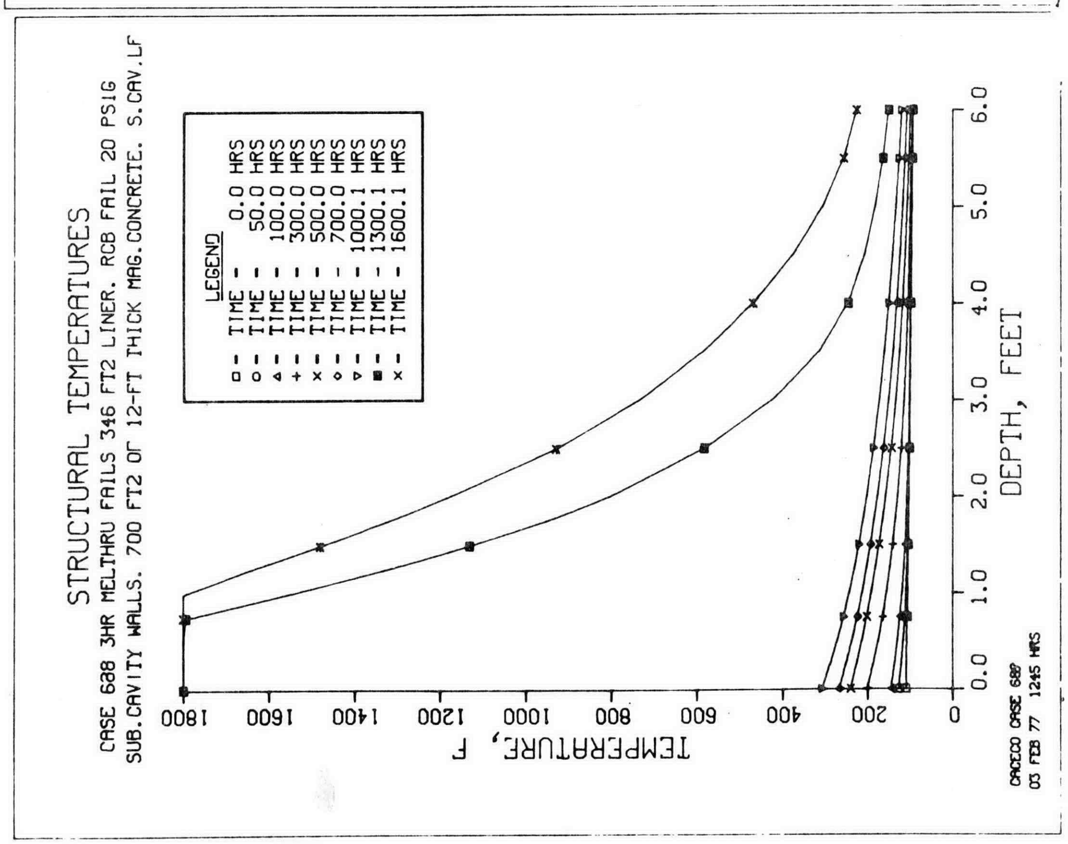
STRUCTURAL TEMPERATURES
CASE 683 3HR MELTHRU FAILS 1402 FT2 LINER. H2+O2 REAC, PURGE
OFF 16.1FT CAV.WALL. IA-1820FT2, EFCO LINER+GAP+4FT MAG.CONCRETE
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.0 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 683
15 DEC 76 0304 HRS


STRUCTURAL TEMPERATURES
CASE 688 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG
CAV.FLOOR CENTER. 346FT2, LNR+F.BRK+I.BRK+32-IN.BSL.CONCRETE.
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 688
03 FEB 77 1245 HRS


STRUCTURAL TEMPERATURES
CASE 688 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG
LO 10FT WAL+OT.FLOR. IA-1500FT2, LINR+GAP+0.5FT FBRK+5.5FT M.CON
LEGEND
TIME - 0.0 HRS
TIME - 50.0 HRS
TIME - 100.0 HRS
TIME - 300.0 HRS
TIME - 500.0 HRS
TIME - 700.0 HRS
TIME - 1000.1 HRS
TIME - 1300.1 HRS
TIME - 1600.1 HRS
TEMPERATURE, F
DEPTH, FEET
CACECO CASE 688
03 FEB 77 1245 HRS



STRUCTURAL TEMPERATURES
CASE 688 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG
SUB.CAVITY FLOOR. 346 FT2 OF 6.8-FT BSL.CONCRETE. SUB.CAV. LEFT
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.1 HRS
■ - TIME - 1300.1 HRS
✕ - TIME - 1600.1 HRS
TEMPERATURE, F
1800
1600
1400
1200
1000
800
600
400
200
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 688
03 FEB 77 1245 HRS



STRUCTURAL TEMPERATURES
CASE 688 3HR MELTHRU FAILS 346 FT2 LINER. RCB FAIL 20 PSIG
SUB.CAVITY WALLS. 700 FT2 OF 12-FT THICK MAG.CONCRETE. S.CAV.LF
LEGEND
□ - TIME - 0.0 HRS
○ - TIME - 50.0 HRS
△ - TIME - 100.0 HRS
+ - TIME - 300.0 HRS
× - TIME - 500.0 HRS
◇ - TIME - 700.0 HRS
▽ - TIME - 1000.1 HRS
■ - TIME - 1300.1 HRS
✕ - TIME - 1600.1 HRS
TEMPERATURE, F
1800
1600
1400
1200
1000
800
600
400
200
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH, FEET
CACECO CASE 688
03 FEB 77 1245 HRS

APPENDIX B-1

FFTF CORE INVENTORY LIBRARY

The table in this appendix shows the isotopic inventory of the FFTR at end-of-equilibrium-cycle. This table was output by COMRADEX for a 100% assignment to the first chamber, thus, this inventory is presented as "release". Other data in the table are:

"CHN" - Decay chains are printed in order. The first member of a chain decays into the next and so on until the chain is completed. Isotopes with very short lives are skipped. In some cases an isotope may be a member of more than one chain; this indicates a split in the chain.

"GP" - The elements are grouped by physical characteristics of the most probable state of compound. 0 - solids (nonvolatile), 1 - halogens, 2 - nobles, 3 - volatile solids (other than halogens and sodium), and 4 - sodium.

"DECAY CONST" - Radioactive Decay Constant in sec^{-1}

"GAMMA VAL" - Gamma Value in (roentgen-ft^2)/(curie-hour)

F Values - "BONE", "THYROID", etc., in Rem/Ci inhaled.

TABLE B-1

ISOTOPIC INVENTORY

ISOTOPE	CHN	GP	DECAY CONST	RELEASE (CI)	GAMMA VAL	BONE	THYROID	TOTAL BODY	NEW LUNG
ZN 72	1	0	4.14062E-06	1.81754E+03	8.534E-01	0.	0.	0.	3.290E+04
GA 72	1	0	1.36552E-05	1.83411E+03	1.396E+01	1.153E+03	0.	2.541E+02	1.012E+04
ZN 73	2	0	2.94953E-02	2.20461E+03	0.	0.	0.	0.	0.
GA 73	2	0	3.94547E-05	2.40389E+03	2.092E+00	0.	0.	0.	1.934E+03
GE 75	3	0	1.39521E-04	8.09965E+03	2.210E-01	0.	0.	0.	4.308E+02
GE * 77	4	0	1.27650E-02	1.75393E+04	4.576E-01	0.	0.	0.	2.328E+01
AS 77	4	3	4.96234E-06	2.33922E+04	6.501E-02	0.	0.	1.097E+02	4.986E+03
GE * 77	5	0	1.27650E-02	9.86621E+03	4.576E-01	0.	0.	0.	2.328E+01
GE 77	5	0	1.70388E-05	1.46457E+04	6.761E+00	0.	0.	0.	8.545E+03
AS 77	5	3	4.96234E-06	1.31581E+04	6.501E-02	0.	0.	1.097E+02	4.986E+03
GE 78	6	0	1.32785E-04	6.04365E+04	1.739E+00	0.	0.	0.	2.182E+03
AS 78	6	3	1.27098E-04	6.28399E+04	5.146E+00	0.	0.	0.	1.867E+03
AS 79	7	3	1.28359E-03	1.28240E+05	2.014E-01	0.	0.	0.	9.852E+01
SE * 79	7	3	2.96975E-03	1.20589E+05	5.429E-01	0.	0.	0.	9.562E-02
SE 79	7	3	3.38150E-13	7.16272E-01	0.	0.	0.	0.	5.150E+04
AS 81	8	3	2.16606E-02	2.96092E+05	0.	0.	0.	0.	1.587E+01
SE 81	8	3	6.24451E-04	1.40691E+05	1.639E-01	0.	0.	0.	1.426E+02
SE * 81	9	3	2.01611E-04	1.33032E+04	4.525E-02	0.	0.	0.	4.324E+02
SE 81	9	3	6.24451E-04	1.40691E+05	0.	0.	0.	0.	1.426E+02
BR 82	10	1	5.43895E-06	5.45379E+03	1.639E-01	0.	0.	1.796E+03	3.221E+02
SE * 83	11	3	9.90200E-03	6.29756E+05	4.707E+00	0.	0.	0.	2.344E+01
BR 83	11	1	8.02245E-05	5.71502E+05	4.824E-02	0.	0.	0.	1.116E+02
KR * 83	11	2	1.03516E-04	5.71566E+05	4.580E-03	0.	0.	0.	0.

ISOTOPE	CHN	GP	DECAY CONST	RELEASE (CI)	GAMMA VAL	BONE	THYROID	TOTAL BODY	NEW LUNG
SE 83	12	3	5.13437E-04	4.85212E+05	1.400E+01	0.	0.	0.	3.834E+02
BR 83	12	1	8.02245E-05	5.71532E+05	4.824E-02	0.	0.	0.	1.116E+02
KR * 83	12	2	1.03516E-04	5.71566E+05	4.580E-03	0.	0.	0.	0.
SE 84	13	3	3.50371E-03	1.57466E+06	0.	0.	0.	0.	9.686E+01
BR 84	13	1	3.63281E-04	1.67223E+06	1.209E+01	0.	0.	0.	4.218E+02
BR * 84	14	1	1.92539E-03	1.09239E+05	1.294E+01	0.	0.	0.	8.074E+01
SE 85	15	3	1.77728E-02	8.45355E+05	0.	0.	0.	0.	1.833E+01
BR 85	15	1	4.02520E-03	1.58324E+06	0.	0.	0.	0.	3.644E+01
KR * 85	15	2	4.29774E-05	1.60637E+06	8.883E-01	0.	0.	0.	0.
SE 85	16	3	1.77728E-02	1.98293E+05	0.	0.	0.	0.	1.833E+01
BR 85	16	1	4.02520E-03	3.71377E+05	0.	0.	0.	0.	3.644E+01
KR * 85	16	2	4.29774E-05	3.76803E+05	8.883E-01	0.	0.	0.	0.
KR 85	16	2	2.04700E-09	1.55667E+04	1.260E+00	0.	0.	0.	0.
RB 86	17	3	4.30148E-07	3.34353E+04	5.818E-01	0.	0.	7.539E+03	2.533E+02
SE 87	18	3	1.23775E-01	6.08806E+05	0.	0.	0.	0.	1.475E+01
BR 87	18	1	1.24219E-02	2.11313E+06	1.704E+01	0.	0.	0.	3.622E+01
KR 87	18	2	1.52204E-04	3.16742E+06	7.397E+00	0.	0.	0.	0.
RB 87	18	3	4.67643E-19	3.01630E-05	0.	0.	0.	3.191E+03	3.459E+01
BR 88	19	1	4.35937E-02	1.69335E+06	2.412E+00	0.	0.	0.	5.561E+00
KR 88	19	2	6.87639E-05	4.46213E+06	9.070E+00	0.	0.	0.	0.
RB 88	19	3	6.52674E-04	4.68055E+06	3.100E+00	0.	0.	0.	3.318E+02
BR 89	20	1	1.54031E-01	1.11755E+06	0.	0.	0.	0.	4.139E+00
KR 89	20	2	3.65580E-03	4.78668E+06	1.297E+01	0.	0.	0.	0.
RB 89	20	3	7.60022E-04	6.12919E+06	1.377E+01	0.	0.	0.	2.113E+02
SR 89	20	0	1.54278E-07	5.14678E+06-	0.	4.140E+05	0.	1.160E+04	2.064E+05

ISOTOPE		CHN	GP	DECAY CONST	RELEASE (CI)	GAMMA VAL	BONE	THYROID	TOTAL BODY	NEW LUNG
BR	90	21	1	4.33213E-01	5.19151E+05	0.	0.	0.	0.	1.658E+00
KR	90	21	2	2.14594E-02	4.51129E+06	1.318E+01	0.	0.	0.	0.
RB	90	21	3	4.27864E-03	5.07661E+06	1.657E+01	0.	0.	0.	7.236E+01
SR	90	21	0	7.81647E-10	9.78105E+04	0.	1.600E+07	0.	1.149E+04	1.094E+06
Y	90	21	0	3.00466E-06	1.03592E+05	0.	2.364E+04	0.	6.291E+02	3.087E+04
KR	91	22	2	7.96713E-02	1.88951E+06	0.	0.	0.	0.	0.
RB	91	22	3	1.19096E-02	4.37454E+06	0.	0.	0.	0.	2.160E+01
SR	91	22	0	2.03100E-05	5.14594E+06	4.376E+00	6.450E+03	0.	4.095E+02	1.002E+04
Y	91	22	0	2.32441E-04	4.79105E+06	3.455E+00	2.130E+02	0.	8.687E+02	3.498E+02
Y	91	22	0	1.36902E-07	4.15919E+06	2.118E-02	3.320E+05	0.	8.879E+03	3.343E+05
KR	91	23	2	7.96713E-02	1.15809E+06	0.	0.	0.	0.	0.
RB	91	23	3	1.19096E-02	2.68117E+06	0.	0.	0.	0.	2.160E+01
SR	91	23	0	2.03100E-05	3.15580E+06	4.378E+00	6.838E+03	0.	4.095E+02	1.002E+04
Y	91	23	0	1.36902E-07	2.54919E+06	2.118E-02	3.320E+05	0.	8.879E+03	3.343E+05
KR	92	24	2	3.76707E-01	1.69979E+06	0.	0.	0.	0.	0.
RB	92	24	3	1.53011E-01	6.16063E+06	0.	0.	0.	0.	6.455E+00
SR	92	24	0	7.10476E-05	9.81208E+06	7.037E+00	3.799E+03	0.	1.235E+02	3.994E+03
Y	92	24	0	5.45436E-05	9.96681E+06	1.369E+00	2.075E+03	0.	6.332E+01	3.862E+03
KR	93	25	2	5.45780E-01	6.83256E+05	0.	0.	0.	0.	0.
RB	93	25	3	1.19507E-01	4.53572E+06	0.	0.	0.	0.	5.094E+00
SR	93	25	0	1.54031E-03	1.17201E+07	7.071E+00	0.	0.	0.	3.214E+02
Y	93	25	0	1.86764E-05	1.23371E+07	9.176E-01	5.594E+03	0.	1.925E+02	1.049E+04
ZR	93	25	0	2.31363E-14	4.99307E+00	0.	2.335E+04	0.	1.225E+03	1.957E+04
KR	94	26	2	3.30067E+00	1.81385E+05	0.	0.	0.	0.	0.
RB	94	26	3	2.57673E-01	2.22592E+06	0.	0.	0.	0.	2.996E+00
SR	94	26	0	9.16852E-03	1.15744E+07	7.922E+00	0.	0.	0.	6.215E+01
Y	94	26	0	6.08018E-04	1.35131E+07	4.239E+00	0.	0.	0.	6.258E+02

ISOTOPE		CHN	GP	DECAY CONST	RELEASE (CI)	GAMMA VAL	BONE	THYROID	TOTAL BODY	NEW LUNG
KR	95	27	2	1.38628E+00	4.16174E+04	0.	0.	0.	0.	0.
SR	95	27	0	2.66592E-02	1.01122E+07	0.	0.	0.	0.	3.504E+01
Y	95	27	0	1.10022E-03	1.48361E+07	1.706E+00	0.	0.	0.	3.027E+02
ZR	95	27	0	1.22480E-07	1.19639E+07	4.697E+00	6.276E+04	0.	1.629E+04	2.221E+05
NB	95	27	0	2.28560E-07	9.69589E+06	4.855E+00	1.320E+04	0.	4.500E+03	7.443E+04
NB	96	28	0	8.22816E-06	6.48910E+04	1.475E+01	0.	0.	0.	4.181E+03
SR	97	29	0	3.46570E+00	2.96493E+06	0.	0.	0.	0.	0.
Y	97	29	0	6.24451E-01	1.12911E+07	0.	0.	0.	0.	0.
ZR	97	29	0	1.14607E-05	1.66811E+07	8.609E-01	4.169E+03	0.	3.919E+02	1.734E+04
NB *	97	29	0	1.26359E-02	1.44449E+07	4.841E+00	0.	0.	0.	1.084E+01
NB	97	29	0	1.56961E-04	1.68169E+07	4.432E+00	1.284E+02	0.	1.163E+01	5.791E+02
NB *	98	30	0	2.26516E-04	1.74344E+07	0.	0.	0.	0.	5.206E+01
ZR	99	31	0	2.88808E-01	1.63340E+07	0.	0.	0.	0.	2.284E+01
NB	99	31	0	4.95100E-02	1.59436E+07	2.192E-01	0.	0.	0.	5.584E+01
MO	99	31	0	2.91637E-06	1.70932E+07	8.941E-01	0.	0.	6.238E+02	1.720E+04
TC *	99	31	0	3.19832E-05	1.63883E+07	7.126E-01	5.225E-02	0.	8.443E+00	1.494E+02
TC	99	31	0	1.04595E-13	0.	0.	1.240E+02	0.	4.961E+01	9.435E+04
ZR	99	32	0	2.88808E-01	1.81488E+06	0.	0.	0.	0.	2.284E+01
NB	99	32	0	4.95100E-02	1.77209E+06	2.192E-01	0.	0.	0.	5.584E+01
MO	99	32	0	2.91637E-06	1.89924E+06	8.941E-01	0.	0.	6.238E+02	1.720E+04
NB	100	33	0	2.88808E-01	6.47523E+07	5.996E+00	0.	0.	0.	2.388E+01
NB	101	34	0	9.90200E-02	2.13003E+07	0.	0.	0.	0.	4.350E+02
MO	101	34	0	7.91256E-04	2.10328E+07	8.598E+00	0.	0.	0.	3.462E+02
TC	101	34	0	8.13545E-04	2.10437E+07	2.732E+00	0.	0.	0.	1.077E+02
MO	102	35	0	1.04075E-03	2.14455E+07	0.	0.	0.	0.	1.887E+02
TC	102	35	0	1.30781E-01	2.11974E+07	1.528E+00	0.	0.	0.	4.871E+01

ISOTOPE	CHN	GP	DECAY CONST	RELEASE (CI)	GAMMA VAL	BONE	THYROID	TOTAL BODY	NEW LUNG
TC 103	36	0	1.36628E-02	4.96009E+07	2.660E-01	0.	0.	0.	1.171E+01
RU 103	36	0	2.02587E-07	1.92505E+07	3.103E+00	1.493E+03	0.	7.732E+02	1.027E+05
RH *103	36	0	2.06292E-04	1.92479E+07	9.050E-03	1.583E+00	0.	8.039E-01	3.990E+01
MO 104	37	0	7.22021E-03	1.84244E+07	0.	0.	0.	0.	5.500E+01
TC 104	37	0	6.41795E-04	2.03758E+07	1.544E+01	0.	0.	0.	4.057E+02
MO 105	38	0	1.25359E-02	1.15804E+07	0.	0.	0.	0.	3.070E+01
TC 105	38	0	1.44434E-03	1.54773E+07	6.221E-01	0.	0.	0.	2.323E+02
RU 105	38	0	4.33646E-05	1.59442E+07	4.405E+00	1.339E+02	0.	6.115E+01	2.911E+03
RH *105	38	0	1.87335E-02	4.11382E+06	7.296E-01	0.	0.	0.	2.130E+03
RH 105	38	0	5.42363E-06	1.59377E+07	4.987E-01	2.759E+02	0.	9.685E+01	3.972E+03
RU 106	39	0	2.17411E-08	4.12861E+06	0.	2.103E+04	0.	2.855E+03	2.204E+06
RH 106	39	0	2.31819E-02	4.13332E+06	1.310E+00	0.	0.	0.	8.905E+00
TC 107	40	0	2.39014E-02	7.11374E+06	0.	0.	0.	0.	1.881E+01
RU 107	40	0	2.75056E-03	9.43444E+06	1.338E+00	0.	0.	0.	9.698E+01
RH 107	40	0	5.32366E-04	9.47665E+06	2.114E+00	0.	0.	0.	1.478E+02
PD 107	40	0	3.38150E-15	5.34602E-01	0.	0.	0.	0.	4.765E+04
RH 109	41	0	7.70156E-03	9.13948E+06	0.	0.	0.	0.	1.083E+03
PD 109	41	0	1.43045E-05	4.93865E+06	3.040E-03	0.	0.	7.792E+01	3.720E+03
AG *109	41	0	1.75035E-02	4.93786E+06	2.488E-02	0.	0.	0.	7.856E-03
PD 111	42	0	5.25105E-04	1.50443E+06	1.316E+00	0.	0.	0.	3.650E+02
AG *111	42	0	1.06637E-02	1.08533E+06	3.676E-01	0.	0.	0.	6.066E+00
AG 111	42	0	1.07396E-06	1.10006E+06	1.503E-01	1.498E+03	0.	3.310E+02	3.338E+04
PD 112	43	0	9.57905E-06	5.62667E+05	2.145E-02	0.	0.	0.	2.167E+04
AG 112	43	0	6.15140E-05	5.84825E+05	3.805E+00	0.	0.	0.	3.539E+03
PD 113	44	0	7.70156E-03	3.91572E+05-	0.	0.	0.	0.	3.879E+01
AG 113	44	0	3.63281E-05	3.49014E+05	3.782E+00	0.	0.	0.	3.544E+03

B-6

ISOTOPE	CHN	GP	DECAY CONST	RELEASE (CI)	GAMMA VAL	BONE	THYROID	TOTAL BODY	NEW LUNG
PD 114	45	0	4.81347E-03	2.79474E+05	0.	0.	0.	0.	1.046E+02
AG 114	45	0	1.50683E-01	2.85299E+05	3.769E+00	0.	0.	0.	2.591E+00
AG 115	46	0	5.50111E-04	1.71556E+05	6.723E+00	0.	0.	0.	4.851E+03
CD 115	46	3	3.59886E-06	1.14133E+05	1.256E+00	0.	0.	4.092E+02	1.718E+04
IN *115	46	0	4.27864E-05	1.14124E+05	1.100E+00	0.	1.084E+01	1.281E+01	6.470E+02
AG *115	47	0	4.07729E-02	2.83972E+05	0.	0.	0.	0.	8.395E+00
CD 115	47	3	3.59886E-05	1.14133E+05	1.256E+00	0.	0.	4.092E+02	1.718E+04
IN *115	47	0	4.27864E-05	1.14124E+05	1.100E+00	0.	1.084E+01	1.281E+01	6.470E+02
CD *117	48	3	5.66291E-05	2.62787E+04	8.458E+00	0.	0.	0.	2.794E+03
CD 117	48	3	7.40534E-05	1.66454E+05	6.040E+00	0.	0.	0.	2.284E+03
IN *117	48	0	9.92469E-05	1.54460E+05	7.646E-01	0.	0.	0.	8.535E+02
CD 118	49	3	2.29669E-04	1.87346E+05	0.	0.	0.	0.	1.265E+03
IN 118	49	0	2.62553E-03	1.87423E+05	1.076E+00	0.	0.	0.	2.146E+00
CD 119	50	3	1.22897E-03	1.26378E+05	1.066E+00	0.	0.	0.	3.252E+02
IN *119	50	0	6.41796E-04	9.26974E+04	4.992E-01	0.	0.	0.	2.422E+02
SN 121	51	0	7.18429E-06	1.99284E+05	0.	0.	0.	0.	2.064E+03
SN *123	52	0	2.88808E-04	8.58892E+04	1.322E-01	0.	0.	0.	2.934E+02
SN 123	53	0	6.21873E-08	1.02406E+05	7.601E-01	0.	0.	0.	3.096E+05
SN 125	54	0	6.31342E-07	6.79154E+04	5.238E-01	3.550E+04	8.121E+02	2.093E+03	9.686E+04
SB 125	54	0	8.04553E-09	1.45325E+04	2.757E+00	1.813E+04	1.764E+01	3.497E+03	2.309E+04
TE *125	54	0	1.38318E-07	1.06039E+04	1.572E-02	0.	0.	7.170E+02	5.568E+04
SN 125	55	0	8.31342E-07	2.55491E+05	5.238E-01	3.550E+04	8.121E+02	2.093E+03	9.686E+04
SB 125	55	0	8.04553E-09	5.46697E+04	2.757E+00	1.813E+04	1.764E+01	3.497E+03	2.309E+04

ISOTOPE	CHN	GP	DECAY CONST	RELEASE (CI)	GAMMA VAL	BONE	THYROID	TOTAL BODY	NEW LUNG
SN 126	56	0	2.19793E-14	3.07524E-01	4.335E-01	0.	0.	0.	8.774E+03
SB *126	56	0	6.06018E-04	2.22060E+04	9.312E-01	0.	0.	0.	1.854E+02
SB 126	56	0	6.46943E-07	2.42904E+04	1.159E+01	0.	0.	0.	8.083E+04
SN 127	57	0	9.08202E-05	1.49218E+05	9.674E+00	0.	0.	0.	2.162E+03
SB 127	57	0	2.11117E-06	2.56379E+05	3.143E+00	0.	0.	0.	3.101E+04
TE *127	57	0	7.36005E-08	1.62113E+05	1.040E-03	1.256E+04	0.	1.685E+03	1.770E+05
TE 127	57	0	2.05924E-05	2.40840E+05	9.710E-03	1.647E+02	1.252E+02	3.636E+01	1.534E+03
SN 127	58	0	9.08202E-05	7.63394E+05	9.674E+00	0.	0.	0.	2.162E+03
SB 127	58	0	2.11117E-06	1.34599E+06	3.143E+00	0.	0.	0.	3.101E+04
TE 127	58	0	2.05924E-05	1.26441E+06	9.710E-03	1.647E+02	1.252E+02	3.636E+01	1.534E+03
SN 128	59	0	1.95602E-04	1.91229E+06	2.907E+00	0.	0.	0.	1.081E+03
SB *128	59	0	1.11080E-03	2.17031E+06	2.007E+01	0.	0.	0.	5.809E+03
SB 129	60	0	4.43633E-05	2.76548E+06	3.128E+00	0.	0.	0.	4.845E+03
TE *129	60	0	2.40193E-07	1.01633E+06	2.739E-01	1.903E+04	6.910E+03	4.709E+03	2.331E+05
TE 129	60	0	1.65033E-04	2.54348E+06	6.269E-01	5.014E+01	4.187E+01	1.953E+01	6.306E+02
I 129	60	1	1.38235E-15	6.38373E-02	2.036E-02	0.	6.698E+06	8.167E+03	3.151E+02
SB 129	61	0	4.43633E-05	1.55358E+06	3.128E+00	0.	0.	0.	4.845E+03
TE 129	61	0	1.65033E-04	1.43071E+06	6.269E-01	5.014E+01	4.187E+01	1.953E+01	6.306E+02
I 129	61	1	1.38235E-15	3.59065E-02	2.036E-02	0.	6.698E+06	8.167E+03	3.151E+02
SN 130	62	0	3.12225E-03	4.06178E+06	0.	0.	0.	0.	8.250E+01
SB 130	62	0	1.75035E-03	1.78903E+06	4.260E+00	0.	0.	0.	5.330E+02
SB 131	63	0	5.02275E-04	8.67759E+06	4.357E+00	0.	0.	0.	7.431E+02
TE 131	63	0	4.62093E-04	1.08742E+07	2.190E+00	0.	0.	0.	2.631E+02
I 131	63	1	9.97694E-07	1.05757E+07	2.432E+00	0.	1.486E+06	2.649E+03	1.132E+03
SB 131	64	0	5.02275E-04	1.53134E+06	4.357E+00	0.	0.	0.	7.431E+02
TE *131	64	0	6.41796E-06	1.88820E+06	7.303E+00	1.120E+03	1.063E+03	7.404E+02	1.775E+04
I 131	64	1	9.97694E-07	1.86629E+06	2.432E+00	0.	1.486E+06	2.649E+03	1.132E+03

ISOTOPE		CHN	GP	DECAY CONST	RELEASE (CI)	GAMMA VAL	BONE	THYROID	TOTAL BODY	NEW LUNG
SN	132	65	0	1.73285E-02	1.67364E+06	0.	0.	0.	0.	9.850E+01
SB	132	65	0	5.50111E-03	5.16655E+06	0.	0.	0.	0.	6.043E+01
TE	132	65	0	2.46845E-06	1.64359E+07	1.346E+00	3.224E+03	2.457E+03	2.014E+03	4.426E+04
I	132	65	1	8.42621E-05	1.67954E+07	1.496E+01	0.	5.288E+04	1.289E+02	1.196E+03
SB	133	66	0	4.81347E-03	3.67810E+06	0.	0.	0.	0.	1.434E+02
TE	*133	66	0	2.08526E-04	7.10989E+06	1.619E+01	0.	0.	0.	9.163E+02
I	133	66	1	9.25668E-06	1.52452E+07	3.101E+00	0.	3.951E+05	5.727E+02	1.973E+03
XE	133	66	2	1.51653E-06	1.54236E+07	1.695E-01	0.	0.	0.	0.
SB	133	67	0	4.81347E-03	1.43037E+06	0.	0.	0.	0.	1.434E+02
TE	133	67	0	9.24187E-04	1.29084E+07	3.413E+00	0.	0.	0.	1.413E+02
I	133	67	1	9.25663E-06	5.92668E+06	3.101E+00	0.	3.951E+05	5.727E+02	1.973E+03
XE	133	67	2	1.51653E-06	6.00000E+06	1.695E-01	0.	0.	0.	0.
SB	134	68	0	8.15459E-01	1.34948E+07	0.	0.	0.	0.	1.090E+00
TE	134	68	0	2.75056E-04	1.62255E+07	7.920E-01	0.	0.	0.	1.104E+03
I	134	68	1	2.19626E-04	2.23797E+07	1.216E+01	0.	2.538E+04	4.326E+01	6.244E+02
CS	134	69	3	1.06623E-08	7.84524E+04	9.640E+00	3.760E+04	0.	5.650E+04	2.190E+02
TE	135	70	0	3.85078E-02	2.37900E+05	0.	0.	0.	0.	3.948E+01
I	135	70	1	2.92390E-05	4.96384E+05	1.018E+01	0.	1.231E+05	2.867E+02	1.692E+03
XE	*135	70	2	7.55075E-04	4.57072E+06	2.741E+00	0.	0.	0.	0.
XE	135	70	2	2.09966E-05	5.58048E+05	1.544E+00	0.	0.	0.	0.
CS	135	70	3	9.55620E-15	9.24230E-02	0.	1.223E+04	0.	3.559E+03	2.536E+01
TE	135	71	0	3.85078E-02	9.67461E+06	0.	0.	0.	0.	3.948E+01
I	135	71	1	2.92390E-05	2.01663E+07	1.018E+01	0.	1.231E+05	2.867E+02	1.692E+03
XE	135	71	2	2.09966E-05	2.26940E+07	1.544E+00	0.	0.	0.	0.
CS	135	71	3	9.55620E-15	3.75854E+00	0.	1.223E+04	0.	3.559E+03	2.536E+01
I	136	72	1	8.35108E-03	1.34089E+07	1.339E+01	0.	0.	0.	4.203E+01
CS	136	73	3	6.17112E-07	8.40810E+05	1.250E+01	2.710E+03	0.	5.660E+03	1.343E+02

ISOTOPE		CHN	GP	DECAY CONST	RELEASE (CI)	GAMMA VAL	BONE	THYROID	TOTAL BODY	NEW LUNG
I	137	74	1	2.81764E-02	8.59621E+06	0.	0.	0.	0.	1.275E+01
XE	137	74	2	3.00842E-03	1.86953E+07	9.762E-01	0.	0.	0.	0.
CS	137	74	3	7.29710E-10	2.58763E+05	0.	5.145E+04	0.	3.163E+04	1.576E+02
BA	*137	74	0	4.53033E-03	2.47776E+05	3.896E+00	0.	0.	0.	5.418E+00
I	138	75	1	1.06637E-01	4.26042E+06	0.	0.	0.	0.	3.251E+00
XE	138	75	2	8.13545E-04	1.47021E+07	8.376E+00	0.	0.	0.	0.
CS	138	75	3	3.58768E-04	1.90414E+07	1.183E+01	0.	0.	0.	3.534E+02
I	139	76	1	2.88808E-01	1.75314E+06	0.	0.	0.	0.	3.010E+00
XE	139	76	2	1.71569E-02	1.35485E+07	2.201E+00	0.	0.	0.	0.
CS	139	76	3	1.24213E-03	1.81475E+07	1.359E+00	0.	0.	0.	2.452E+02
BA	139	76	0	1.38684E-04	1.85029E+07	2.553E-01	0.	0.	0.	9.438E+02
XE	140	77	2	5.09662E-02	7.84691E+06	1.183E+01	0.	0.	0.	0.
CS	140	77	3	1.08643E-02	1.55504E+07	7.766E+00	0.	0.	0.	6.585E+00
BA	140	77	0	6.27242E-07	1.70191E+07	1.524E+00	9.007E+04	0.	7.259E+03	1.633E+05
LA	140	77	0	4.78595E-06	1.70957E+07	1.198E+01	4.765E+03	0.	8.369E+02	2.540E+04
XE	141	78	2	4.02988E-01	3.46734E+06	0.	0.	0.	0.	0.
CS	141	78	3	2.77256E-02	1.25617E+07	0.	0.	0.	0.	1.731E+01
BA	141	78	0	6.31275E-04	1.75312E+07	1.904E+00	0.	0.	0.	5.059E+02
LA	141	78	0	4.97517E-05	1.76373E+07	1.529E-01	0.	0.	0.	3.005E+03
CE	141	78	0	2.46617E-07	1.62985E+07	3.936E-01	2.070E+04	0.	1.727E+03	5.452E+04
XE	142	79	2	5.66148E-01	1.17302E+06	0.	0.	0.	0.	0.
CS	142	79	3	4.07729E-01	6.83954E+06	0.	0.	0.	0.	1.798E+00
BA	142	79	0	1.07966E-03	1.49328E+07	3.751E+00	0.	0.	0.	3.452E+02
LA	142	79	0	1.25025E-04	1.54216E+07	9.998E+00	0.	0.	0.	1.668E+03
CS	143	80	3	4.07729E-01	3.09162E+06	0.	0.	0.	0.	1.982E+00
BA	143	80	0	5.09662E-02	1.25696E+07	0.	0.	0.	0.	2.798E+00
LA	143	80	0	6.25167E-04	1.40548E+07	1.509E+00	0.	0.	0.	3.986E+02
CE	143	80	0	5.83451E-06	1.41368E+07	1.940E+00	4.132E+03	0.	3.511E+02	1.606E+04
PR	143	80	0	5.90756E-07	1.40532E+07	0.	2.293E+04	0.	1.136E+03	4.861E+04

ISOTOPE		CHN	GP	DECAY CONST	RELEASE (CI)	GAMMA VAL	BONE	THYROID	TOTAL BODY	NEW LUNG
CS	144	81	3	6.79549E-01	1.16449E+06	0.	0.	0.	0.	1.143E+00
BA	144	81	0	6.30127E-02	8.61214E+06	0.	0.	0.	0.	8.858E-01
LA	144	81	0	1.73283E-02	1.16750E+07	0.	0.	0.	0.	6.282E-01
CE	144	81	0	2.82083E-08	4.31606E+06	9.241E-02	7.739E+05	0.	4.756E+04	1.422E+06
PR	144	81	0	6.68538E-04	4.33425E+06	1.718E-01	0.	0.	0.	3.130E+03
CE	145	82	0	3.50071E-03	1.15651E+07	5.028E+00	0.	0.	0.	6.320E+01
PR	145	82	0	3.21971E-05	1.01008E+07	9.241E-02	0.	0.	0.	2.856E+03
CE	146	83	0	8.13545E-04	8.35624E+06	2.068E+00	0.	0.	0.	3.132E+02
PR	146	83	0	4.77369E-04	8.33732E+06	1.042E+01	0.	0.	0.	4.342E+02
ND	147	84	0	7.29978E-07	6.83239E+06	9.251E-01	1.465E+04	0.	1.152E+03	3.767E+04
PM	147	84	0	8.37372E-09	8.07972E+05	0.	6.819E+04	0.	3.383E+03	2.003E+05
SM	147	84	0	2.05411E-19	1.90523E-06	0.	0.	0.	0.	9.186E+07
ND	149	85	0	1.11234E-04	4.54914E+06	2.134E+00	2.393E+02	0.	2.418E+01	1.332E+03
PM	149	85	0	3.62597E-06	4.45149E+06	6.019E-01	3.987E+03	0.	3.142E+02	1.295E+04
ND	151	86	0	9.31640E-04	2.69739E+06	1.913E+00	0.	0.	0.	1.791E+02
PM	151	86	0	6.77964E-06	2.70077E+06	1.578E+00	0.	0.	0.	6.004E+03
SM	151	86	0	2.36733E-10	1.04090E+04	4.977E-03	2.862E+04	0.	2.317E+03	2.151E+06
SM	153	87	0	4.12259E-06	1.38983E+06	2.099E-01	2.044E+03	0.	1.546E+02	6.851E+03
SM	155	88	0	5.20375E-04	7.12968E+05	4.909E-01	0.	0.	0.	1.912E+02
EU	155	88	0	4.57911E-09	4.79978E+04	2.762E-01	5.698E+04	0.	8.134E+03	2.458E+05
SM	156	89	0	2.04829E-05	4.34029E+05	6.312E-01	0.	0.	0.	5.303E+03
EU	156	89	0	5.27793E-07	5.14565E+05	5.508E+00	0.	0.	0.	1.098E+05
EU	157	90	0	1.26670E-05	3.26013E+05	1.686E+00	0.	0.	0.	3.931E+03
EU	158	91	0	2.51685E-04	3.85721E+05	3.590E+00	0.	0.	0.	6.542E+02

ISOTOPE		CHN	GP	DECAY CONST	RELEASE (CI)	GAMMA VAL	BONE	THYROID	TOTAL BODY	NEW LUNG
GD	159	92	0	1.03516E-05	1.24780E+05	2.245E-01	6.526E+02	0.	7.115E+01	3.779E+03

COOLANT INCLUDED WITH FISSION PRODUCTS FOR DOSE CALCULATIONS
620307.000LB SODIUM AVAILABLE FOR RELEASE

ISOTOPE		CHN	GP	DECAY CONST	RELEASE (CI)	GAMMA VAL	BONE	THYROID	TOTAL BODY	NEW LUNG
NA	22	93	4	8.38914E-09	2.54829E+02	1.280E+01	0.	0.	1.390E+04	3.074E+02
NA	24	94	4	1.28734E-05	3.33625E+06	1.960E+01	0.	0.	1.280E+03	5.579E+02

FUEL INCLUDED WITH FISSION PRODUCTS FOR DOSE CALCULATIONS
100.0000000 PERCENT OF FUEL RELEASED TO FIRST CHAMBER

ISOTOPE		CHN	GP	DECAY CONST	RELEASE (CI)	GAMMA VAL	BONE	THYROID	TOTAL BODY	NEW LUNG
PU	238	95	0	2.46900E-10	1.73946E+05	0.	3.200E+08	0.	0.	3.111E+08
PU	239	96	0	9.01900E-13	2.36189E+04	0.	4.100E+08	0.	0.	2.938E+08
PU	240	97	0	3.33000E-12	4.07297E+04	0.	4.000E+08	0.	0.	2.938E+08
PU	241	98	0	1.69000E-09	7.46757E+06	0.	4.300E+06	0.	0.	2.662E+05
AM	241	98	0	4.79500E-11	4.17297E+04	4.385E-01	1.042E+03	0.	8.340E+01	1.364E+08
PU	242	99	0	5.79700E-14	1.40000E+02	0.	3.700E+08	0.	0.	2.828E+08
CM	242	100	0	4.93600E-08	1.85703E+06	0.	5.970E+02	0.	3.970E+01	7.980E+07
CM	244	101	0	1.19700E-09	1.15541E+05	0.	1.294E+03	0.	8.610E+01	2.269E+08

APPENDIX B-2

This section presents curves which were obtained as a result of the HAA computer calculations.

The curves provide the suspended concentration of sodium oxide and fission products as a function of time for each of the cases described in Section 5.0 and Section 6.0 of the report.

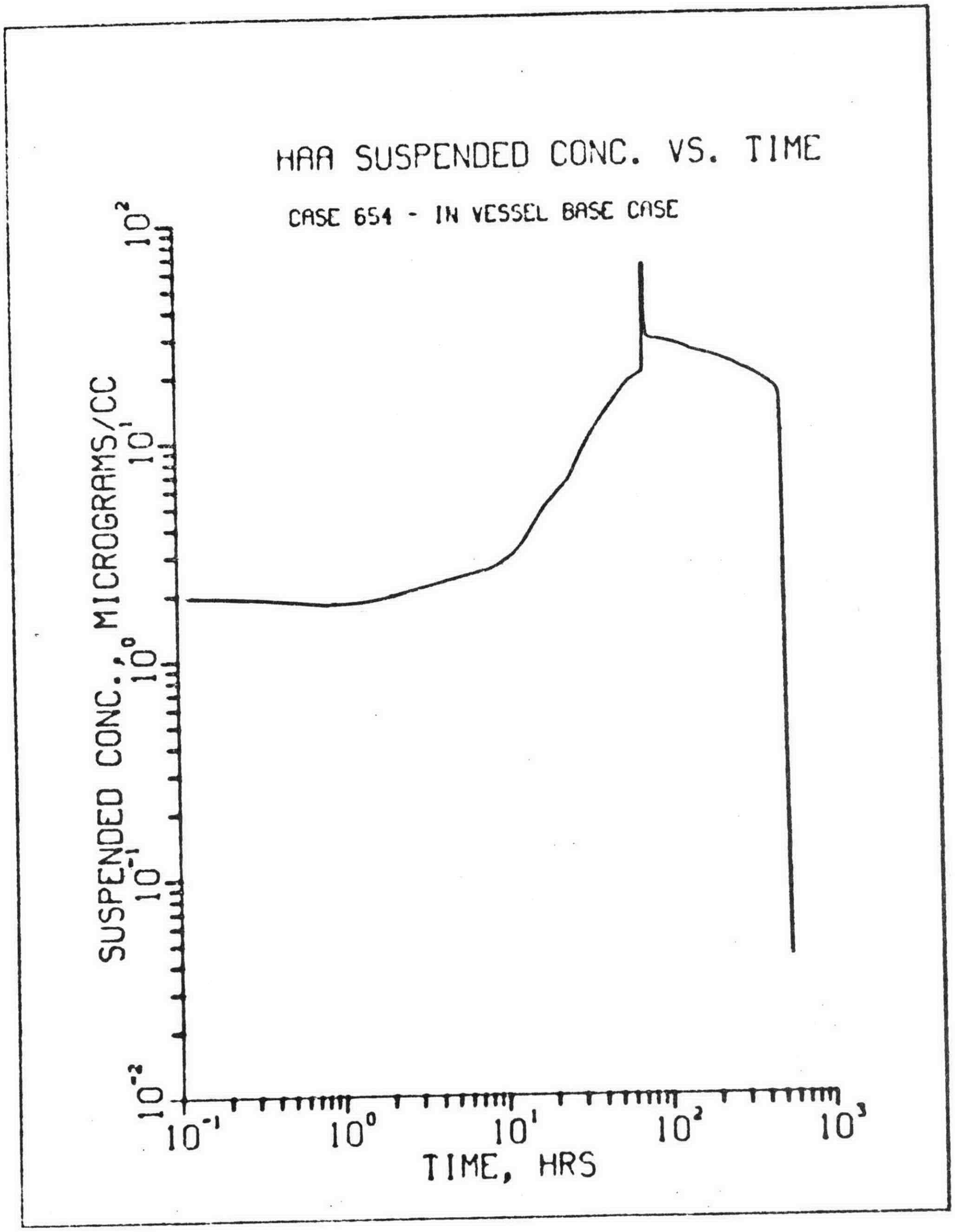
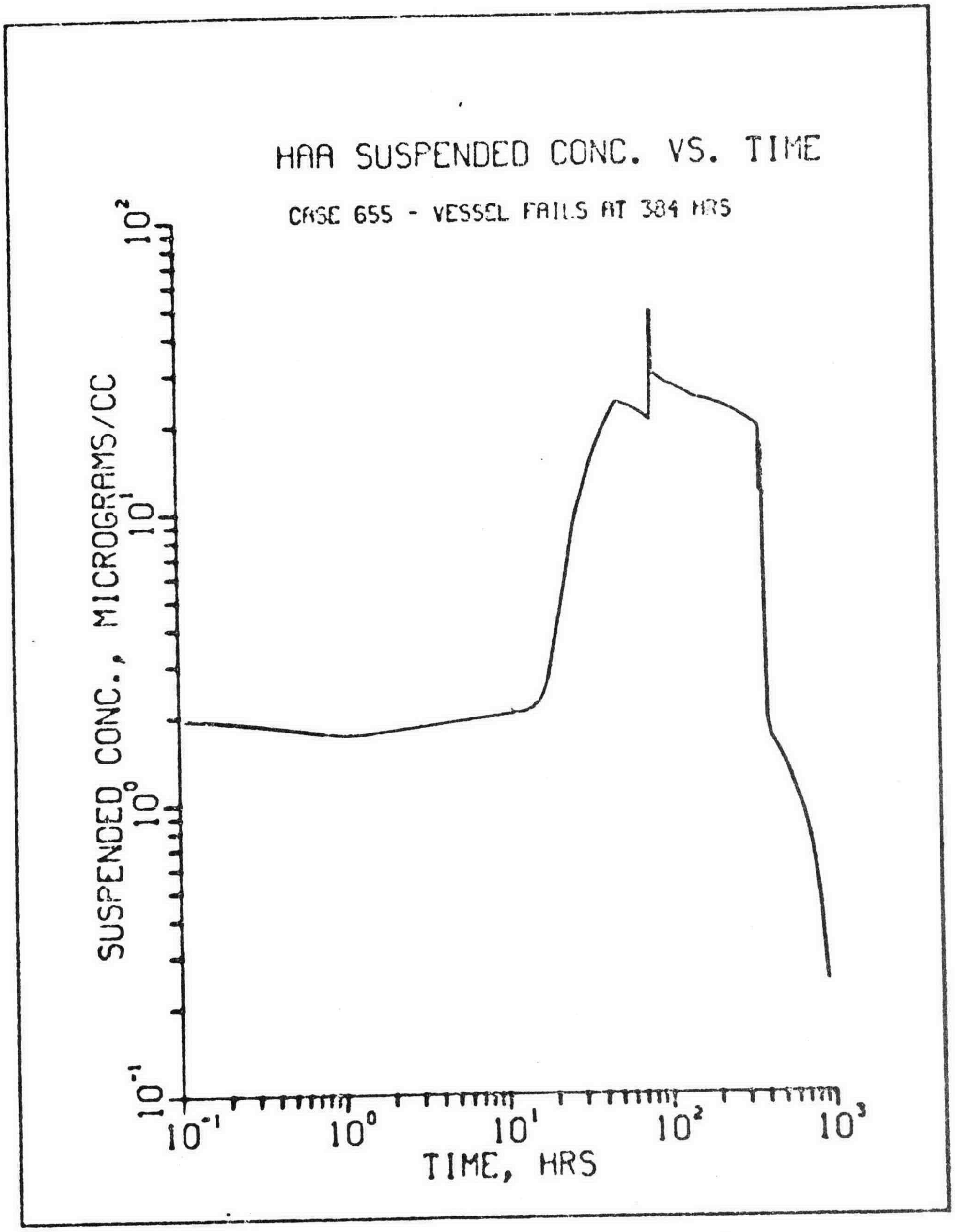

HAA SUSPENDED CONC. VS. TIME
CASE 654 - IN VESSEL BASE CASE
SUSPENDED CONC., MICROGRAMS/CC
10^-2
10^-1
10^0
10^1
10^2
10^-1
10^0
10^1
10^2
10^3
TIME, HRS

FIGURE B-2-1



HAA SUSPENDED CONC. VS. TIME
CASE 655 - VESSEL FAILS AT 384 HRS
SUSPENDED CONC., MICROGRAMS/CC
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
TIME, HRS

FIGURE B-2-2

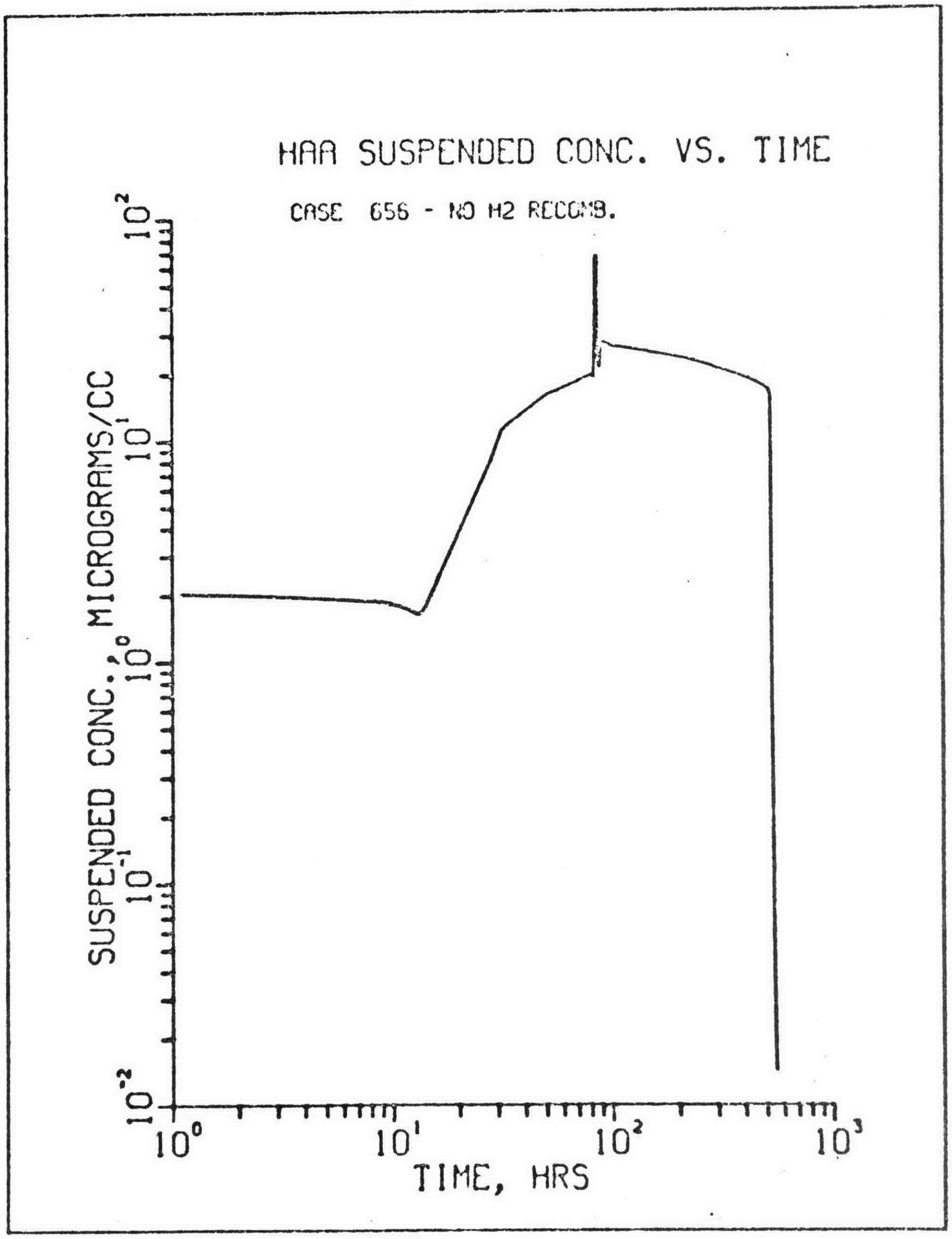
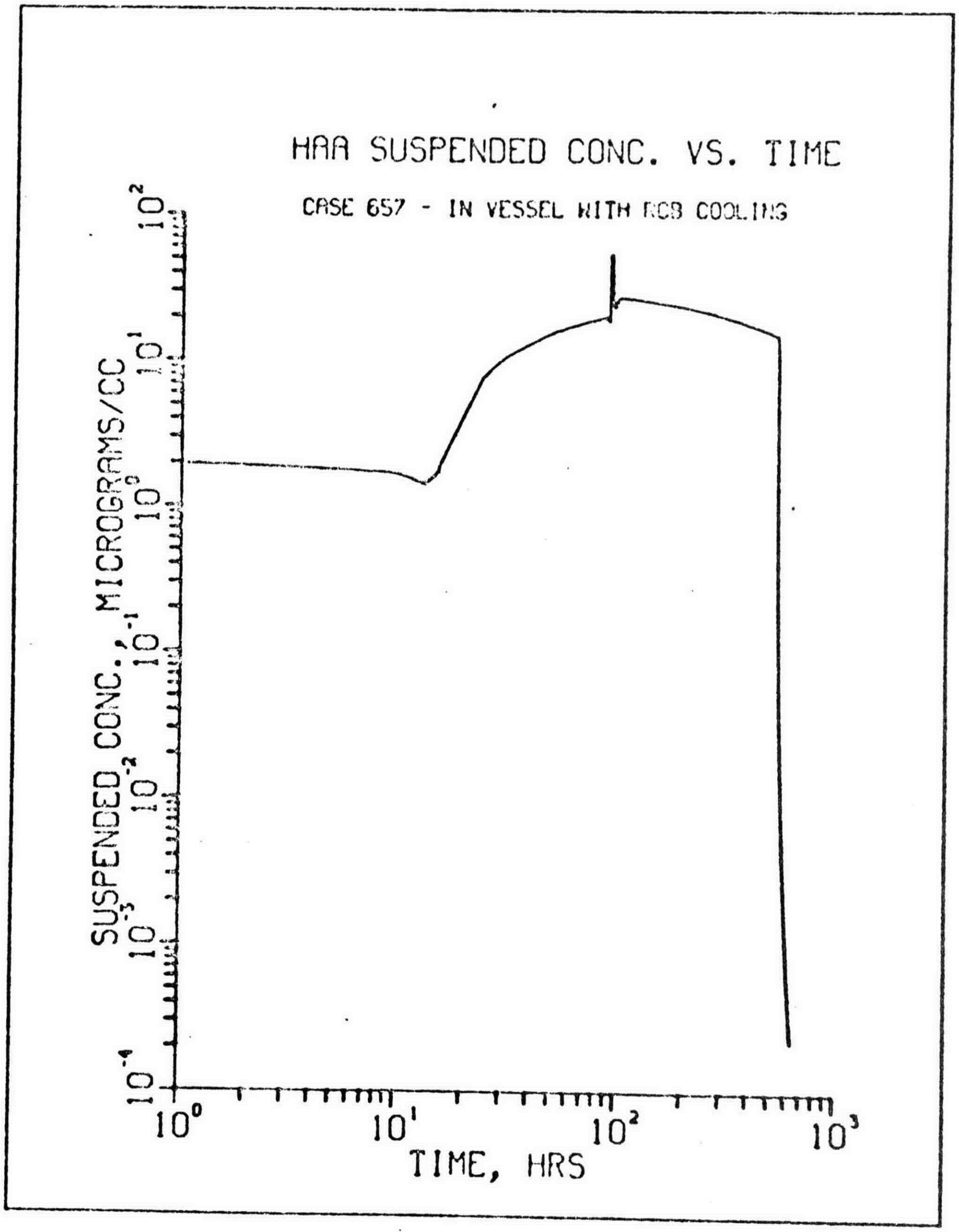

HAA SUSPENDED CONC. VS. TIME
CASE 656 - NO H2 RECOMB.
SUSPENDED CONC., MICROGRAMS/CC
10^2
10^1
10^0
10^{-1}
10^{-2}
10^0
10^1
10^2
10^3
TIME, HRS

FIGURE B-2-3



HAA SUSPENDED CONC. VS. TIME
CASE 657 - IN VESSEL WITH RCB COOLING
SUSPENDED CONC., MICROGRAMS/CC
10^-4
10^-3
10^-2
10^-1
10^0
10^1
10^2
10^0
10^1
10^2
10^3
TIME, HRS

FIGURE B-2-4

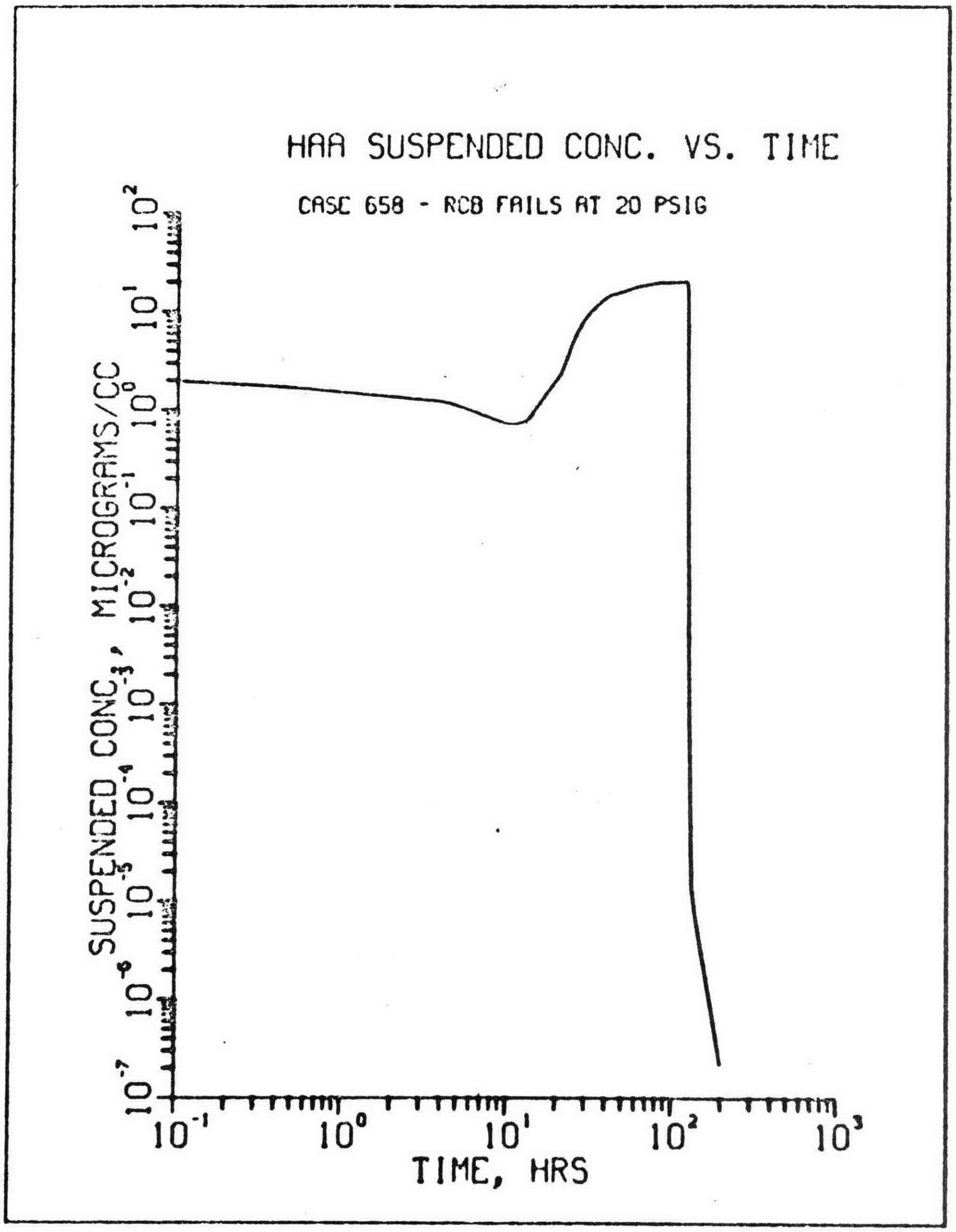

HAA SUSPENDED CONC. VS. TIME
CASE 658 - RCB FAILS AT 20 PSIG
SUSPENDED CONC., MICROGRAMS/CC
10^-7
10^-6
10^-5
10^-4
10^-3
10^-2
10^-1
10^0
10^1
10^2
10^-1
10^0
10^1
10^2
10^3
TIME, HRS

FIGURE B-2-5

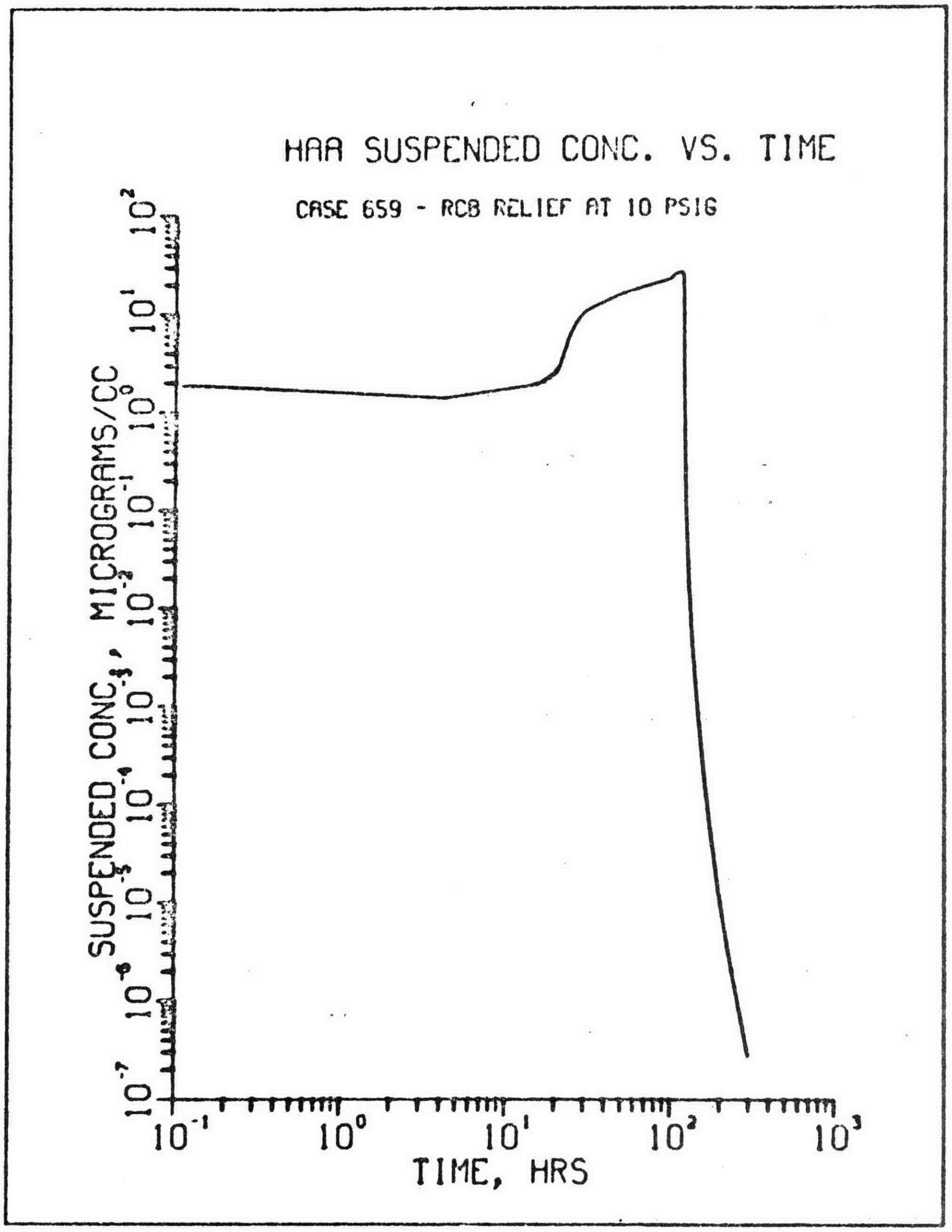

HAA SUSPENDED CONC. VS. TIME
CASE 659 - RCB RELIEF AT 10 PSIG
SUSPENDED CONC., MICROGRAMS/CC
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
TIME, HRS

FIGURE B-2-6

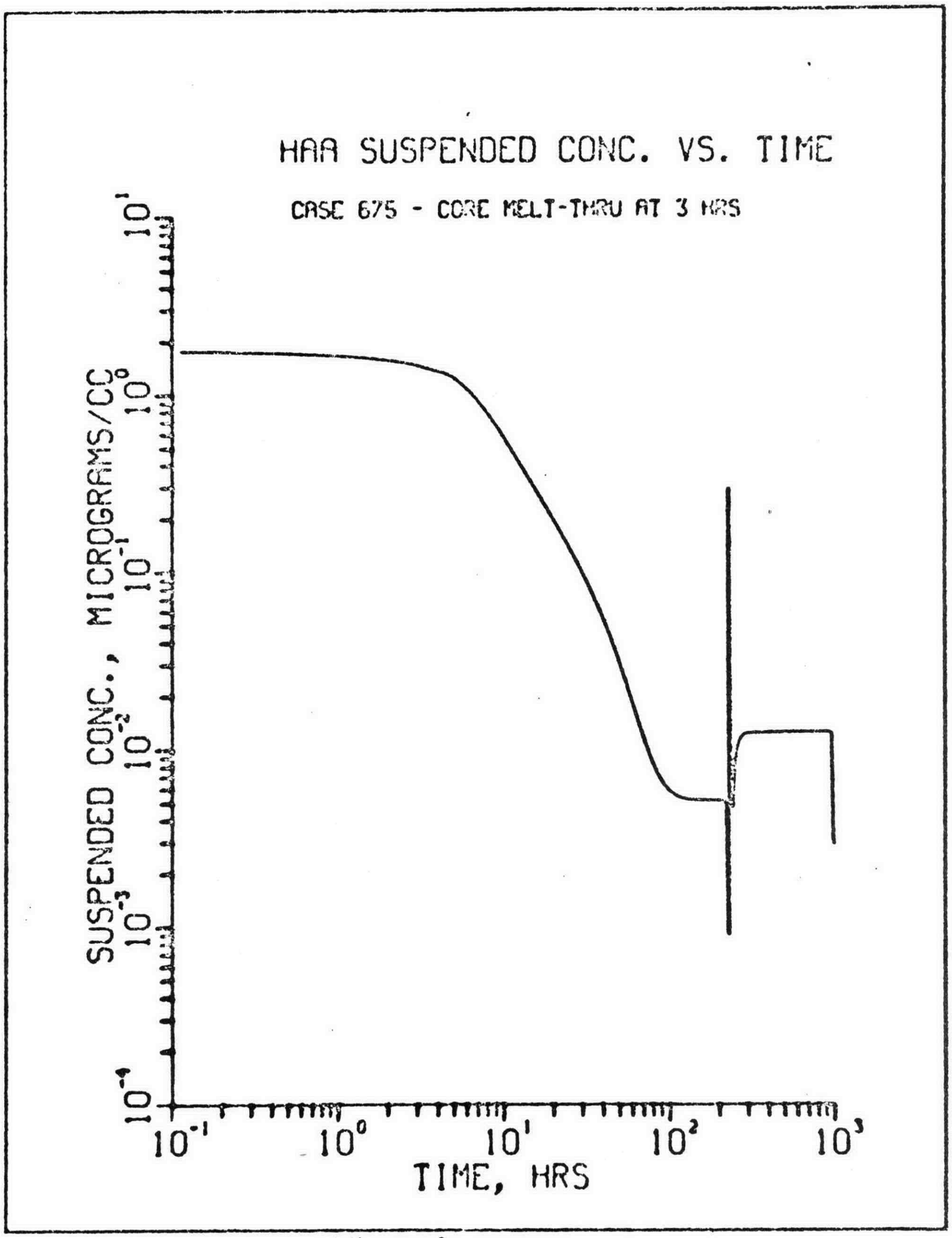
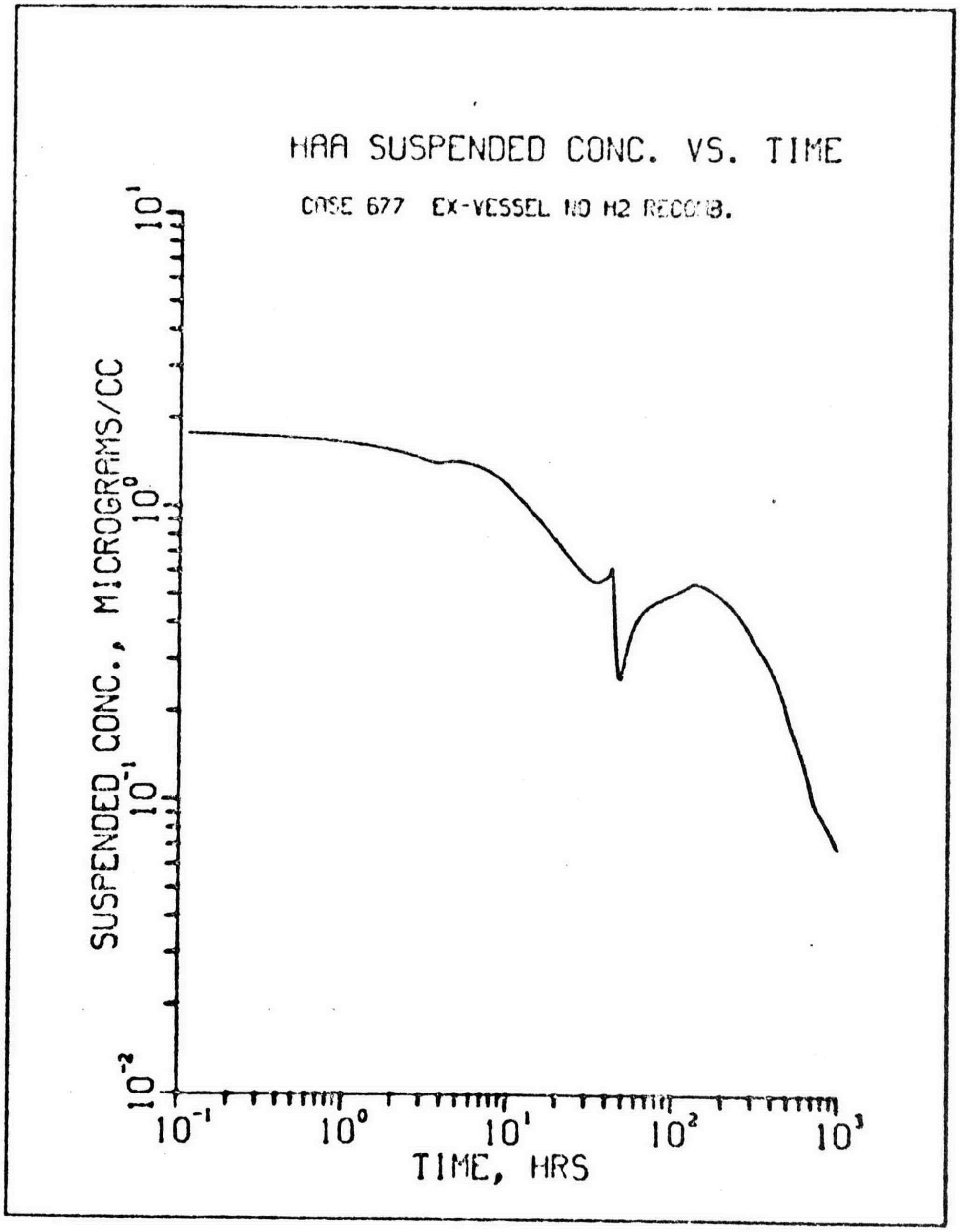

HAA SUSPENDED CONC. VS. TIME
CASE 675 - CORE MELT-THRU AT 3 HRS
SUSPENDED CONC., MICROGRAMS/CC
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
TIME, HRS

FIGURE B-2-7



HAA SUSPENDED CONC. VS. TIME
CASE 677 EX-VESSEL NO H2 RECOMB.
SUSPENDED CONC., MICROGRAMS/CC
10¹
10⁰
10⁻¹
10⁻²
10⁻¹
10⁰
10¹
10²
10³
TIME, HRS

FIGURE B-2-8

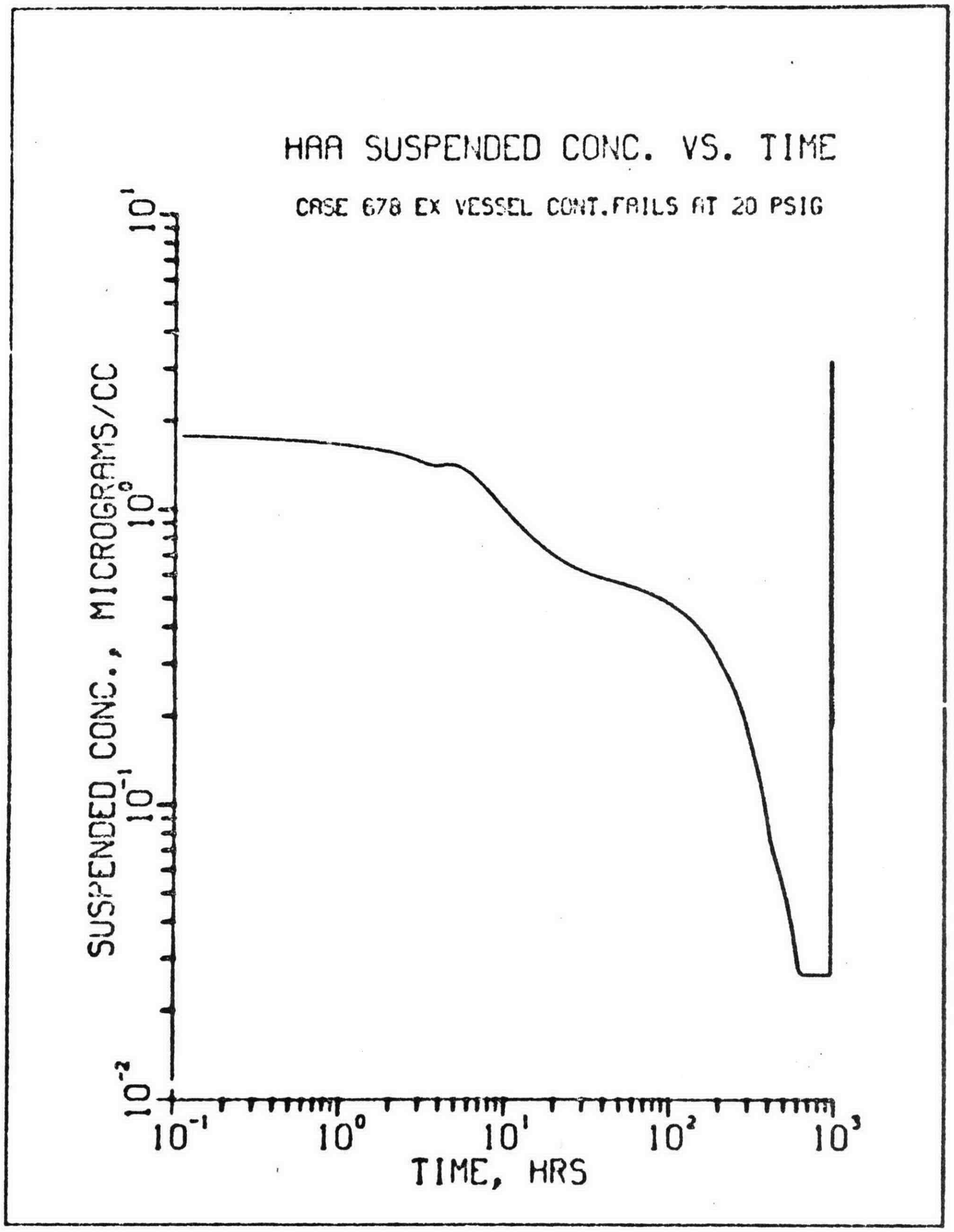

HAA SUSPENDED CONC. VS. TIME
CASE 678 EX VESSEL CONT.FAILS AT 20 PSIG
SUSPENDED CONC., MICROGRAMS/CC
TIME, HRS

FIGURE B-2-9

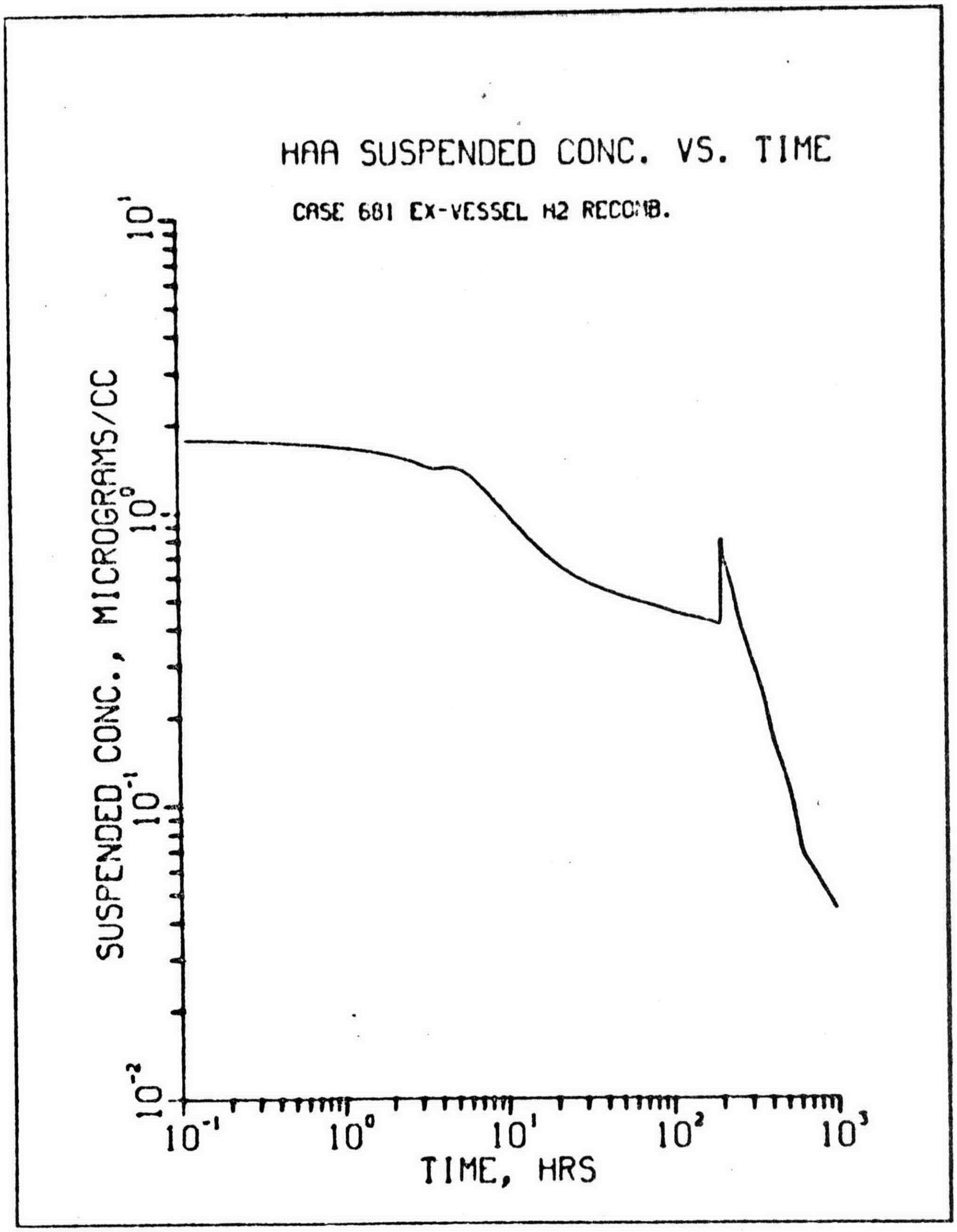
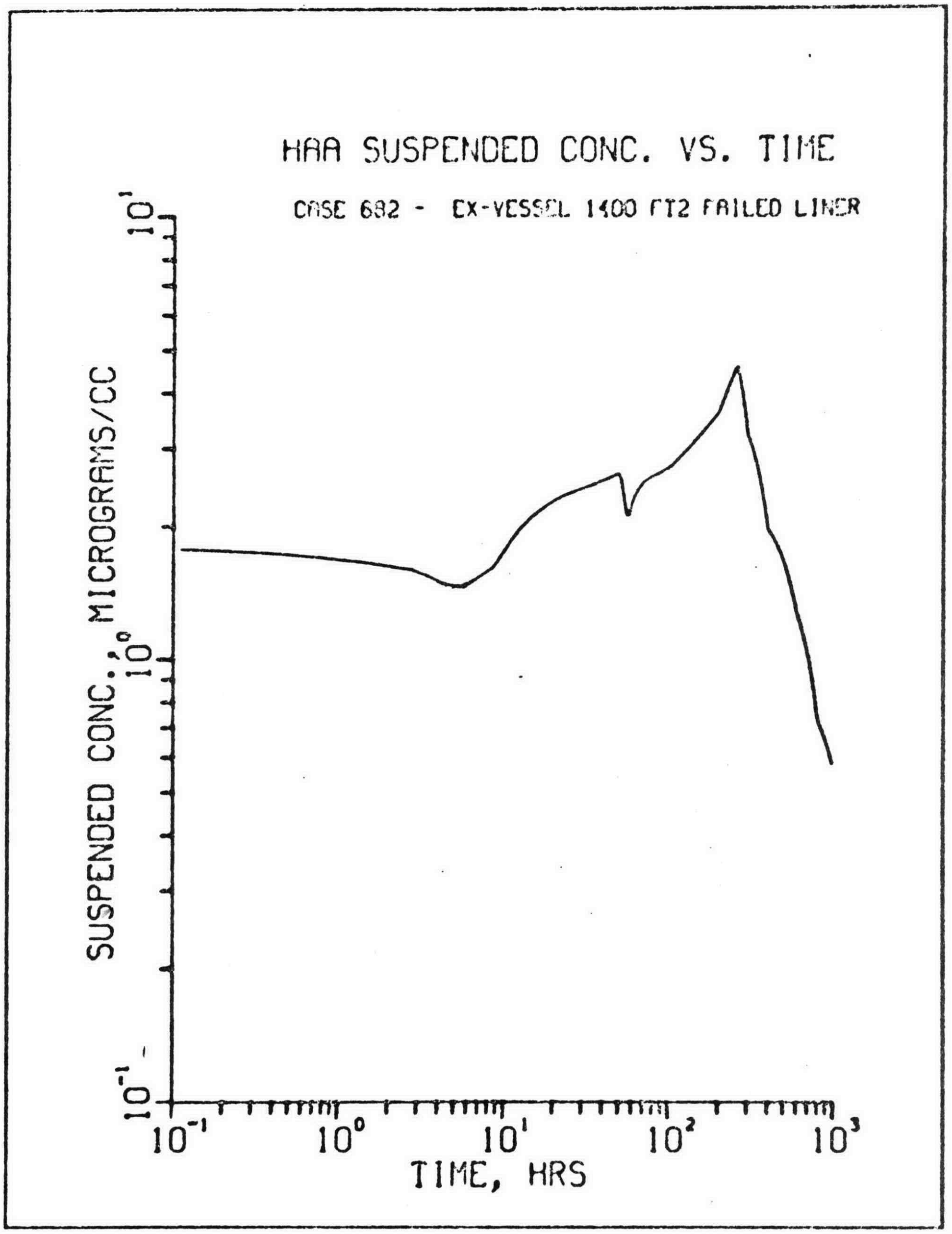
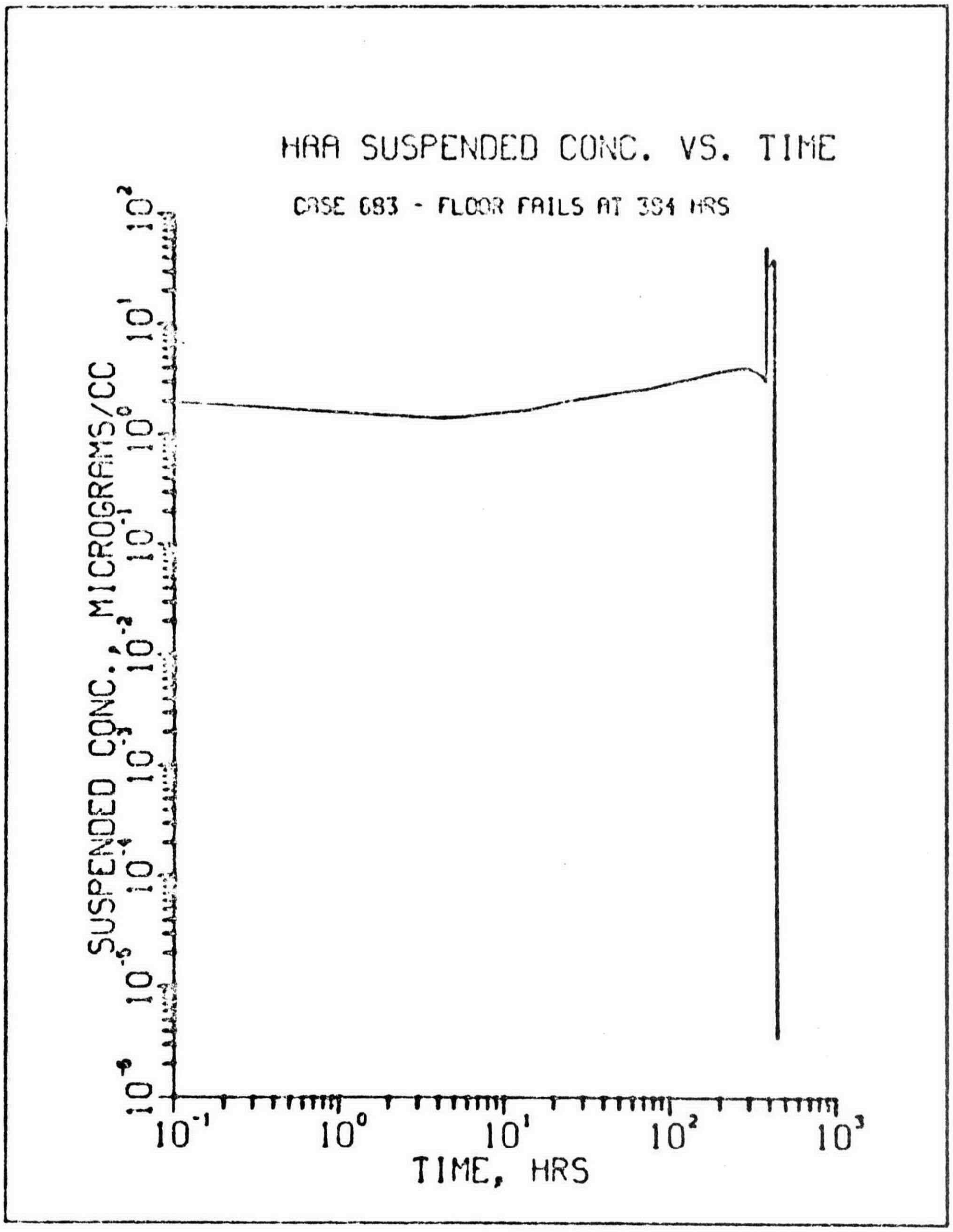

HAA SUSPENDED CONC. VS. TIME
CASE 681 EX-VESSEL H2 RECOMB.
SUSPENDED CONC., MICROGRAMS/CC
10^1
10^0
10^-1
10^-2
10^-1
10^0
10^1
10^2
10^3
TIME, HRS

FIGURE B-2-10



HAA SUSPENDED CONC. VS. TIME
CASE 682 - EX-VESSEL 1400 FT2 FAILED LINER
SUSPENDED CONC., MICROGRAMS/CC
10^{1}
10^{0}
10^{-1}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
TIME, HRS

FIGURE B-2-11



HAA SUSPENDED CONC. VS. TIME
CASE 683 - FLOOR FAILS AT 384 HRS
SUSPENDED CONC., MICROGRAMS/CC
TIME, HRS

FIGURE B-2-12

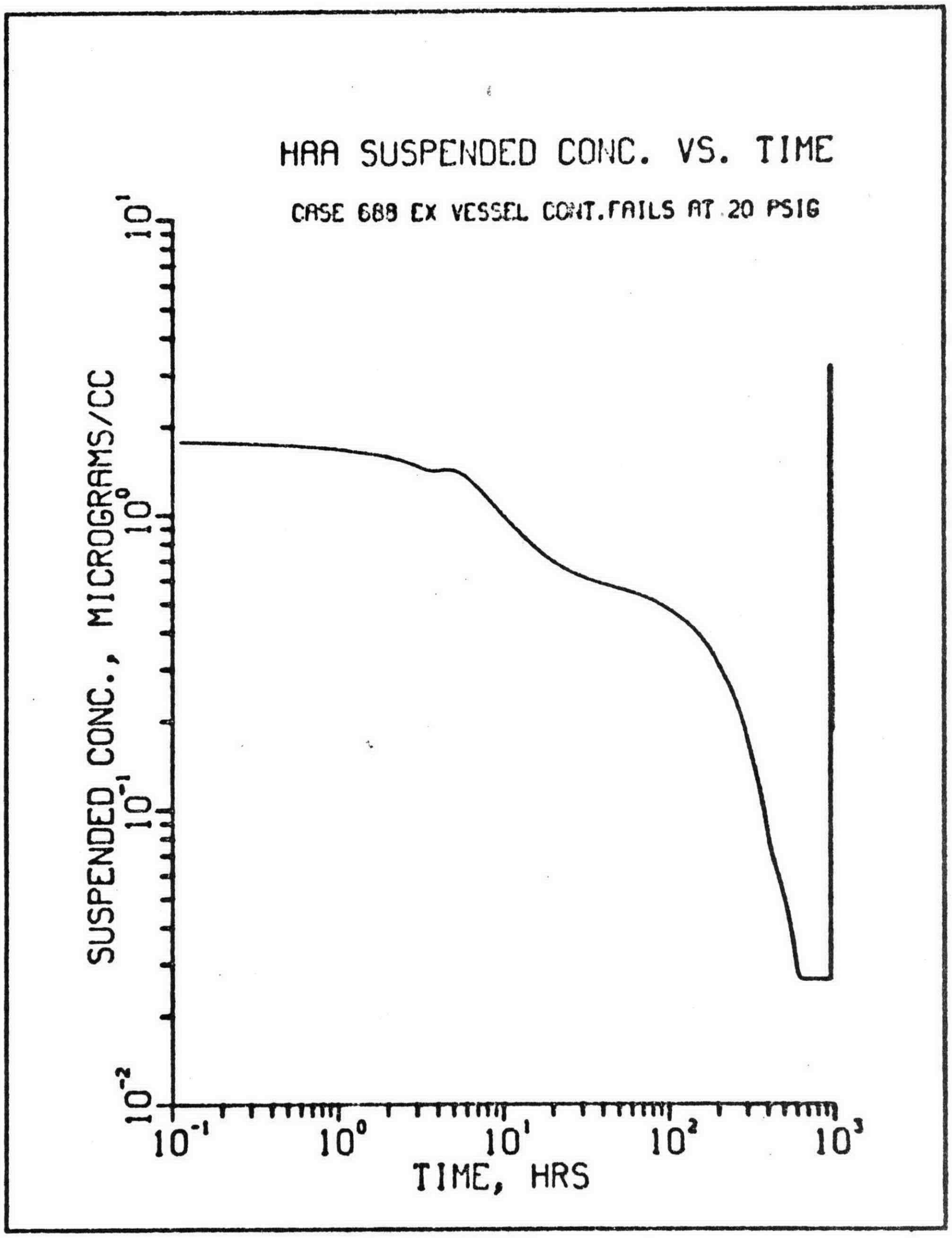

HAA SUSPENDED CONC. VS. TIME
CASE 688 EX VESSEL CONT.FAILS AT 20 PSIG
SUSPENDED CONC., MICROGRAMS/CC
10^1
10^0
10^-1
10^-2
10^-1
10^0
10^1
10^2
10^3
TIME, HRS

FIGURE B-2-13

APPENDIX B-3

FILTRATION EFFECTS

This appendix provides the remainder of the COMRADEX cases which considered effluent filtration. Both the radioactivity release curves and the resultant dose curves are included for each case with the exception of Case 654 which may be found in Section 6-14.

ACTIVITY RELEASE - CASE 655F

GROUP COMPARISON CHAMBER NO. 1

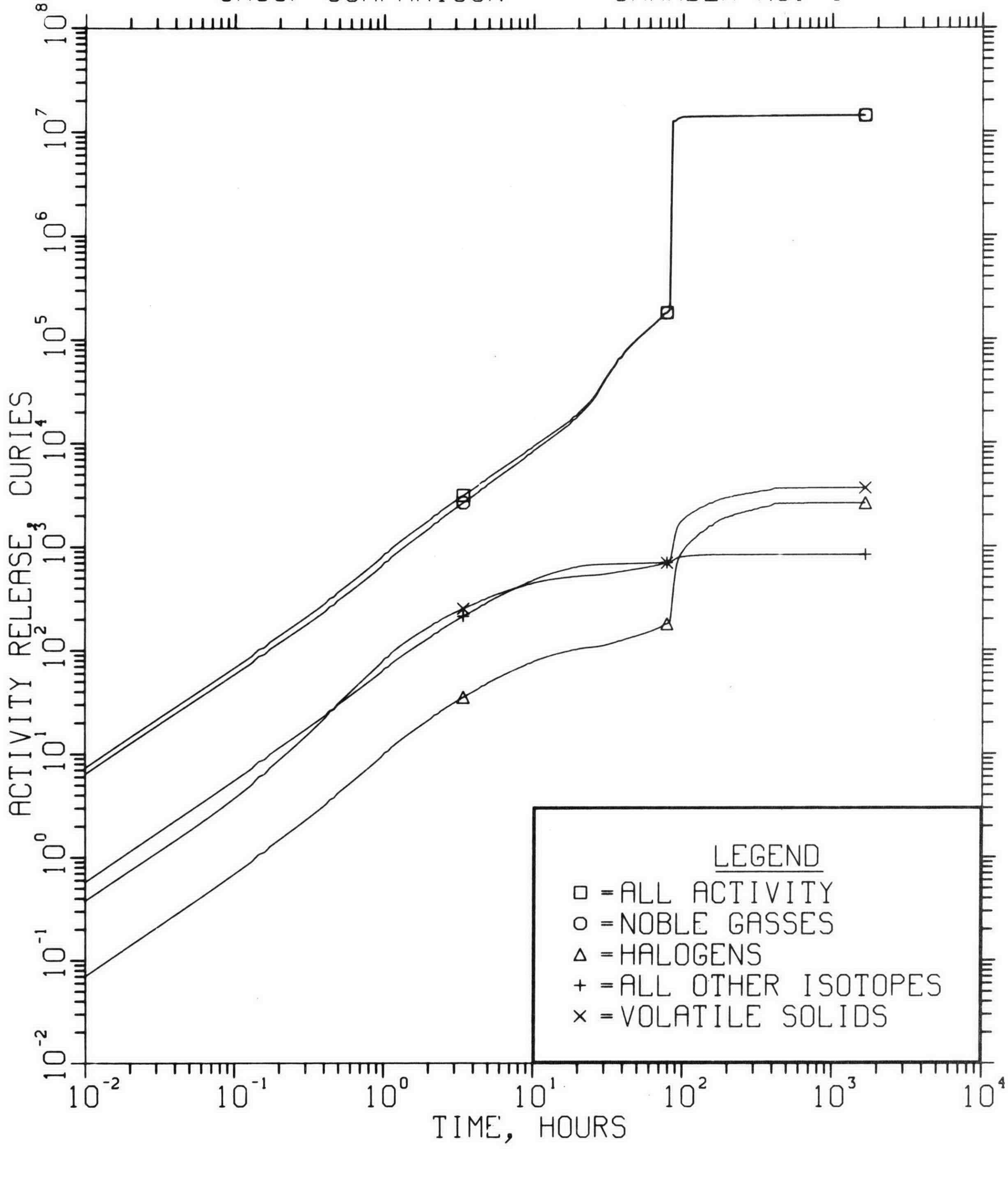


FIGURE B-3-1

JOB COMRDR PLOT NO. 2 TIME 22.57 DATE 03/10/77 DISSPLA, CDC 6000 V.1

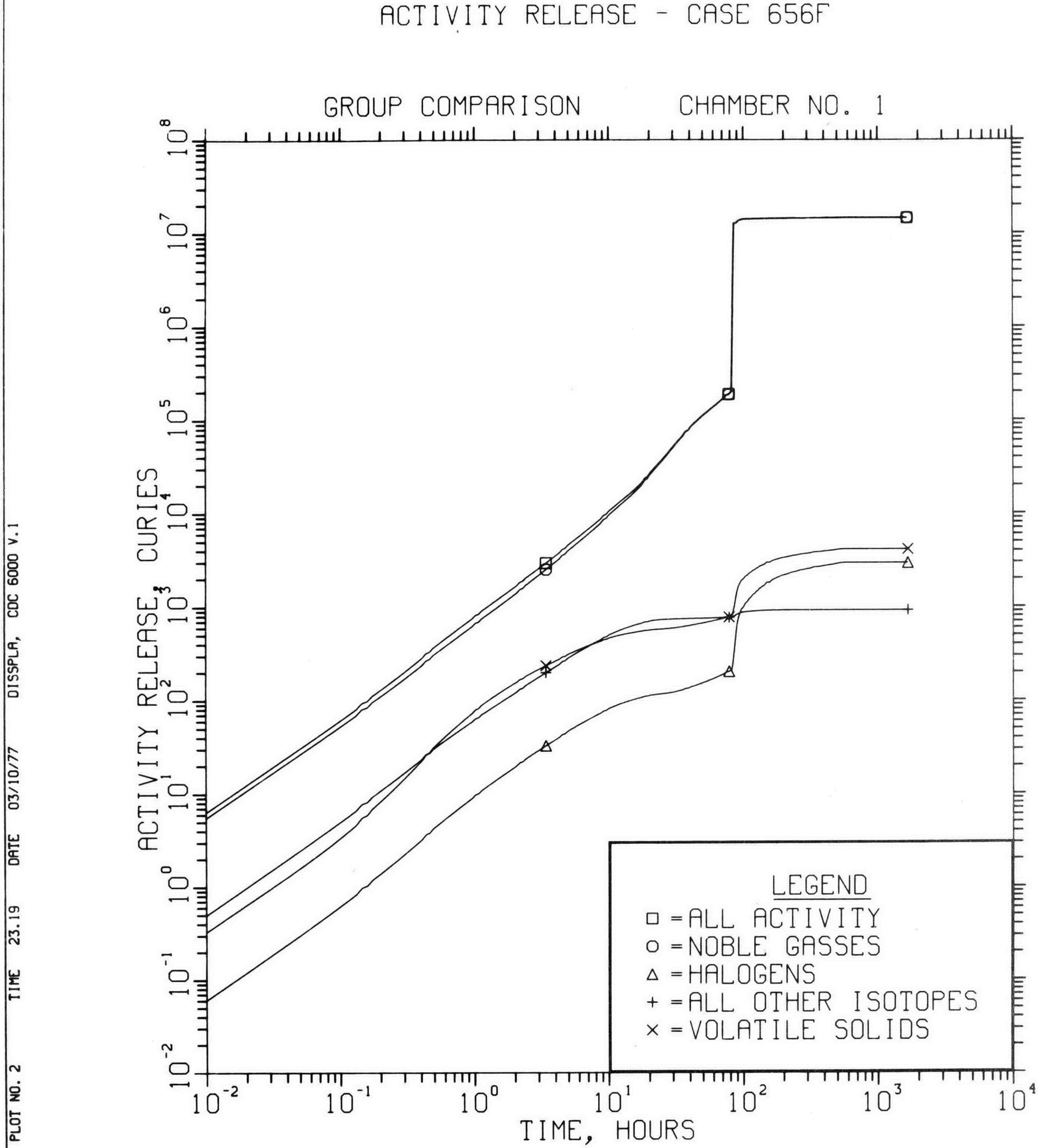

ACTIVITY RELEASE - CASE 656F
GROUP COMPARISON CHAMBER NO. 1
ACTIVITY RELEASE, CURIES
TIME, HOURS
LEGEND
□ = ALL ACTIVITY
○ = NOBLE GASSES
△ = HALOGENS
+ = ALL OTHER ISOTOPES
× = VOLATILE SOLIDS
JOB COMRDR PLOT NO. 2 TIME 23.19 DATE 03/10/77 DISSPLA, CDC 6000 V.1

FIGURE B-3-2

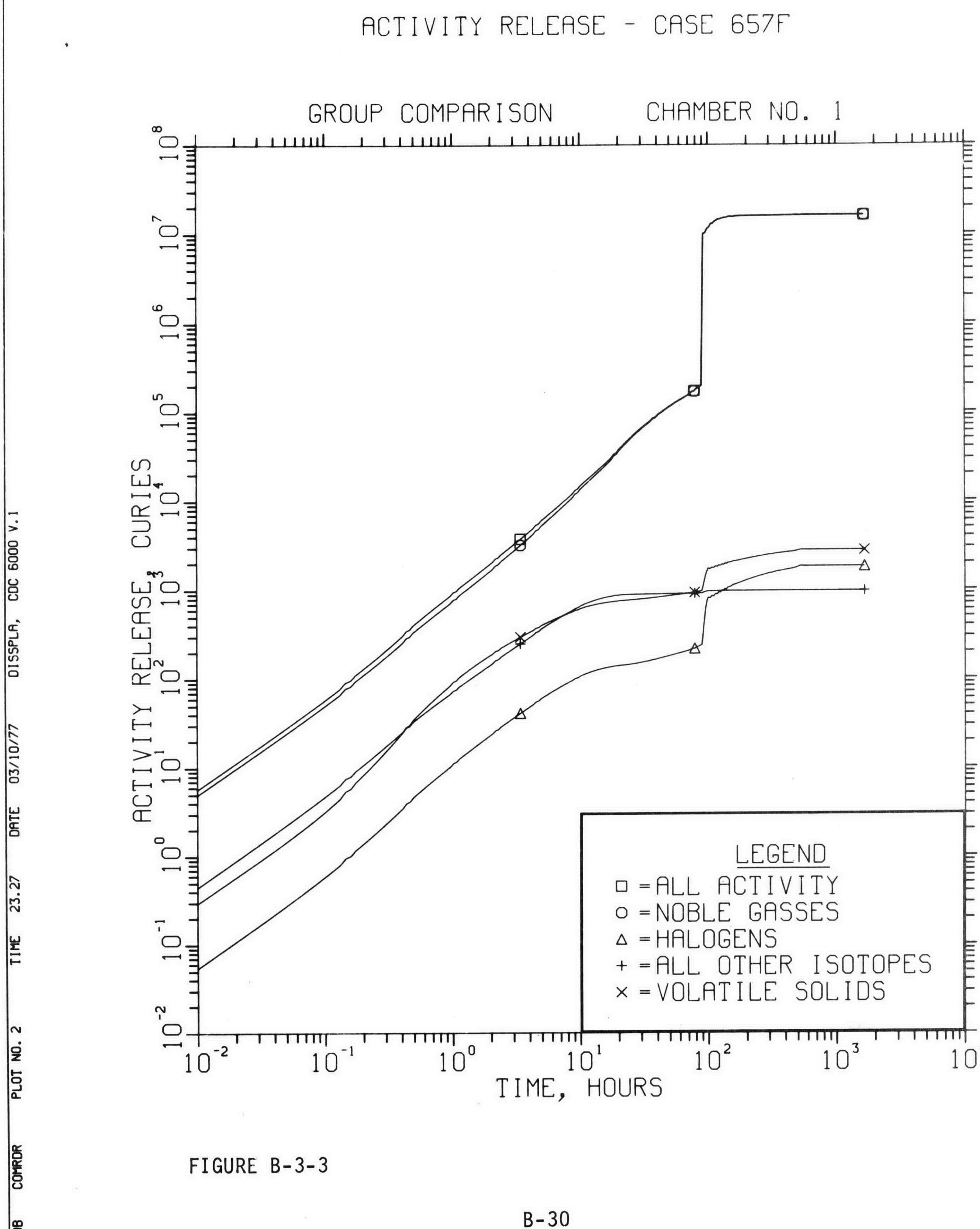
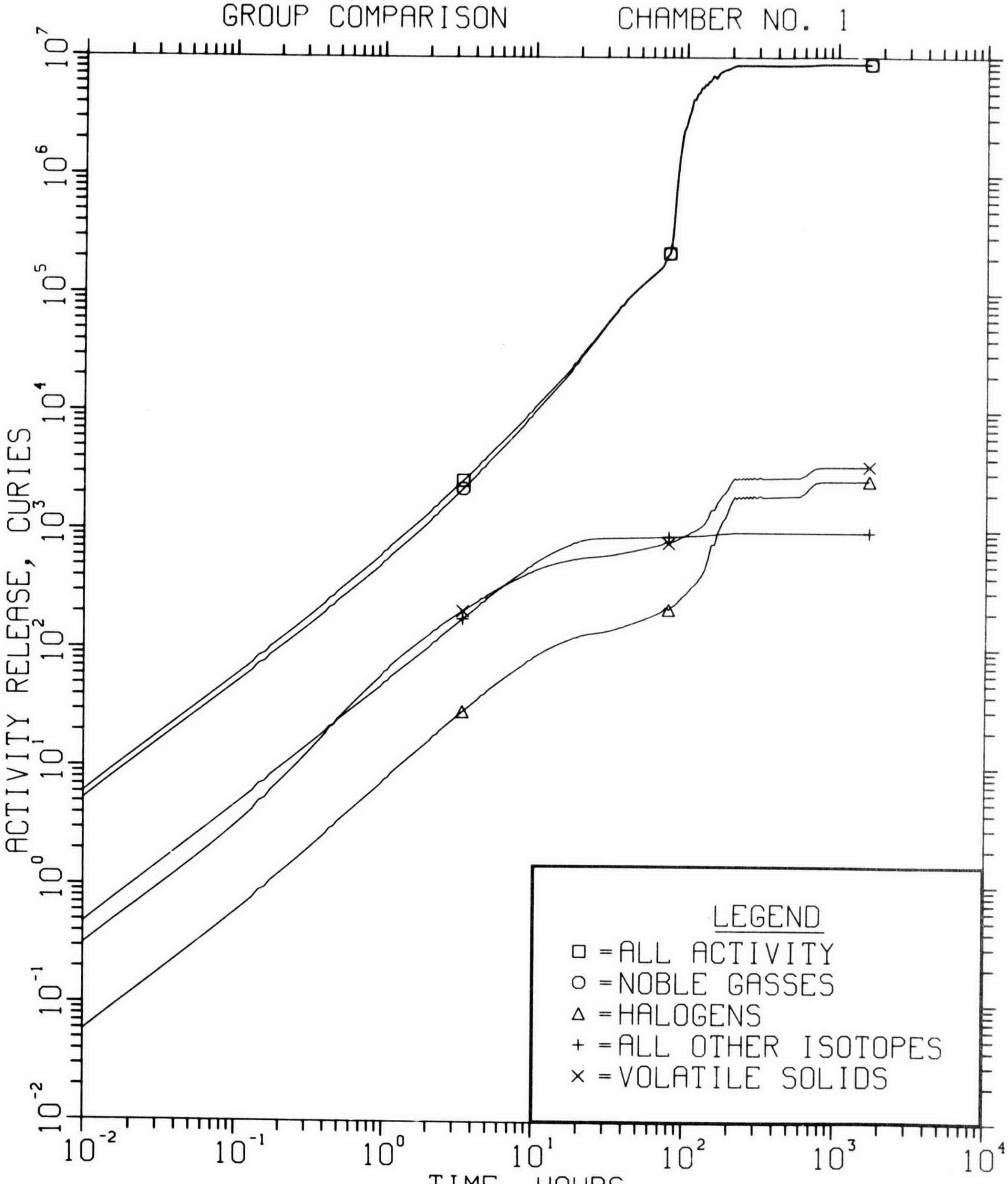

ACTIVITY RELEASE - CASE 657F
GROUP COMPARISON CHAMBER NO. 1
ACTIVITY RELEASE, CURIES
TIME, HOURS
LEGEND
□ = ALL ACTIVITY
○ = NOBLE GASSES
△ = HALOGENS
+ = ALL OTHER ISOTOPES
× = VOLATILE SOLIDS
JOB COMRDR PLOT NO. 2 TIME 23.27 DATE 03/10/77 DISSPLA, CDC 6000 V.1

FIGURE B-3-3

ACTIVITY RELEASE - CASE 659F



JOB COMRDR PLOT NO. 2 TIME 23.49 DATE 03/10/77 DISSPLA, CDC 6000 V.1

FIGURE B-3-4

CASE 675F - ACTIVITY RELEASE CURVES

GROUP COMPARISON CHAMBER NO. 1

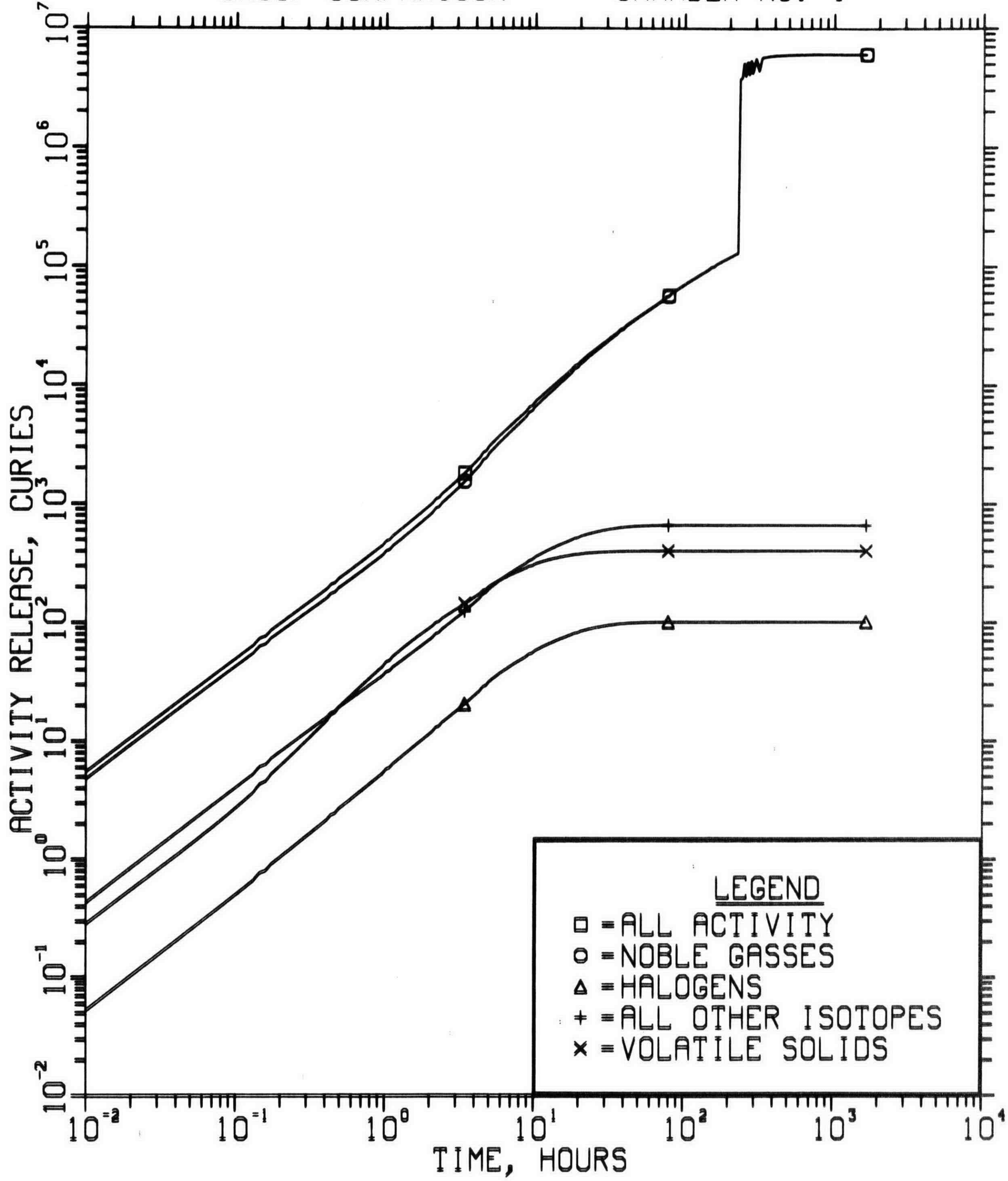


FIGURE B-3-5

JOB CONRDJ PLOT NO. 1 TIME 16.20 DATE 03/25/77 DISSPLA, CDC 6000 V.1

CASE 677F - ACTIVITY RELEASE CURVES

GROUP COMPARISON CHAMBER NO. 1

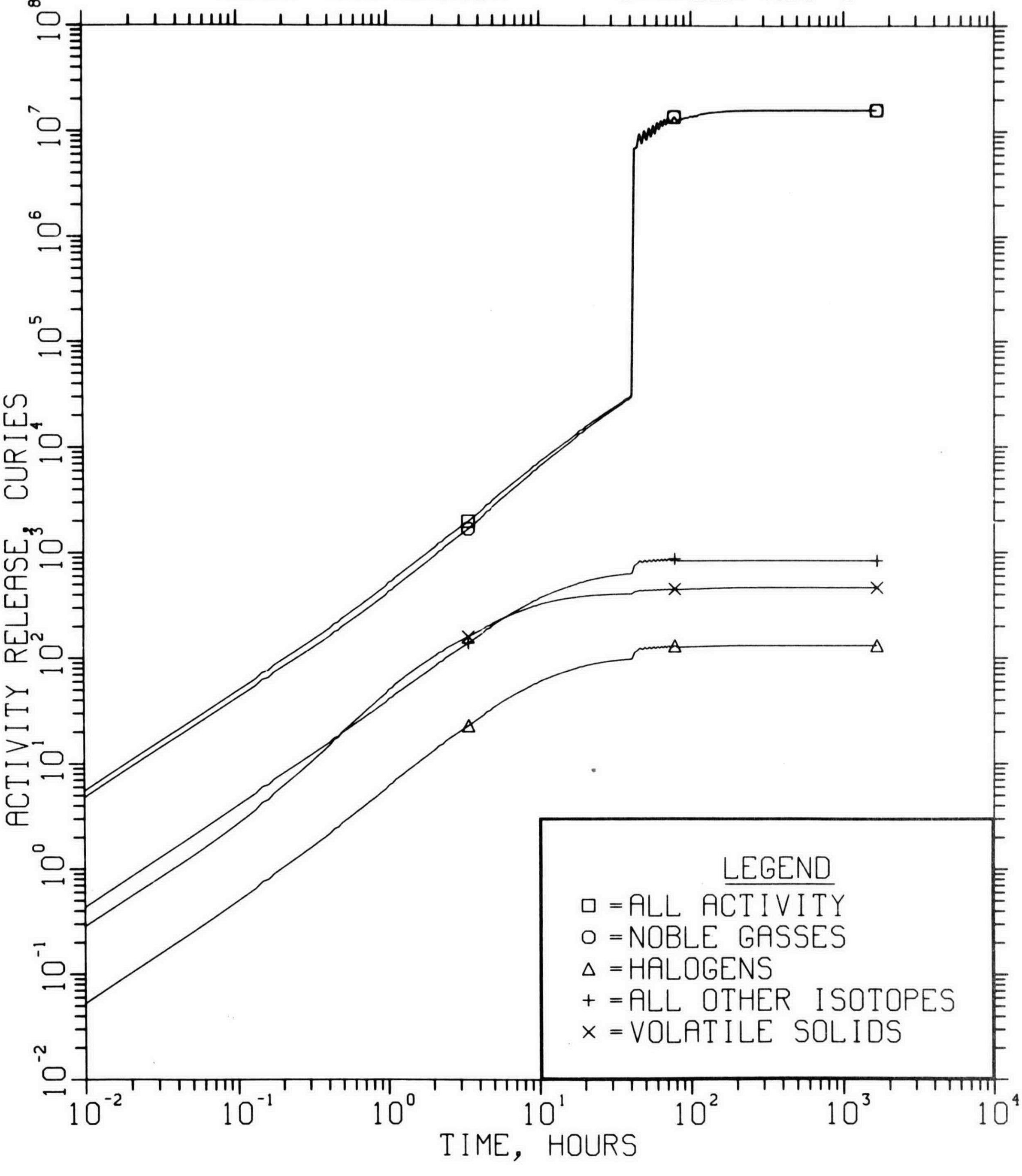
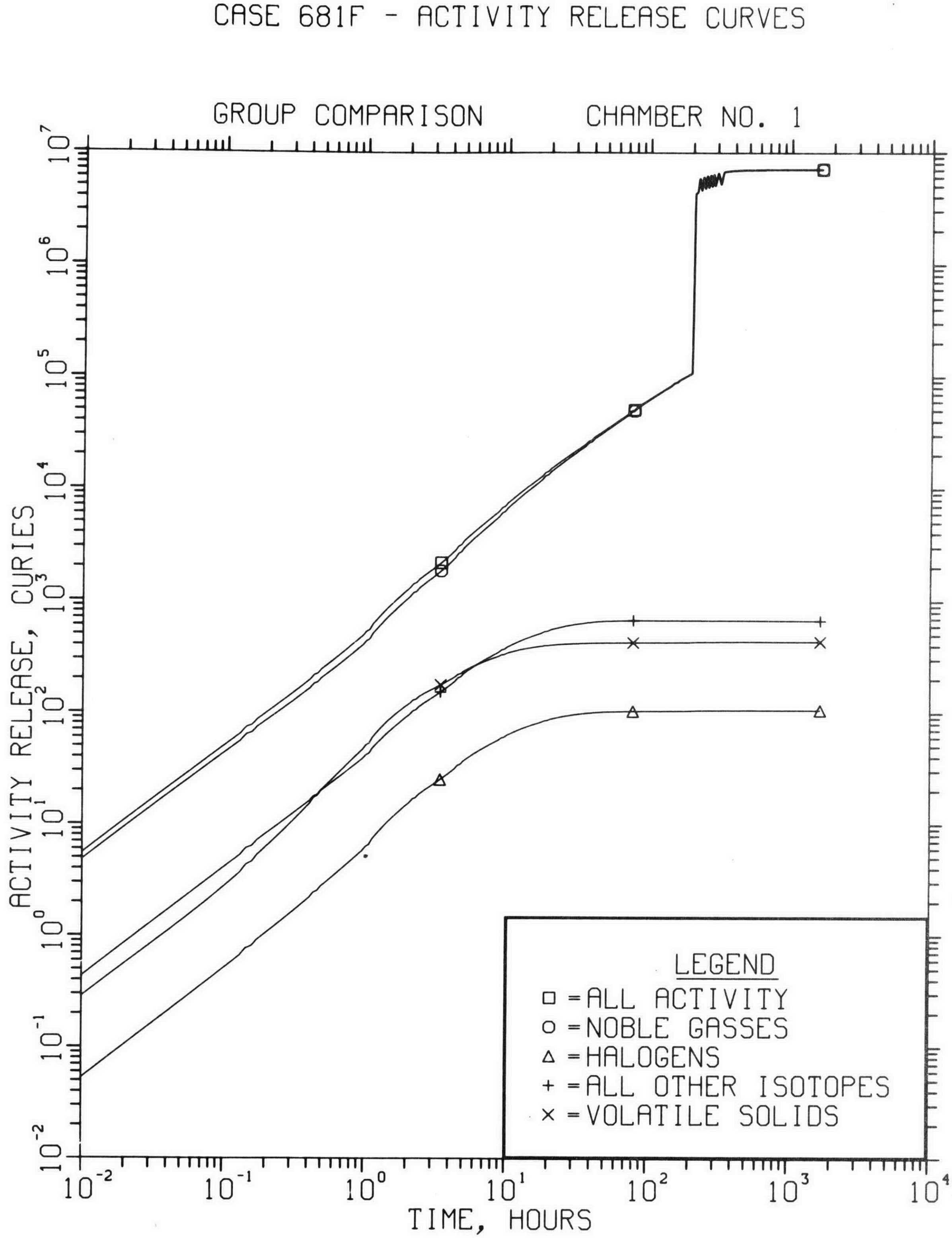


FIGURE B-3-6

JOB COMRDJ PLOT NO. 1 TIME 16.39 DATE 03/25/77 DISSPLA, CDC 6000 V.1



JOB COMRDO PLOT NO. 1 TIME 12.29 DATE 03/28/77 DISSPLA, CDC 6000 V.1

FIGURE B-3-7

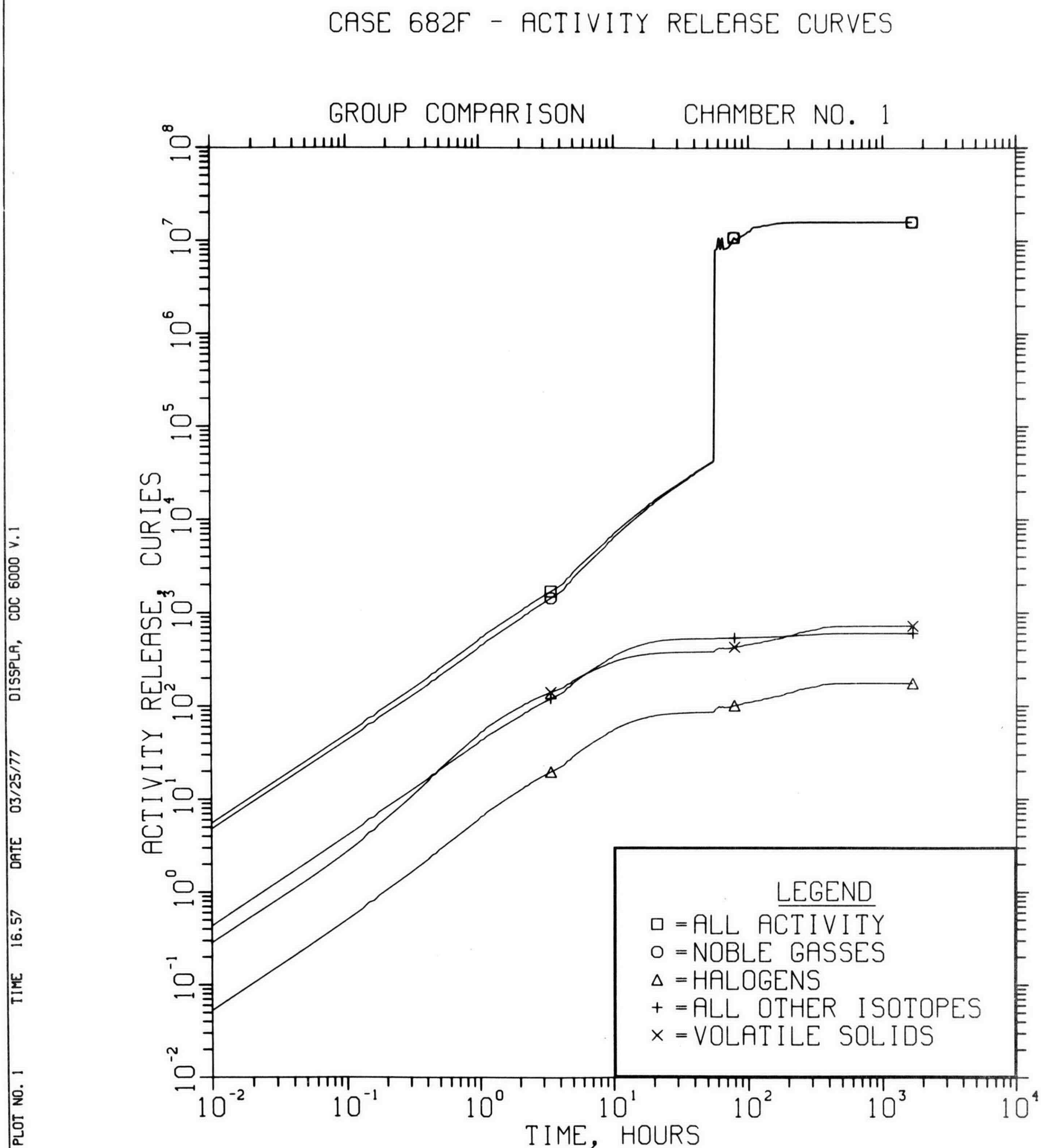
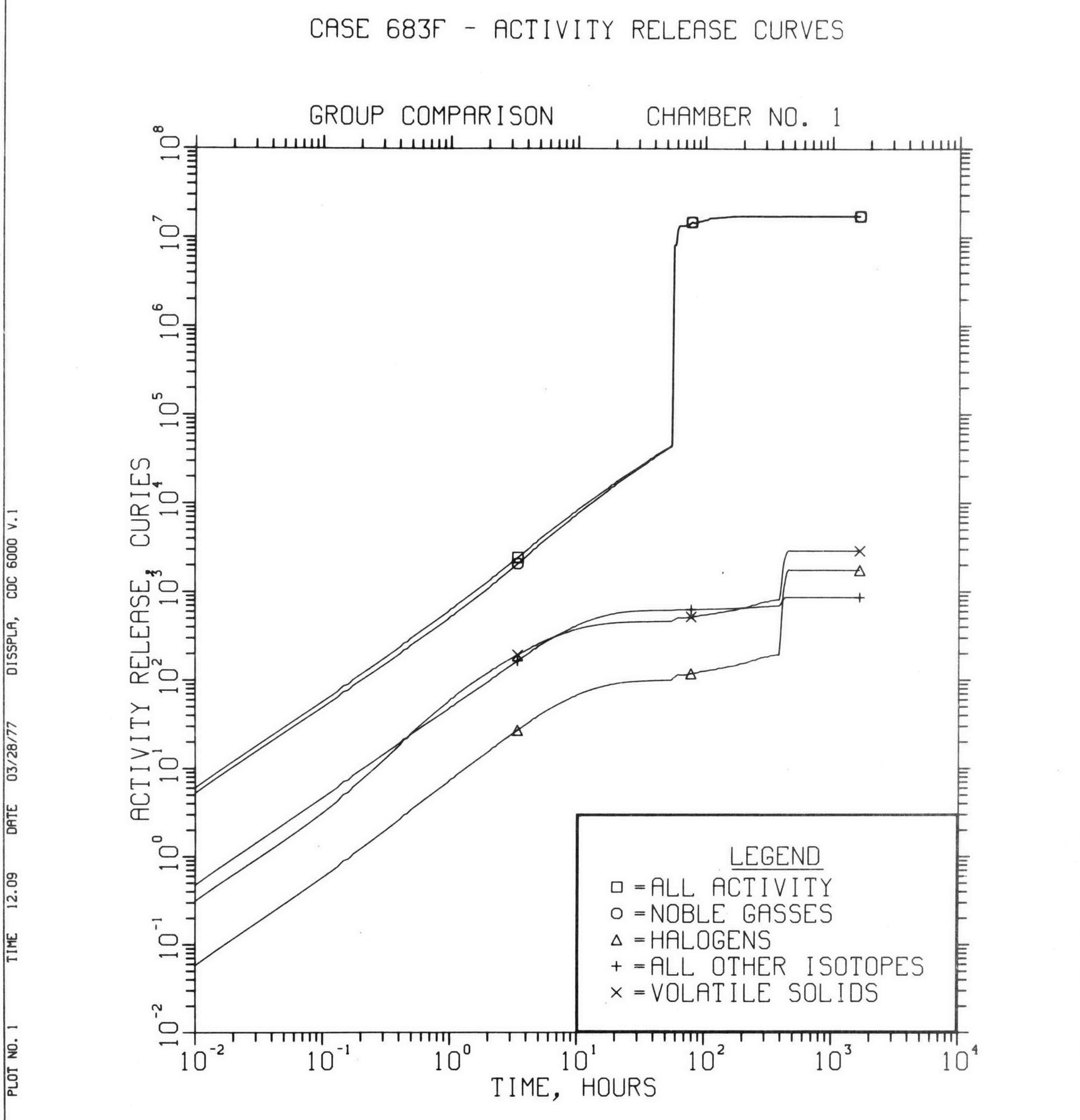

CASE 682F - ACTIVITY RELEASE CURVES
GROUP COMPARISON CHAMBER NO. 1
ACTIVITY RELEASE, CURIES
TIME, HOURS
LEGEND
□ = ALL ACTIVITY
○ = NOBLE GASSES
△ = HALOGENS
+ = ALL OTHER ISOTOPES
× = VOLATILE SOLIDS
JOB COMRON PLOT NO. 1 TIME 16.57 DATE 03/25/77 DISSPLA, CDC 6000 V.1

FIGURE B-3-8



CASE 683F - ACTIVITY RELEASE CURVES
GROUP COMPARISON CHAMBER NO. 1
ACTIVITY RELEASE, CURIES
TIME, HOURS
LEGEND
□ = ALL ACTIVITY
○ = NOBLE GASSES
△ = HALOGENS
+ = ALL OTHER ISOTOPES
× = VOLATILE SOLIDS
JOB COMRDD PLOT NO. 1 TIME 12.09 DATE 03/28/77 DISSPLA, CDC 6000 V.1

FIGURE B-3-9

CASE 675F - DOSE VS DISTANCE CURVES

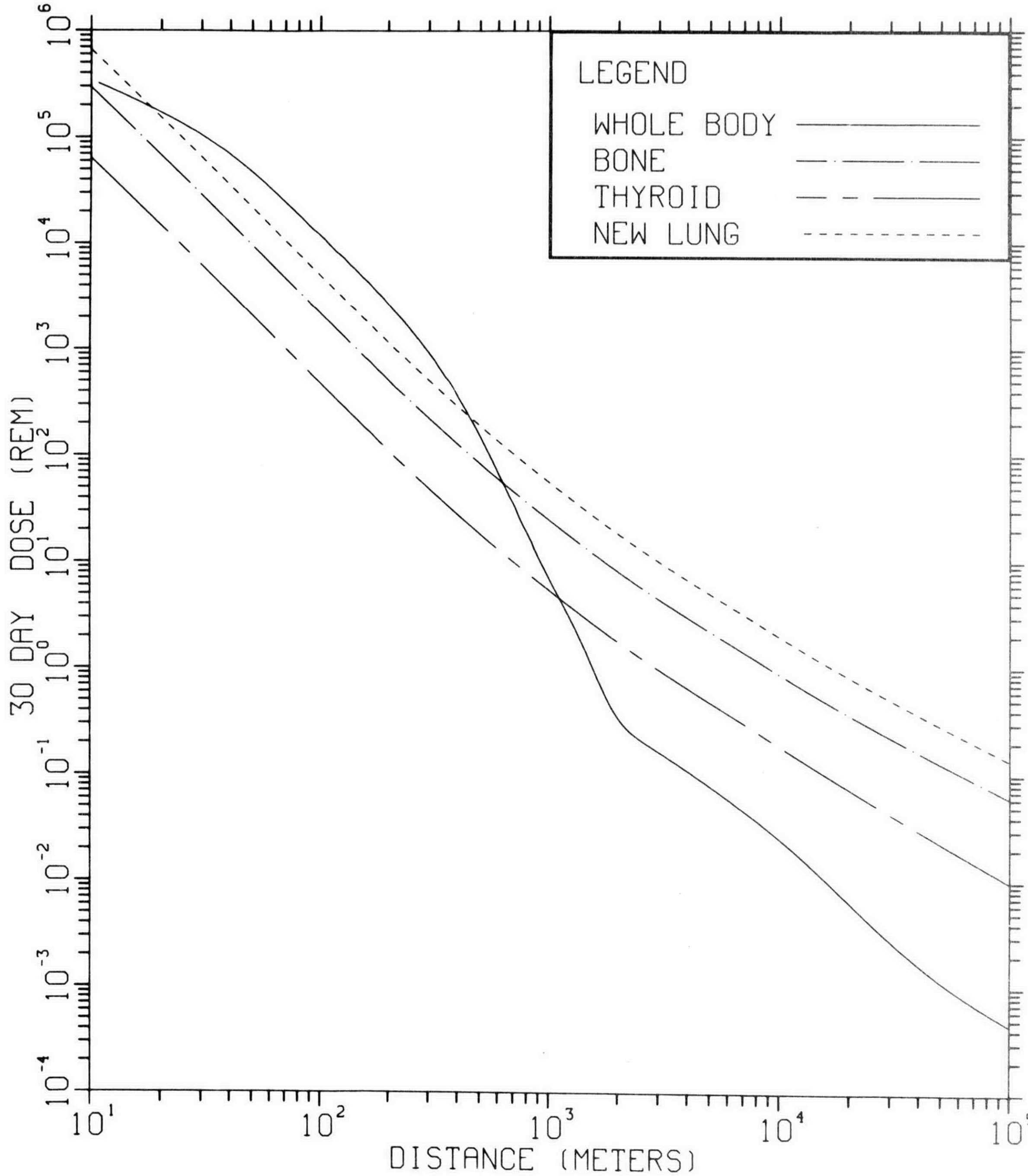


FIGURE B-3-10

JOB COMRDJ PLOT NO. 2 TIME 16.21 DATE 03/25/77 DISSPLA, CDC 6000 V.1

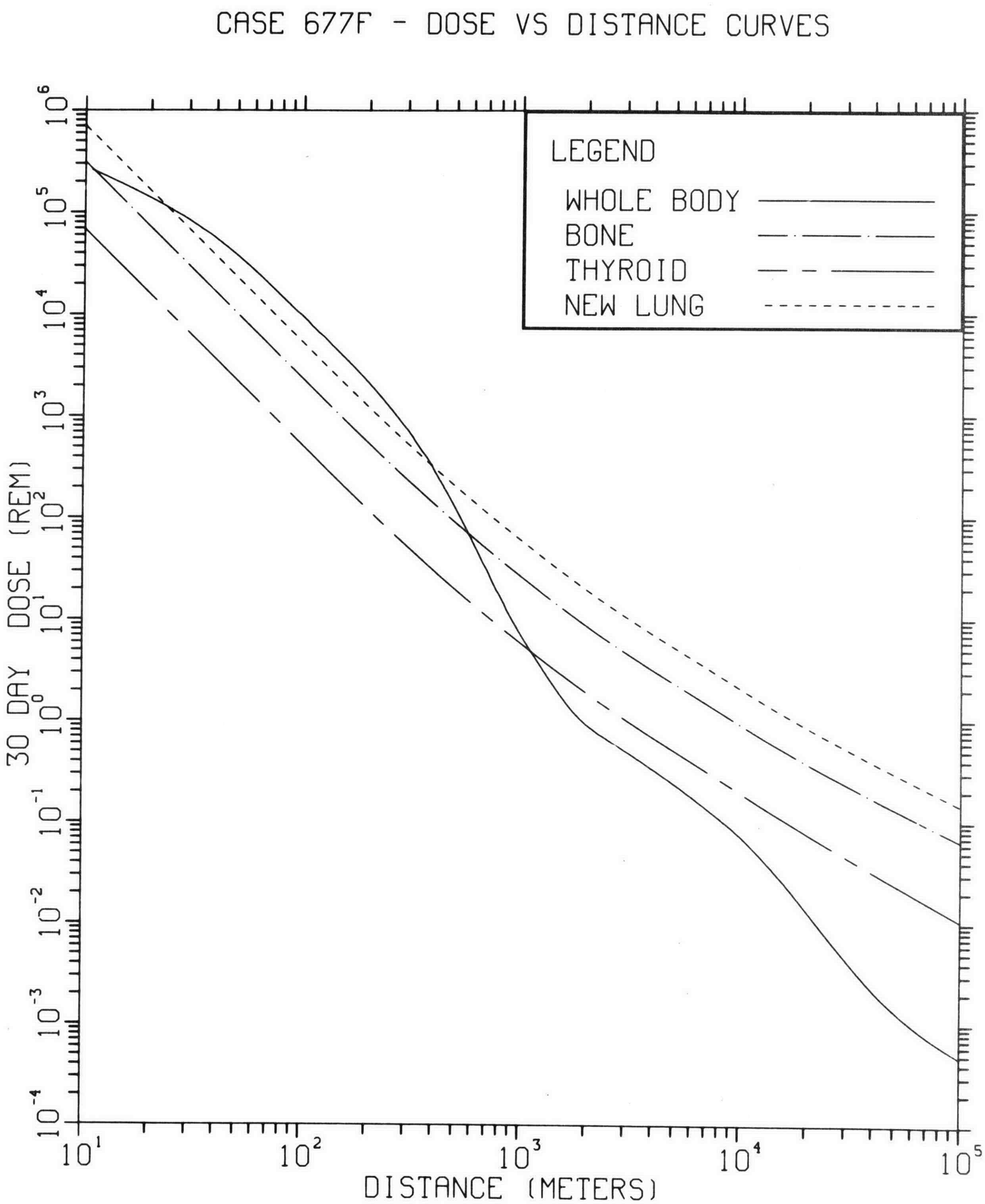


FIGURE B-3-11

JOB COMRDJ PLOT NO. 2 TIME 16.39 DATE 03/25/77 DISSPLA, CDC 6000 V.1

CASE 681F - DOSE VS DISTANCE CURVES

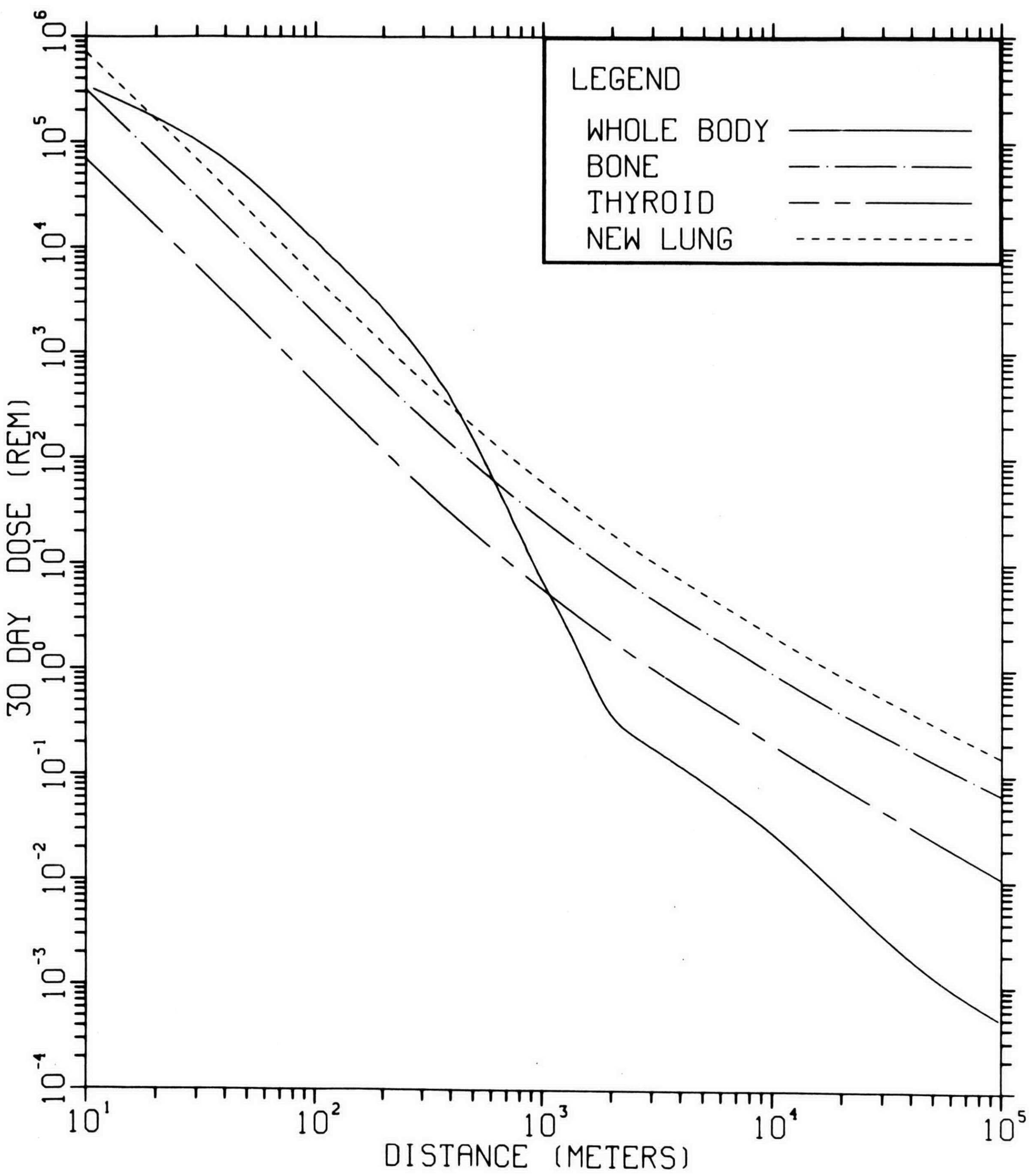


FIGURE B-3-12

CASE 682F - DOSE VS DISTANCE CURVES

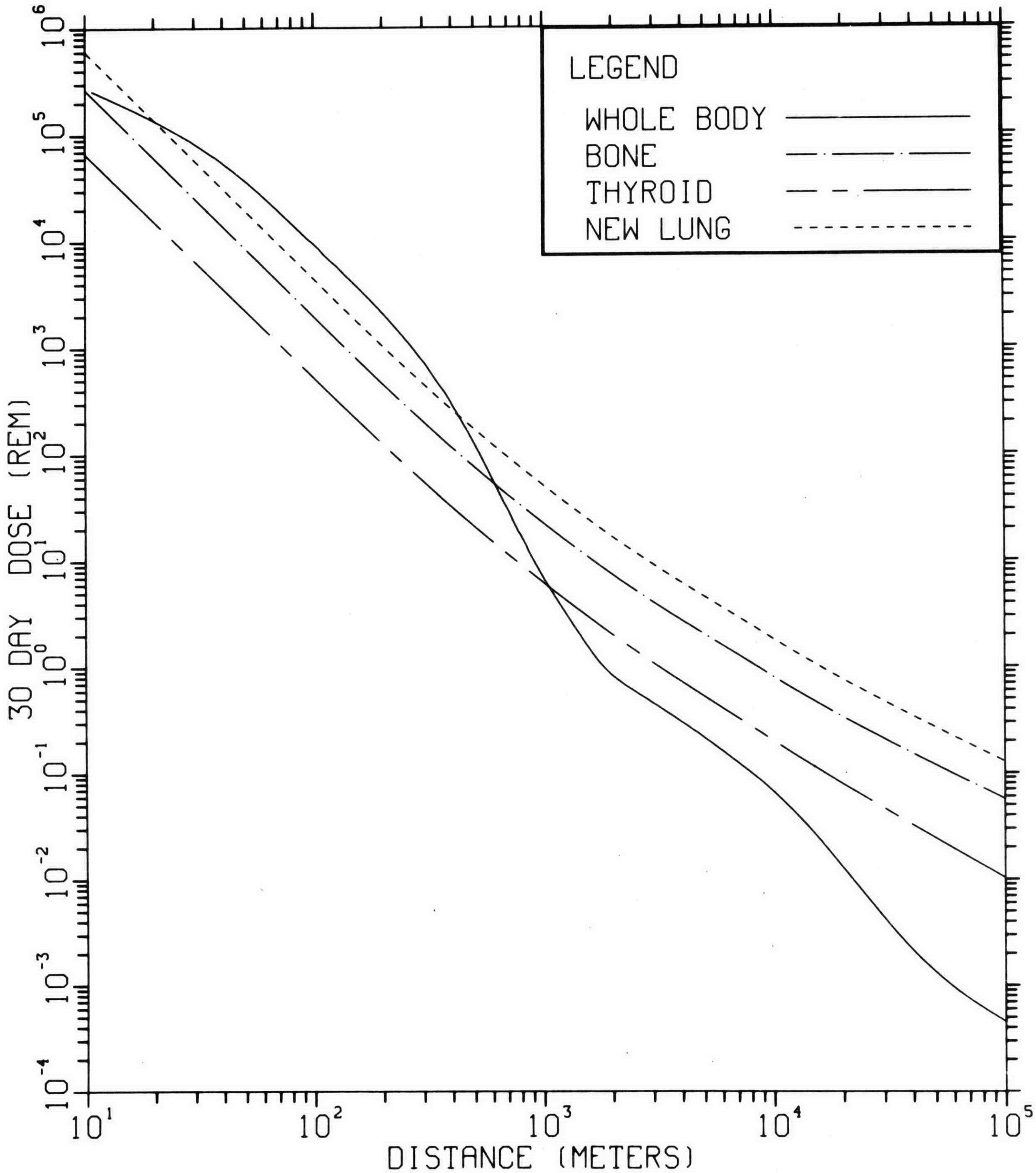


FIGURE B-3-13

CASE 683F-DOSE VS DISTANCE CURVES

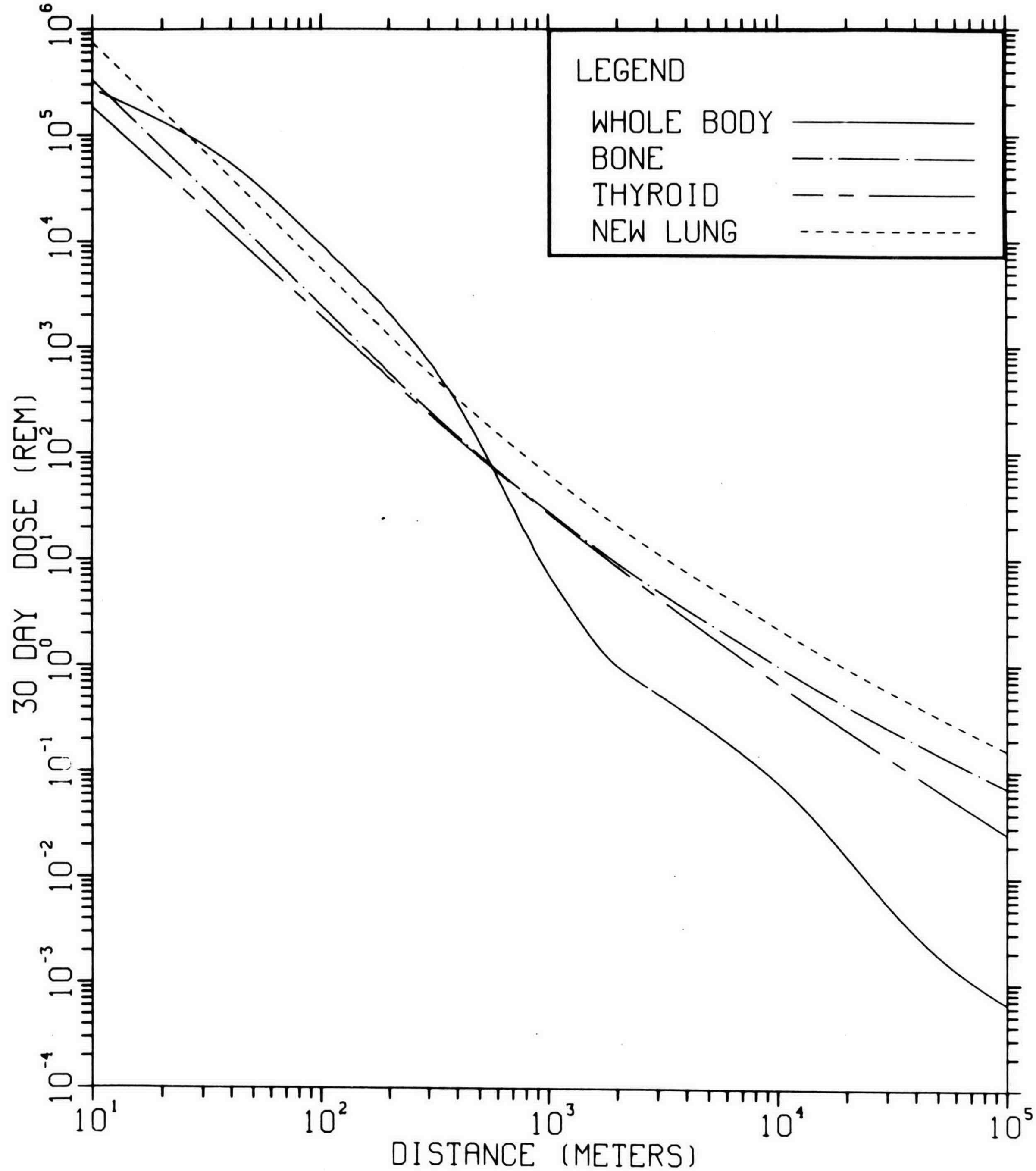


FIGURE B-3-14

JOB COMRDC PLOT NO. 2 TIME 12.10 DATE 03/28/77 DISSPLA, CDC 6000 V.1

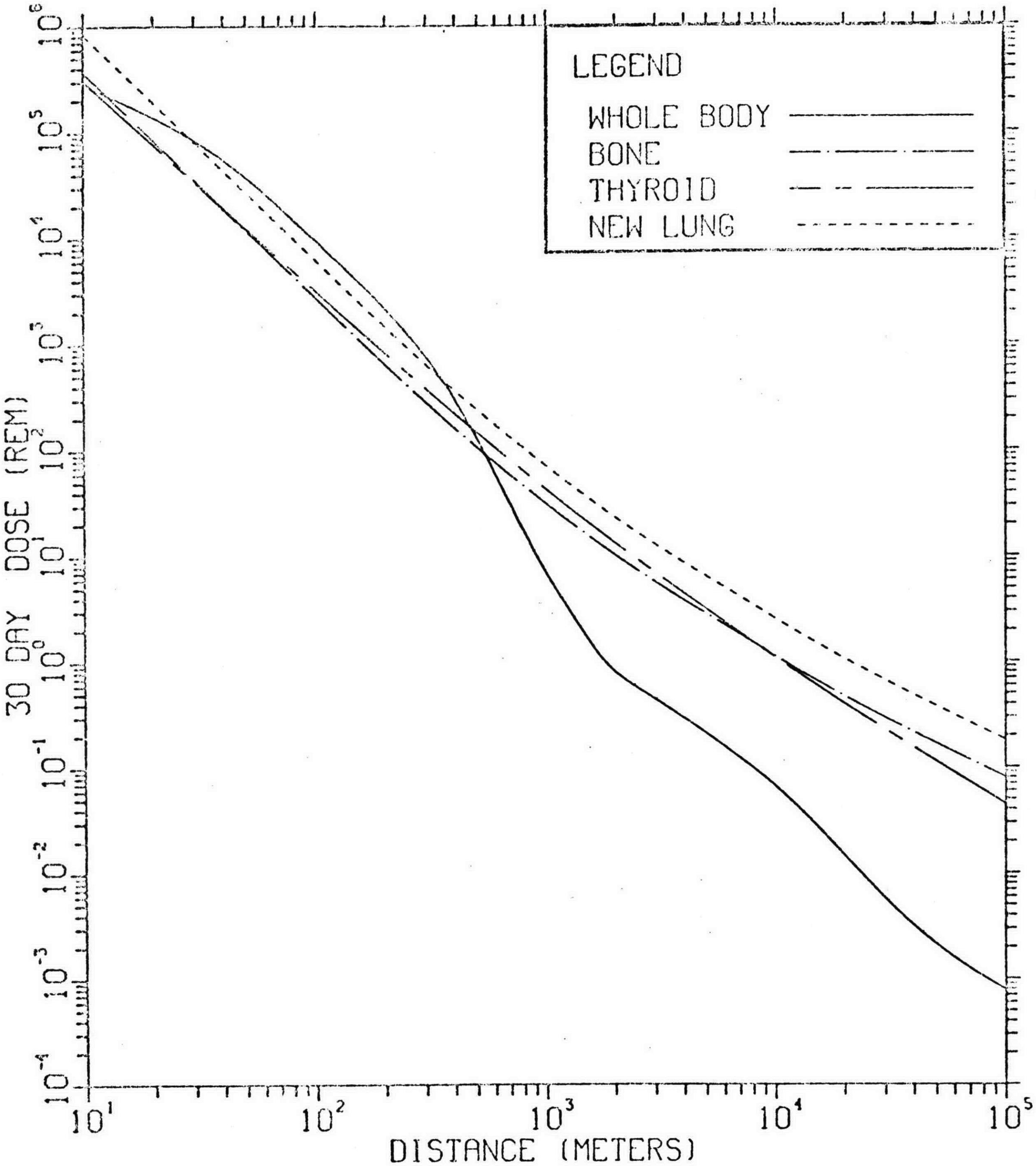


FIGURE B-3-15. Case 655F, Dose vs. Distance.

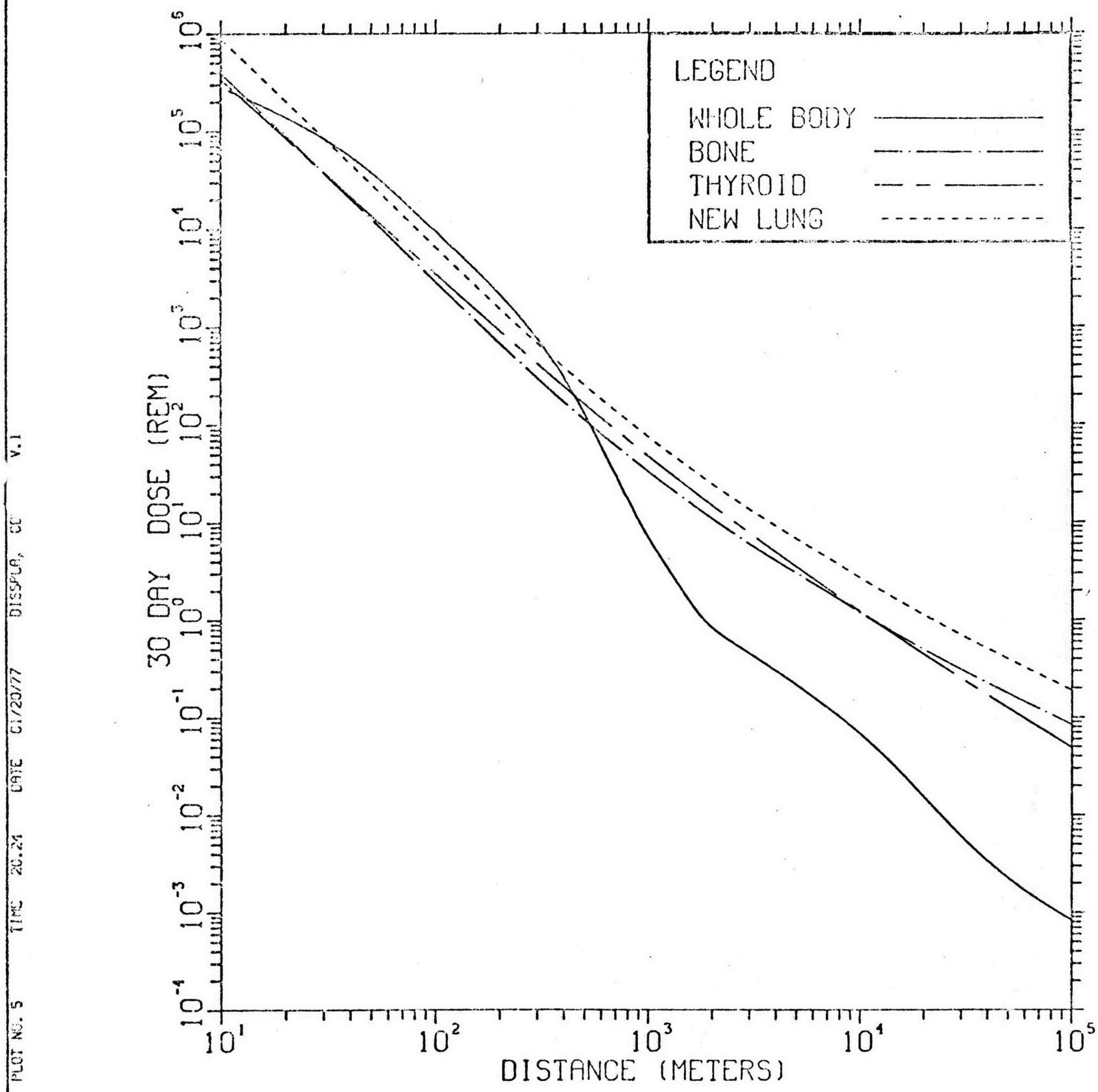


FIGURE B-3-16. Case 656F, Dose vs. Distance.

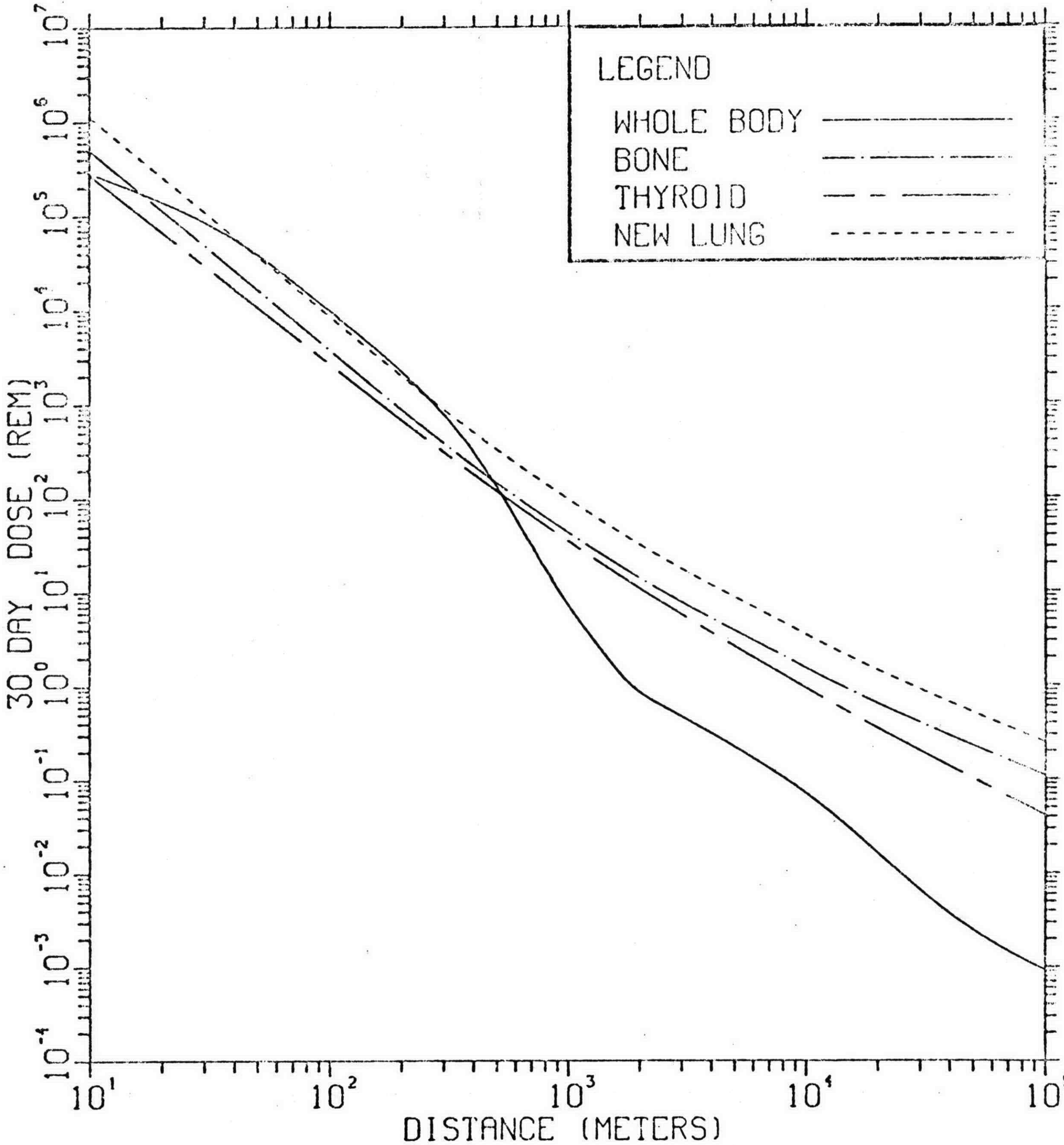


FIGURE B-3-17. Case 657F, Dose vs. Distance.

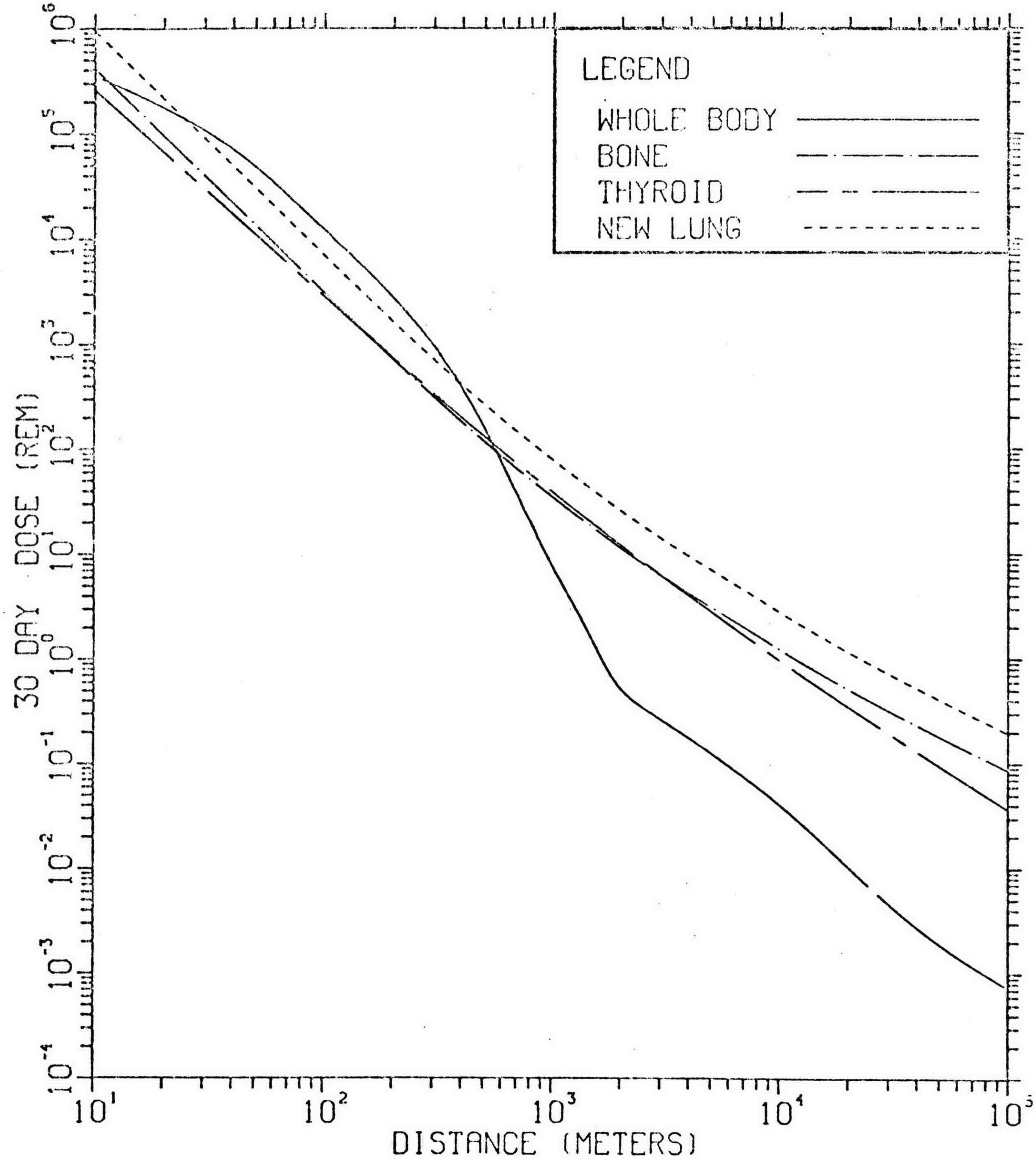


FIGURE B-3-18. Case 659F, Dose vs. Distance.

APPENDIX C

CALCULATIONS OF PENETRATION OF CONTAINMENT STRUCTURES BY FUEL DEBRIS

The AYER computer program was used to calculate the depth of penetration of the molten fuel into containment concrete and the earth below (Reference 1). The AYER code was developed by Los Alamos Scientific Laboratory and was modified by the Westinghouse Advanced Reactors Division. The code implicitly solves the general two-dimensional equations of heat conduction and includes the effects of time (transient problems), in-plane anisotropic thermal conductivity, and interface thermal contact resistance using the finite element method (Reference 2).

Materials properties, geometry and the decay heat from the core debris are part of the code input data, as are the initial temperature and boundary conditions. The temperature distribution within the pool is determined by conduction and the boundary conditions at the limits of the mesh.

The AYER code performs two operations during a time step. First the code searches the elements adjacent to the existing pool to determine if the average temperature of its nodes is greater than the melting point of material. If so, the element is added to the pool zone and the properties of the pool material are recalculated using appropriate mass or volume weighting. The change in phase of the melting material is included in the form of an effective specific heat given by

$$C_{eff} = \frac{H}{2\Delta T}$$

where H is the latent heat

C_{eff} is the resulting effective specific heat

and ΔT is the temperature range over which the transition takes place.

1. S. F. Bankert, AYER Code Calculations of Core Debris Penetration, HEDL-TC-839, April 1977.

2. R. G. Lawton, The AYER Heat Conduction Computer Program, Los Alamos Scientific Laboratory, LA-5613-MS, May 1974.

With the new pool properties in hand, the code solves the heat conduction equations, including the boundary conditions. One of the deficiencies in the code appears at this point, in that no physical mixing of the pool takes place. The conduction temperatures determine the pool temperature conditions. At designated times, the code outputs the temperature at the nodes, the average and maximum temperatures in each zone, volumes of the zones, and information on the heat balance of the zones.

The conduction model probably results in pool center temperatures which are unrealistically high, and pool-edge temperatures which are too low. Possibly the pool could grow faster with a convective mixing model. Whether the pool would penetrate deeper with a convection model has not been evaluated. All of the decay energy has been accounted for, and it is considered unlikely that a realistic model would predict significantly greater penetration.

In modeling both the cavity floor and subcavity floor, two zones were used. They were labeled fuel and basalt, and their properties are listed in Table C-1. The properties of the earth, basalt concrete, and bricks which make up the cavity floor are similar and the code handles only constant properties. Hence, it was decided to lump them together as basalt concrete.

Table C-2 lists the decay heat table used in these calculations. It includes the whole FFTF core along with its associated heavy metals and fuel hardware.

Two CACECO cases were used to determine the final disposition of the core debris. Case 654 boiled dry in the vessel and the core debris melted through to the cavity floor (In-Vessel Case). Case 683 collapses the cavity floor and boil-dry takes place with the core debris in the subcavity under a bed of sodium-concrete reaction product debris (Ex-Vessel Case).

In-Vessel Case

The AYER code analysis for CACECO Case 654 began at 527 hours with the core inventory of 2,850 kg of fuel spread evenly over the cavity floor under the reactor vessel. For purposes of analysis, the initial fuel temperature was set at the fuel melting point. The cavity floor over the subcavity (see Figure C-1) is 3.25 feet thick and was modeled with a rectangular axisymmetric mesh of 3 inch by 6 inch rectangles (Figure C-2). Table C-3 gives the boundary heat transfer coefficients from the boundaries of the mesh to the listed sink temperatures. Material properties and boundary conditions were held constant. The cavity floor was assumed to fail when the pool had expanded to within 6 inches of the bottom. A new pool having the same volume, composition and average temperature as that in the cavity floor was assumed to form on the subcavity floor. The axisymmetric subcavity floor mesh consisted of 12 inch by 6 inch wide rectangles shown in Figure C-3. The initial pool was 1.5 ft thick to include the pool from the cavity floor. The boundary heat transfer coefficients and temperatures are given in Table C-4.

The initial temperature conditions for both the cavity floor and the subcavity floor were taken as those in the structures at the end of CACECO Case 654. Figures C-4 and C-5 show the temperature profiles along the centerline at the start time of the AYER run (527 hours).

Penetration depth for Case 654 is based on the loss of 75 percent of decay heat from the surface of the pool. This assumption is based on the high potential for radiant heat transmission at the temperature of molten concrete. If the initial 10 ft diameter pool is taken at 2100°F, and is radiating to the reactor cavity walls, a temperature difference of 155°F would transmit 1.1×10^6 Btu/hr, or 100 percent of the decay energy at 1,000 hrs, the approximate time when oxidation of cavity molten steel is completed. At the melting temperature of steel, radiant heat transmission could, of course, be greater still.

In-Vessel Case (cont'd)

Heat transmission by convection and radiation at far lower temperatures than the material melting points discussed above were estimated from CACECO Case 682. Case 682 had a sodium pool on the cavity floor for over 1,600 hours because it never boiled, due to heat loss to the cavity walls and roof. Table C-6 lists the heat losses to the reactor cavity walls and roof as a function of time in CACECO Case 682. The heat absorption in Table C-5 can be taken as a minimum because the cavity atmosphere temperature is much lower than that for molten basalt. The walls eventually heat up (as calculated in this case) and absorb less heat because they are adiabatic on the far surface. The cavity roof on the other hand reaches a steady heat transmission state because its far surface is in contact with the building atmosphere. The building with its large surface can be expected to dissipate energy transferred through the cavity roof.

The data from Table C-5 are plotted on Figure C-6, together with a curve representing 75 percent of the decay energy. As the figure indicates, even with the low temperature heat transfer of CACECO Case 682, 75 percent of the decay energy can be dissipated in the upward direction. As discussed previously, simple radiation from the pool surface to the inside of the cavity can transmit 100 percent of the decay energy (at 1,000 hours) with only a 155°F temperature difference at the melting point of basalt.

The AYER code analysis of Case 654 started at 527 hours with the core debris spilled onto the 346 ft^2 cavity floor under the reactor vessel. The initial conditions for the AYER analysis were arbitrarily set with the fuel debris at its melting point (5160°F). A more realistic temperature would have been that of molten steel (2600°F). Even with the conservative assumption of molten fuel, the core debris, when spilled onto the 260°F cavity floor, chilled quickly to about 1500°F, shown as the initial point in Figure C-7, at 527 hours. This debris subsequently heated and melted into the firebrick, insulating brick, and basalt concrete of the cavity floor, forming a molten concrete pool. The pool size increased by melting sideways and downward into the basalt concrete (melting point taken at 2100°F) until, at 890 hours, the fuel-concrete pool had melted through 33 inches of the 39-inch-thick floor. The average pool temperature increased during this phase to 2620°F as shown in Figure C-7. At 890 hours, the cavity floor was assumed to collapse, spilling the fuel-concrete pool into the subcavity.

The AYER analysis was restarted at 890 hours with the concrete-fuel pool on the floor of the subcavity. The pool at 2620°F spilled onto the 123°F subcavity floor, chilled quickly to about 2580°F, as shown in Figure C-7, at 930 hours. The AYER analysis indicated a pool surface temperature of 2100°F (nominal melting point of basalt concrete) after the stainless steel had been consumed by the steel-water reaction. The average pool temperature increased to a maximum of 3000°F at 2,000 hours (83 days) and then decreased as the pool continued to grow. At 6,850 hours (285 days), the average pool temperature had decreased to 2320°F, as shown in Figure C-7, when the pool volume attained its maximum size of 1,500 ft^3. Also at this time the pool reached its maximum penetration of about 7 feet below the former surface of the subcavity floor. This penetration distance would place the fuel-concrete debris at the bottom of the concrete base under the containment vessel of the RCB, at elevation 467 feet.

Ex-Vessel Case

CACECO Case 683 ended at 429 hours after boiling off and reacting away the sodium in the subcavity. The cavity floor was assumed to fail at 384 hours and the fuel was assumed to be on the subcavity floor covered with 5.5 feet of sodium reaction product debris from the cavity floor and subcavity walls. The reaction products were assumed to have the properties of basalt. Initial temperatures were taken from the CACECO output at 429 hours. Figures C-8 and C-9 are plots of the initial temperatures of the

Ex-Vessel Case (cont'd)

subcavity floor and wall. The boundary conditions are given in Table C-6. The initial temperature of the reaction debris covering the pool was taken as the final sodium temperature of 1600°F. The mesh configuration is shown in Figure C-10.

In this case, heat loss in the upward direction was initially set at 10,000 Btu/hr to allow for the thermal resistance of the overburden of material. When the pool melted through in the upward direction, heat loss from the top surface was assumed to be equal to 75 percent of the decay energy. The basis for this latter assumption is the same as the in-vessel case.

The AYER code analysis of Case 683 started at 429 hours with the core debris on the 346 ft^2 subcavity floor buried under 5.5 feet of concrete debris from the cavity floor and subcavity walls. The initial conditions for the AYER analysis were arbitrarily set with the fuel debris at its melting point (5160°F). A more realistic temperature would have been that of molten steel (2600°F). Even with the conservative assumption of molten fuel, the core debris, when spilled onto the 1610°F subcavity floor, cooled quickly to 3190°F, as shown in Figure C-11, at 430 hours. This fuel subsequently heated and melted into the basalt concrete above and below it, forming a molten fuel concrete pool. The pool size increased by melting upward, sideways and downward into the basalt concrete (melting point taken at 2100°F) until the pool reached the surface at 750 hours. Prior to this time the heat loss from the molten-fuel-concrete pool was limited by the covering of concrete debris. After the pool broke through, 75 percent of the decay power was assumed to be dissipated from the surface.

The average molten fuel-concrete pool temperature, shown in Figure C-11, increased to a maximum of 4400°F at 1,100 hours (46 days) and then decreased as the molten fuel-concrete pool continued to grow. At 6,220 hours (254 days), Ex-Vessel Case (cont'd)

the average pool temperature had decreased to 2790°F when the pool volume attained its maximum size of 8,150 ft^3. Also, at this time, the pool reached its maximum penetration of about 13 feet below the former surface of the subcavity floor.

Conclusion

The AYER Heat Conduction Code has been used to continue two CACECO cases to determine the final deposition of the FFTF core debris. It was found that a) the depth of penetration was finite and at least 80 feet above the water table and b) the pool temperature did not reach the melting temperature of the fuel. The pool formed by the core debris in the continuation of CACECO Case 654 (boil-dry in the reactor cavity) reaches maximum temperature of 3000°F at 2,000 hours and has a maximum penetration of 7 feet at 6,850 hours. The continuation of CACECO Case 683 (core debris buried on subcavity floor at boil-dry) leads to a maximum pool temperature of 4400°F at 1,100 hours and a maximum penetration of 13 feet at 6,220 hours.

Table C-1

PROPERTIES OF FUEL AND BASALT

Property	Fuel Value	Basalt Value
Specific Heat, Btu/lb °F	0.12	0.25
Thermal Conductivity, Btu/hr ft °F	1.70	0.50
Density, lb/ft^3	524	150
Melting Point, °F	5162	2012
Latent Heat of Melting, Btu/lb	164.3	166.7

Table C-2

FTR DECAY HEAT AFTER HCDA

Time, Hrs	Decay Heat, Btu/Hr
384.0	1.82×10^6
420.0	1.74×10^6
480.0	1.62×10^6
600.0	1.42×10^6
720.0	1.28×10^6
840.0	1.19×10^6
960.0	1.11×10^6
1080.0	1.02×10^6
1200.0	9.37×10^5
1600.0	7.75×10^5
2000.0	6.70×10^5
2400.0	5.94×10^5
4800.0	3.30×10^5
9636.0*	1.57×10^5

*Linear extrapolation was used beyond 9636 hours.

Table C-3

CAVITY FLOOR BOUNDARY CONDITIONS

Coefficient	Heat Transfer Coefficient, Btu/hr ft °F	Temperature, °F
h_1, through subcavity to ground	0.072	125
h_2, through subcavity walls to ground	0.044	90
h_3, through walls to H&V rooms	0.147	145
h_4, off pool surface	*	*

Table C-4

SUBCAVITY FLOOR BOUNDARY CONDITIONS

Coefficient	Heat Transfer Coefficient, Btu/hr ft^2 °F	Temperature
h_1, to earth	0.23	90.
h_2, to earth	0.23	90.
h_3, off the pool to subcavity and cavity	*	*

* $h\Delta t$ was chosen to provide an upward heat flux equivalent to 75 percent of core decay energy.

Table C-5

HEAT ABSORBED BY CAVITY WALLS AND ROOF IN CACECO CASE 682

Time, hour	Cavity Atmosphere Temperature, °F	Heat into Walls, Btu/hr	Heat into Roof, Btu/hr	Total, Btu/hr
504	1476	12.72_{+5}	2.59_{+5}	15.31_{+5}
672	1479	10.11_{+5}	2.36_{+5}	12.47_{+5}
1000	1479	6.14_{+5}	2.14_{+5}	8.28_{+5}
1320	1469	4.03_{+5}	2.18_{+5}	6.21_{+5}
1625	1453	2.65_{+5}	2.14_{+5}	4.79_{+5}

Table C-6

SUBCAVITY FLOOR BOUNDARY CONDITIONS (CASE 683)

Coefficient	Heat Transfer Coefficient, Btu/hr ft^2 °F	Temperature, °F
h_1, to earth	0.23	90.
h_2, to earth	0.23	90.
h_3, off the debris bed to subcavity, and cavity	*	*

* Low value of heat loss assumed until breakthrough. A breakthrough $h\Delta t$ was chosen to provide an upward heat flux equivalent to 75 percent of core decay energy.

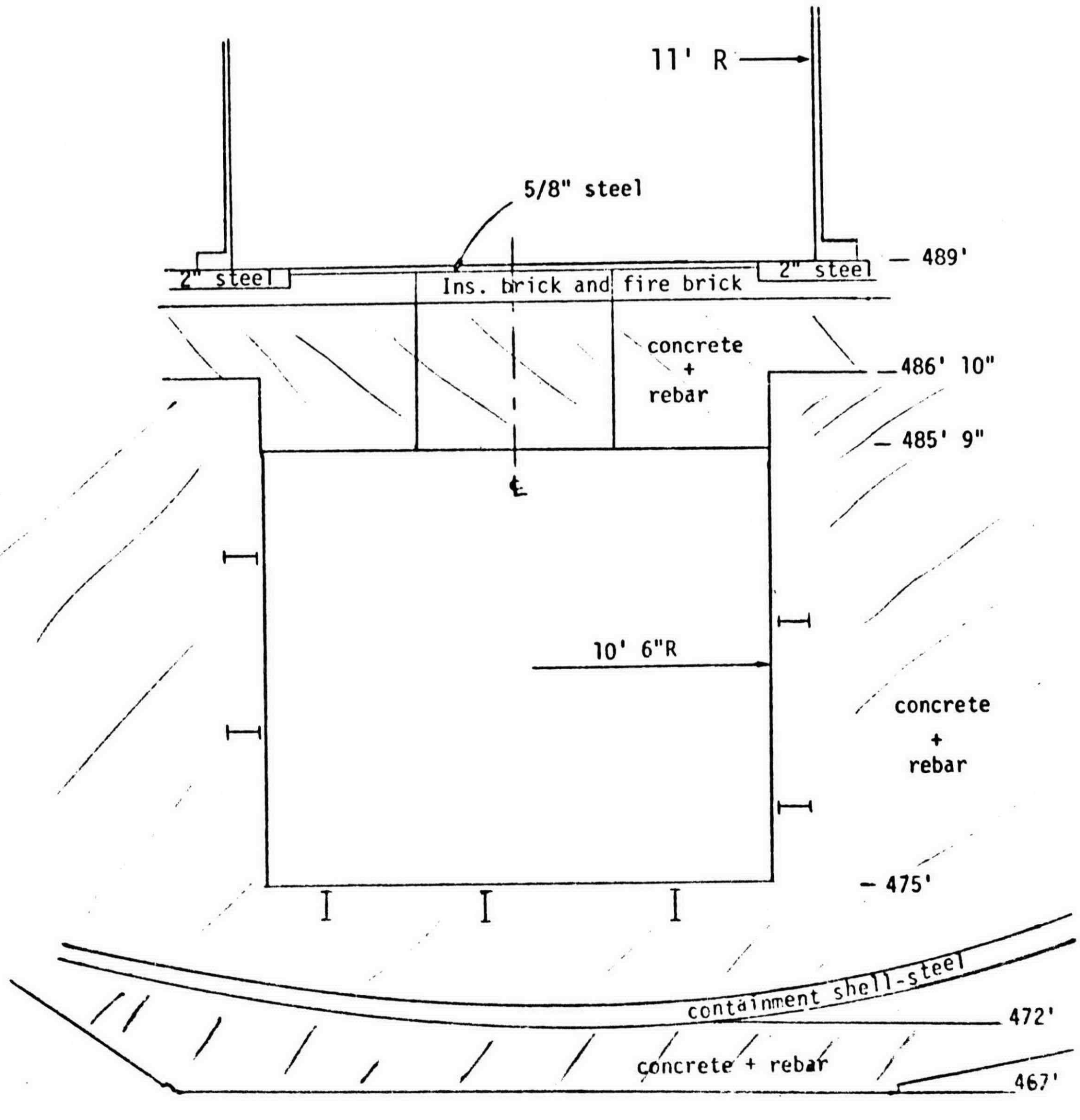


FIGURE C-1. Basic FFTF Cavity and Subcavity Configuration.

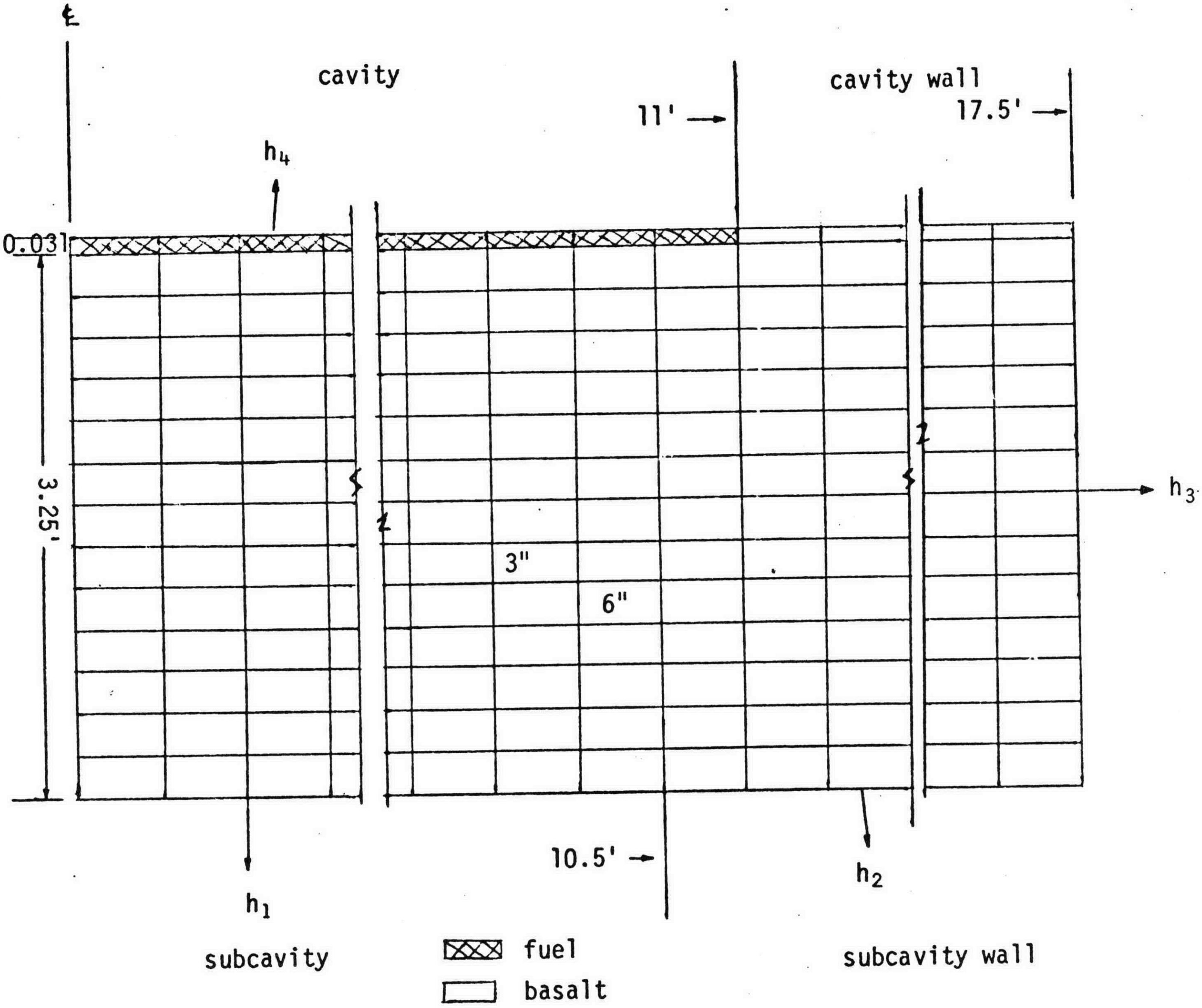


FIGURE C-2. Subcavity Floor Model for Case 654.

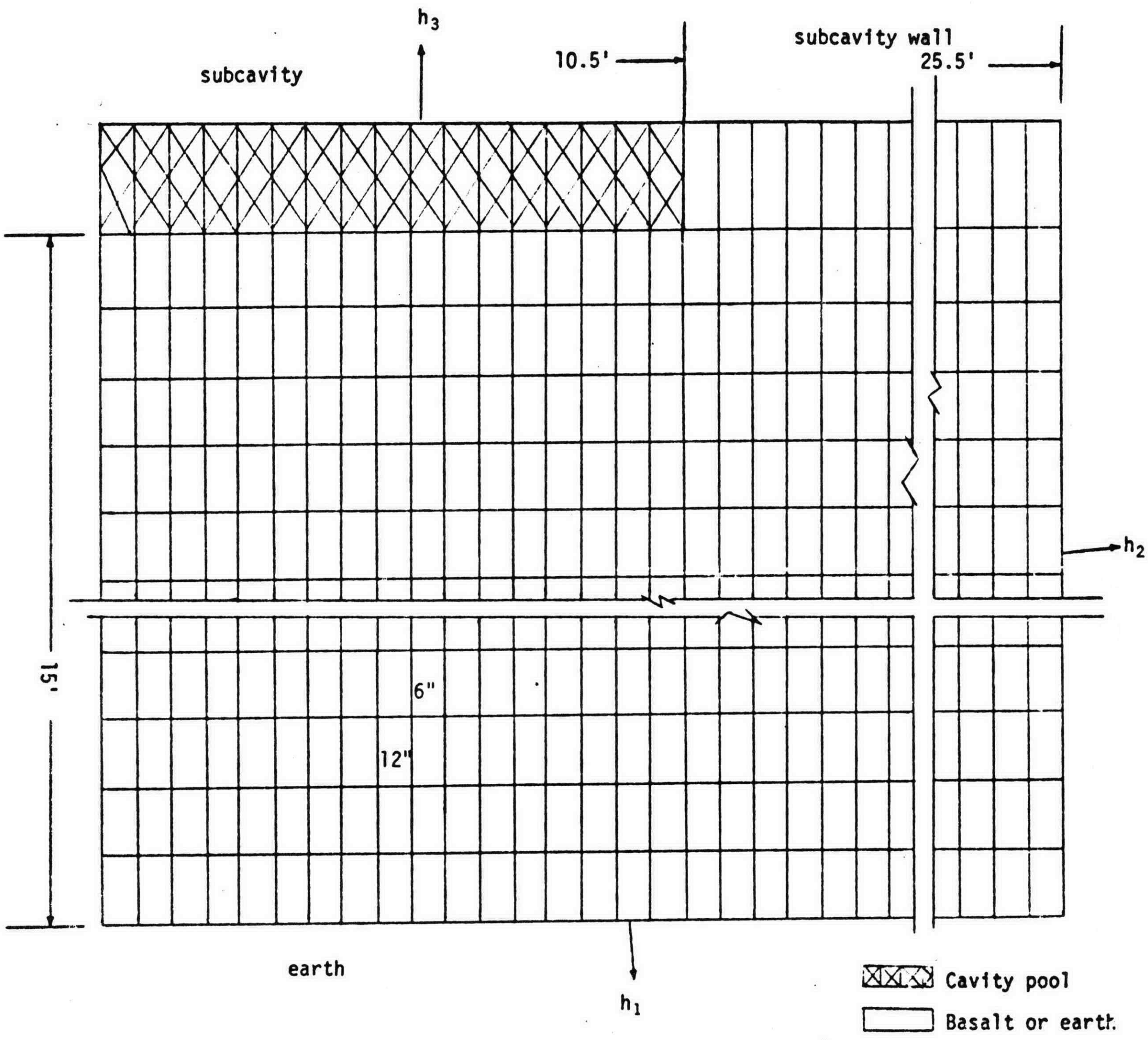


FIGURE C-3. Subcavity Floor Mesh for Case 654.

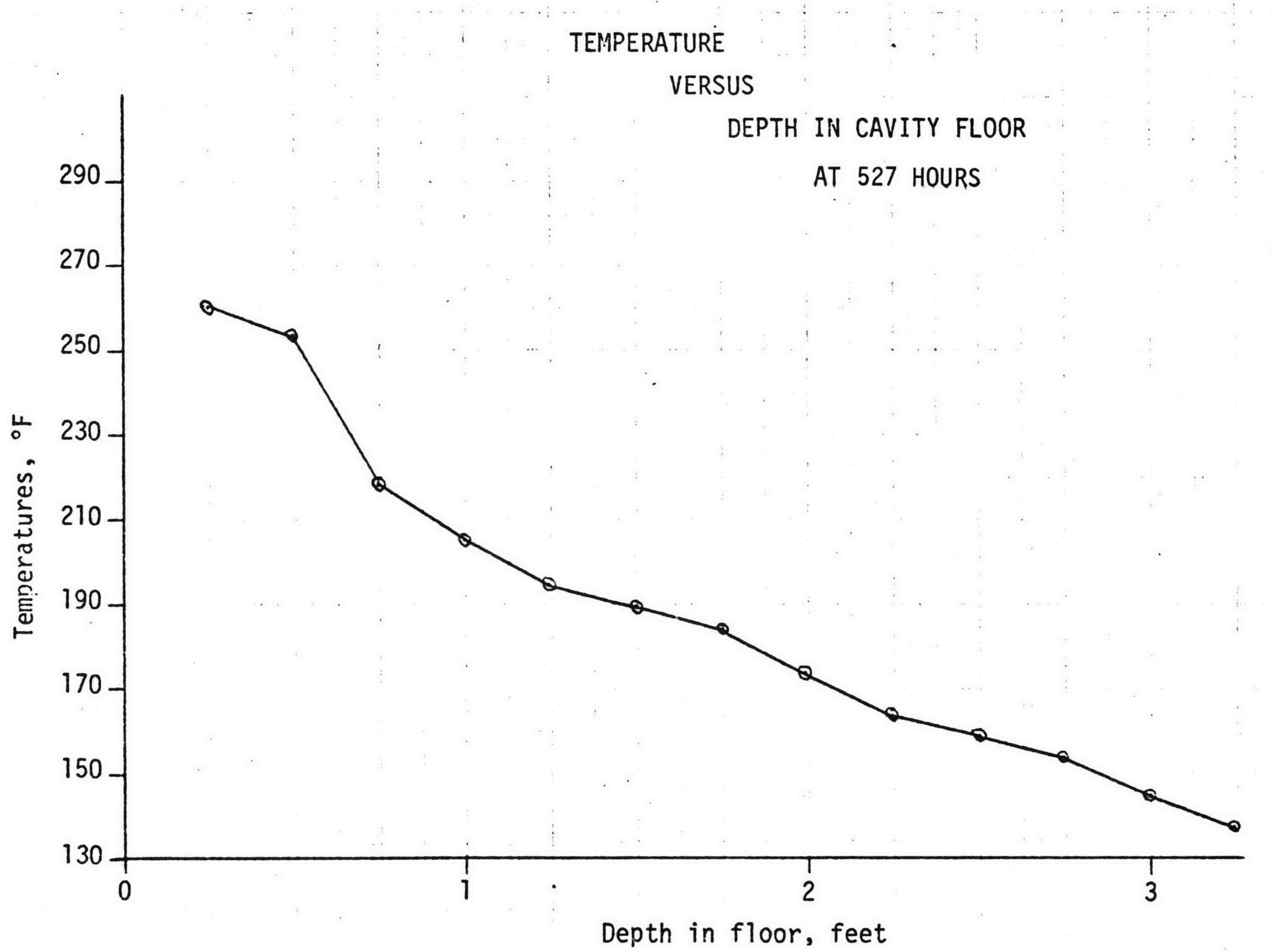


FIGURE C-4. Temperature vs Depth in Cavity Floor. (CACECO Case 654)

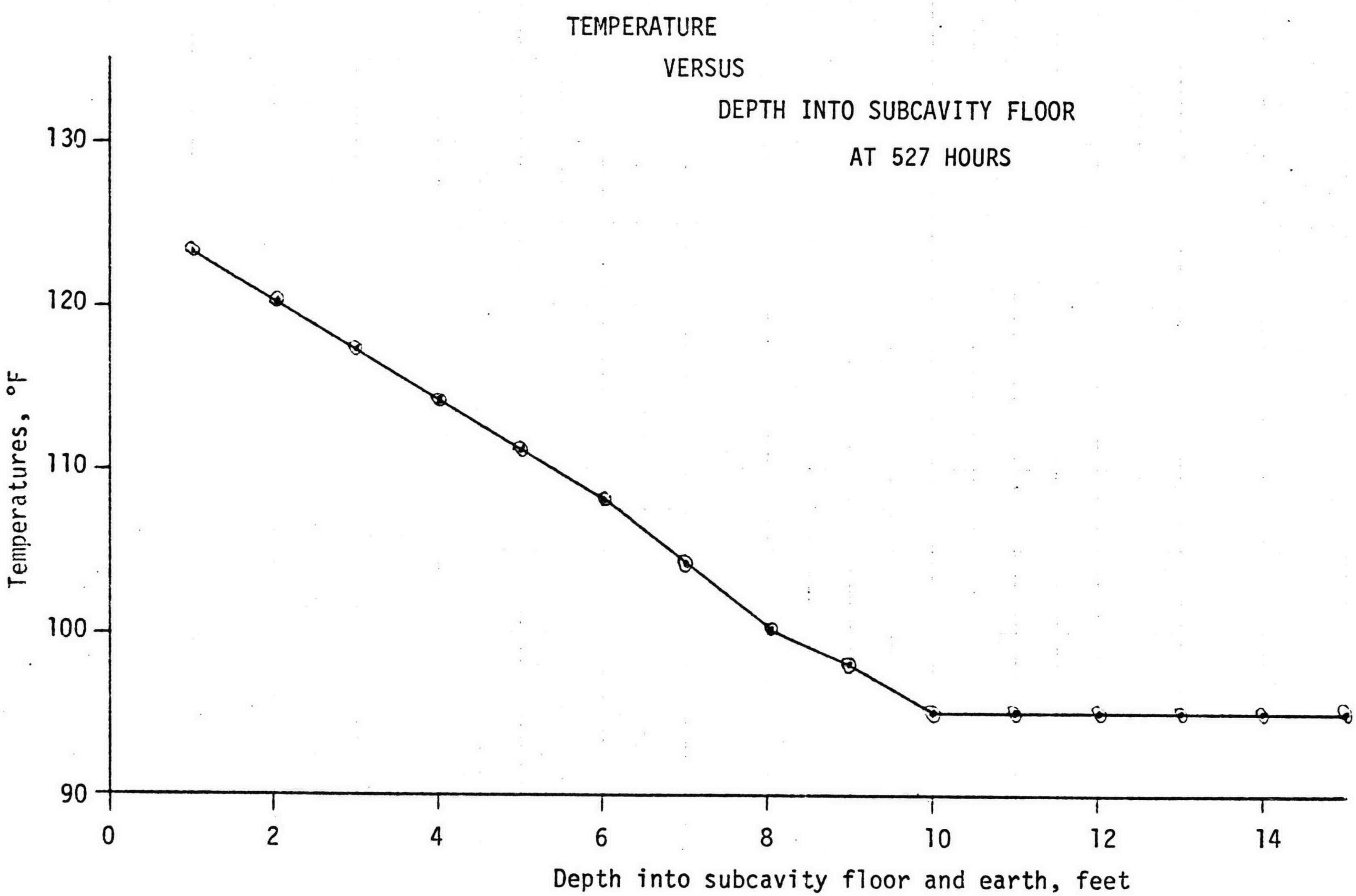


FIGURE C-5. Temperature vs Depth into Subcavity Floor. (CACECO Case 654)

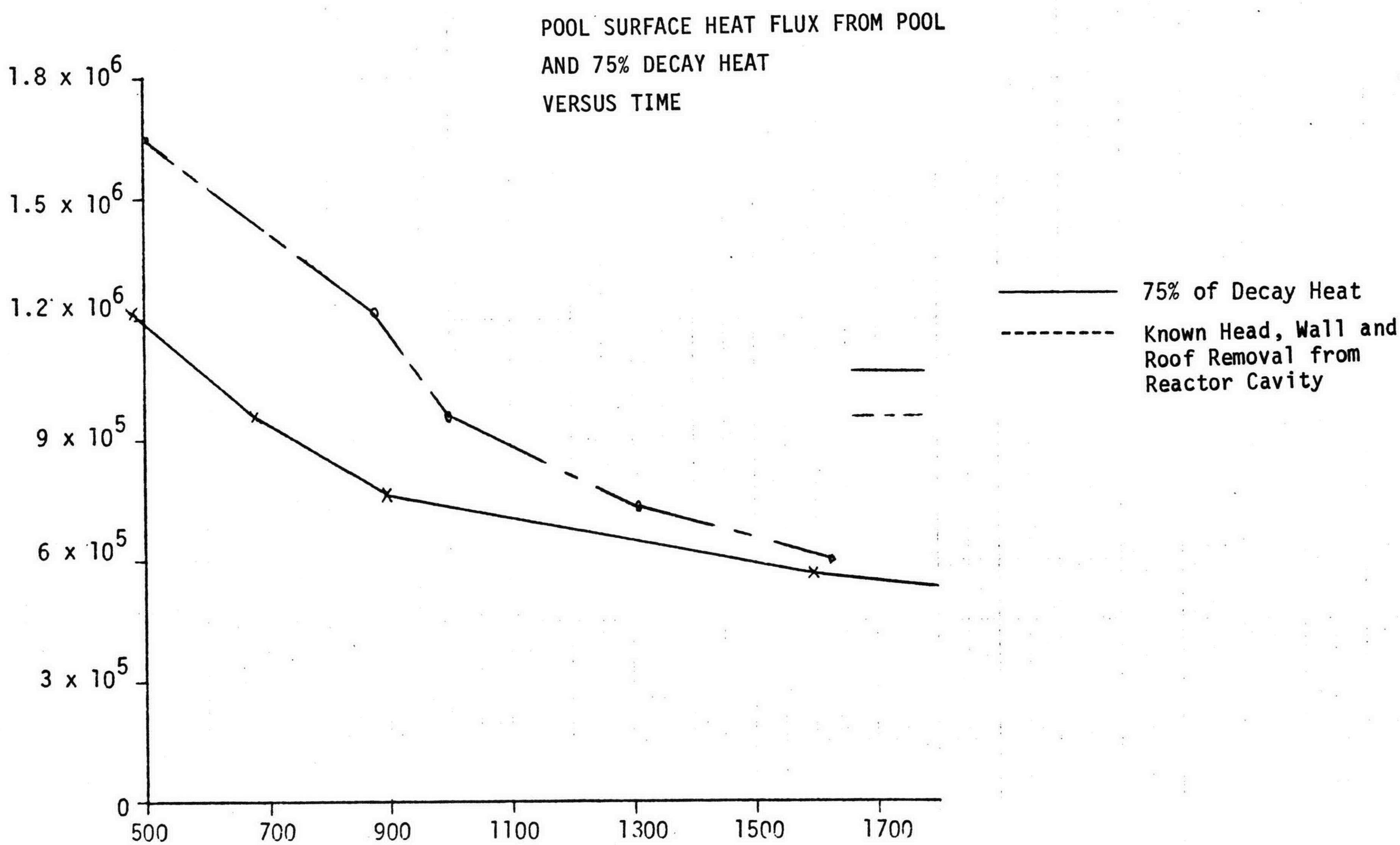


FIGURE C-6. Pool Surface Heat Flux and 75% Decay Heat vs Time After HCDA.

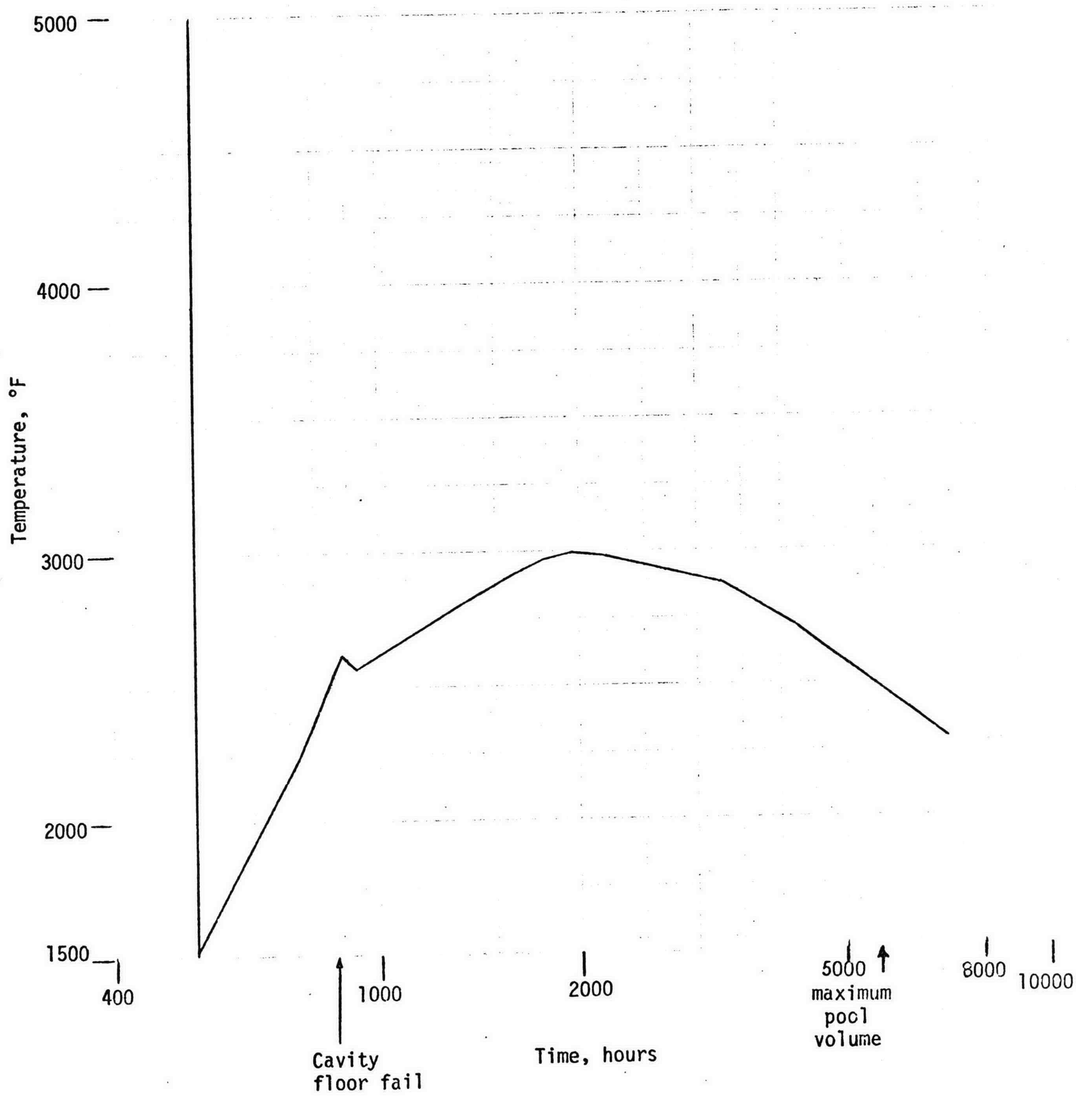


FIGURE C-7. Average Pool Temperature Versus Time (CACECO Case 654 Cont.)

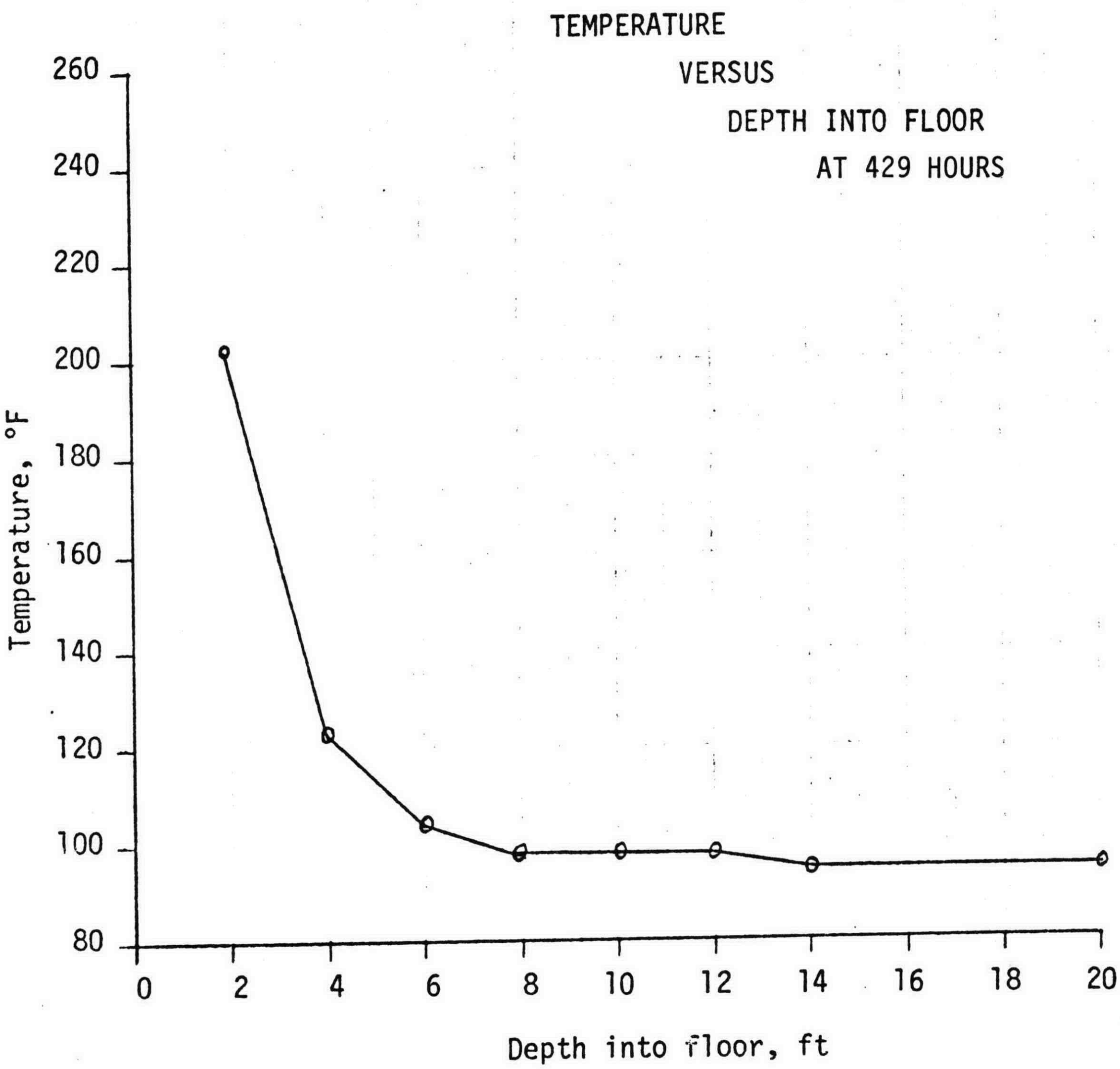


FIGURE C-8. Subcavity Floor Initial Temperatures. (Continuation of CACECO Case 683)

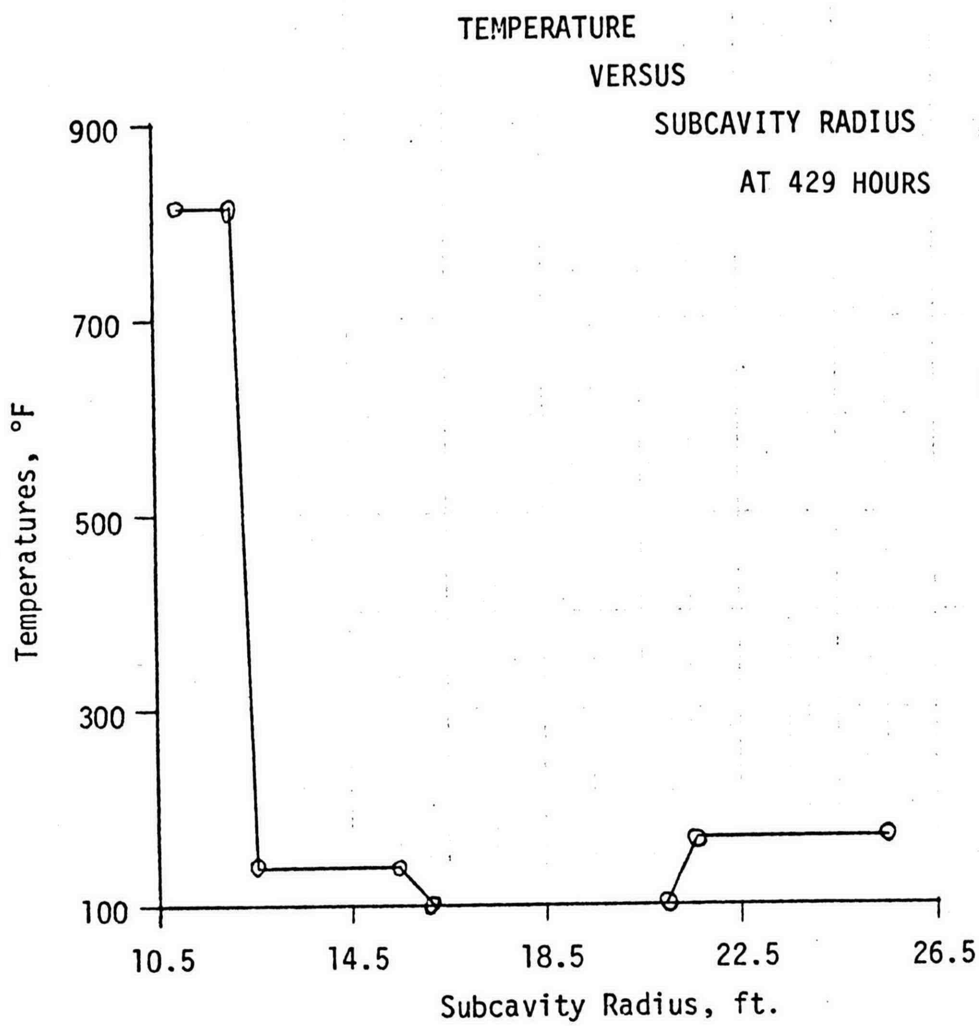


FIGURE C-9. Temperature vs Subcavity Radius. (Continuation of CACECO Case 683)

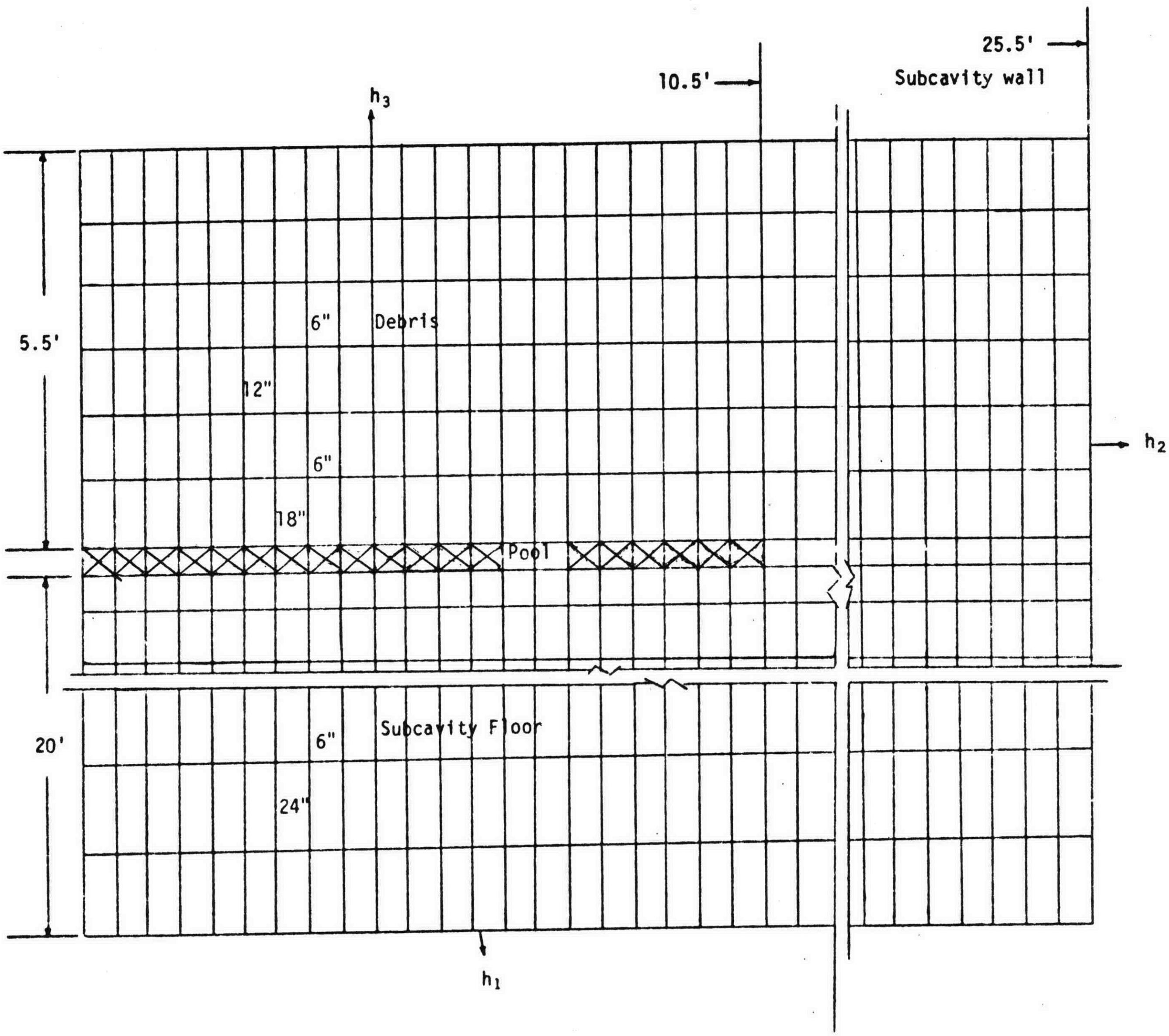


FIGURE C-10. Subcavity Floor Grid (Cont. of CACECO Case 683).

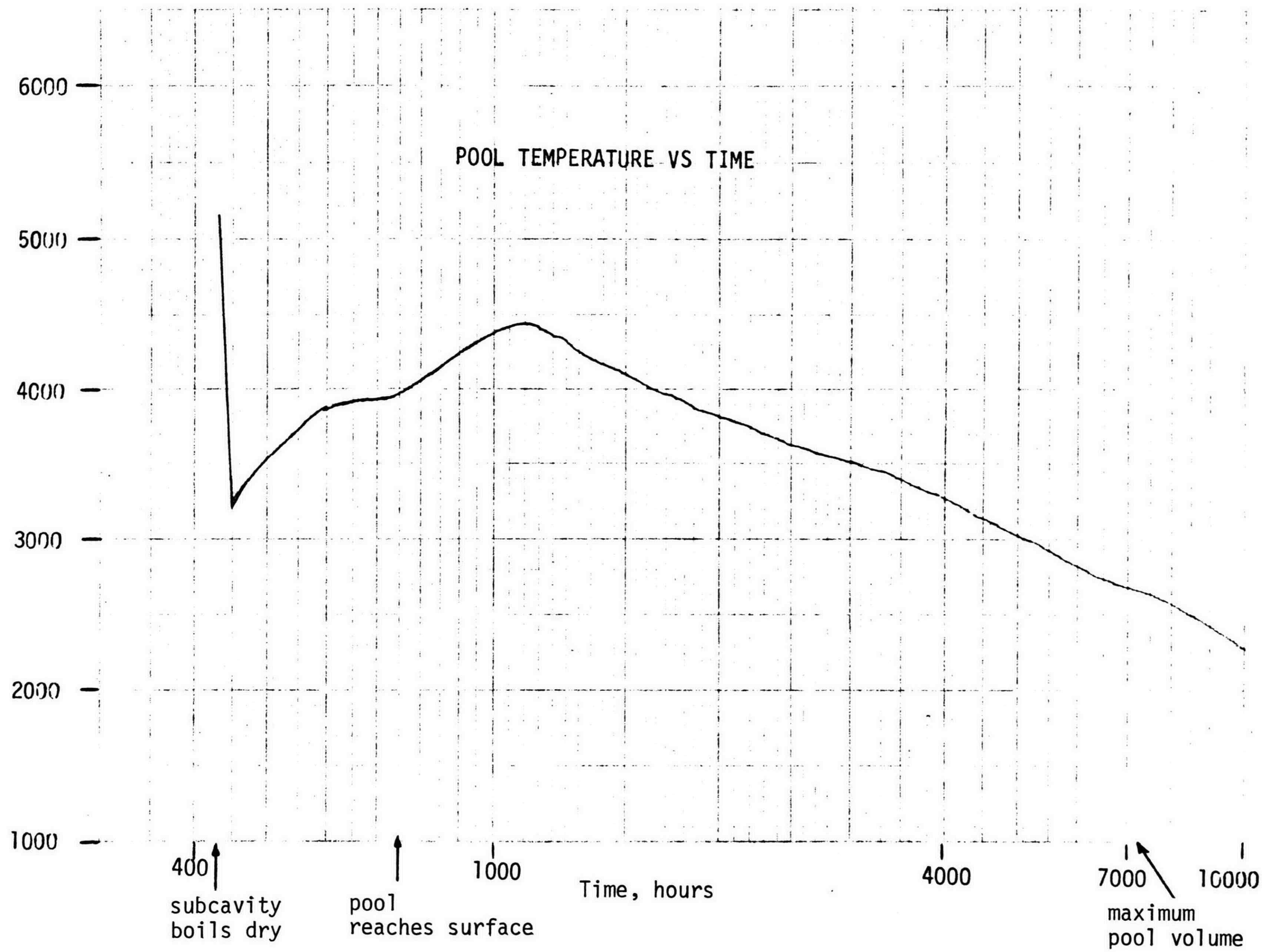


FIGURE C-11. Average Pool Temperature Versus Time (CACECO 683 Continuation).

APPENDIX D

FISSION PRODUCT AND RADIOACTIVE MATERIAL RELEASE AND TRANSPORT

This appendix presents the bases for the models and assumptions used in the study for the release of radioactive material into the containment atmosphere after the postulated initial release.

The radiological analyses were performed on the basis that the release of radioactive material contributing to offsite exposures, after the initial release, would be that due to volatile fission products evaporating or boiling off from sodium in the reactor vessel or cavity.

Consideration was also given to possible additional sources, in order to assess the validity of the conclusion that these volatile fission products would be of predominant significance. Two phases of the accident sequence were considered: sodium boilup and post-boilup.

D.1 Sodium Boilup Phase

D.1.1 Fission Product Release

The initial assumption for fission product release from sodium was that those elements with a boiling point as low as that of sodium, or with a likely chemical component with a boiling point as low as that of sodium, would be subject to release as volatile fission products. The elements so identified were arsenic, selenium, bromine, rubidium, cadmium, iodine and cesium. This selection was supported as a conservative one by ANL investigation[D-1] into the chemical form, location, and volatility of radioactive materials under potential LMFBR accident conditions. Table D-1 presents volatility data from the ANL study for the isotopes selected by ANL as having the greatest volatility. Strontium and barium are also included in the table to illustrate why they are not included among the volatile elements. ANL's study indicated that at a temperature far above that of boiling sodium (2500°K, 4040°F) only

TABLE D-1

VOLATILITY OF SELECTED FISSION PRODUCTS

DISTRIBUTION %*

ELEMENT	GROUP*	2500°K OXIDE	2500°K METAL	2500°K GAS	4000°K OXIDE	4000°K METAL	4000°K GAS
As	III	-0-	-0-	100.0	-0-	-0-	100.0
Se	III	-0-	76.3	23.7	-0-	25.6	74.4
Br	III	-0-	-0-	100.0	-0-	-0-	100.0
Rb	III	0.6	49.1	50.3	19.4	33.4	47.2
Sr	I	100.0	-0-	-0-	100.0	-0-	-0-
Ag	III	-0-	99.1	0.9	0.1	69.7	30.2
Cd	III	4.5	16.1	79.4	3.5	6.4	90.1
In	III	0.0	98.4	1.6	0.0	66.1	33.9
Sn	III	53.3	46.3	0.4	59.0	30.6	10.4
Sb	III	-0-	98.5	1.5	1.1	66.2	32.7
Te	III	-0-	87.9	12.1	6.3	55.3	38.4
I	III	-0-	-0-	100.0	-0-	-0-	100.0
Cs	III	0.5	49.9	49.6	11.8	38.7	49.5
Ba	I	100.0	-0-	-0-	99.9	-0-	0.1

* L. Baker, et al., Postaccident Heat Removal Technology, ANL/RAS 74-12, July 1974.

80 percent of the cadmium, half of the rubidium and cesium, and a quarter of the selenium would be in the gas phase at equilibrium. About one-eighth of the tellurium and about 1 percent of the silver, indium, tin, and antimony is in the gas phase at 2500°K; however, at sodium boiling temperature, only negligible amounts would be vapor.

In the present analysis, Castleman's predictions[D-2] of fission product release from sodium were utilized for calculating the release rate of rubidium, cesium, iodine (as sodium iodide), and bromine. The sodium boiloff rate was used as the release rate for arsenic, selenium, and cadmium.

Castleman concluded that the fraction of a fission product vaporized from sodium could be expressed as:

$$F = 1-(1-F_s)^{A\Psi}$$

where F = fraction of the fission product vaporized

F_s = fraction of the sodium vaporized

Ψ = ratio of the individual gas phase diffusivities - since Ψ is always less than unity, setting it at unity will provide the upper limit for fission product release

$A = ae^{(b/T)}$

and a and b are constants for the specific elements and T is the absolute temperature (°K).

Values for a and b are coefficients obtained from the Castleman study, and are shown in Table D-2.

TABLE D-2

CONSTANTS FOR CALCULATING THE EXTENT OF FISSION-PRODUCT VAPORIZATION AS A FUNCTION OF THE SODIUM VAPORIZED

Fission Product	Temperature Range, °K	Contents*	
		a	b
Cesium	700- 900	0.121	5,073
Rubidium	700- 900	0.213	4,184
Strontium	700-1000	5.41	-5,270
Iodine†	700-1100	0.37	-150
Barium	700-1100	1.73	-7,003
Tellurium	725-1100	2.81	-10,150
Antimony	1000-1100	2227	-21,989

* The constants a and b were evaluated by employing vapor-pressure data within the indicated temperature range but are not necessarily restricted to this range for practical use.

† Present as NaI.

As previously noted, tellurium and antimony were not included as dose contributors in the present study, because of their low volatility. Strontium and barium were not included because it was concluded in the ANL study[(D-1)] that they would exist in oxide chemical form which would be nonvolatile.

In the present study, the constants for cesium were used for both rubidium and cesium, and those for iodine were used for both iodine and bromine.

D.1.2 Plutonium Release During Boilup

Plutonium was considered to represent the most significant of non-volatile materials in terms of any possible impact on offsite exposures. Previous studies of dose contribution have suggested a radionuclide hazard rating concept to identify the most important species. Table D-3 presents a list of these major contributors. This table is abstracted from a recent

TABLE D-3

RADIOLOGICAL SIGNIFICANCE OF SELECTED NONVOLATILE ISOTOPES IN MOLTEN FUEL/STEEL POOL

Isotope	Hazard Ranking (Normalized to ^{241}Pu)
^{241}Pu	1.00
^{238}Pu	0.72
^{240}Pu	0.27
^{239}Pu	0.22
^{242}Cm	0.05
^{244}Cm	0.01
^{243}Cm	0.005
^{241}Am	0.04
^{144}Ce	0.02
^{141}Ce	0.001

study[(D-3)] based on the core inventory and radiological dose conversion factors (F-factors) which are functions of the radiological half-life, type of radiation emitted, and the biological affinity of each isotope.

The nuclides have been normalized to ^{241}Pu to indicate the importance on a relative scale. It may be seen that the plutonium isotopes account for about 94 percent of the total dose from the nonvolatile isotopes. Curium isotopes will contribute an additional 3 percent, ^{241}Am will contribute about 2 percent and the cerium isotopes will contribute about 1 percent. All other nonvolatile dose contributors will be negligible on these bases.

Because of its low volatility and its probable physical form as a bed of coarse particulates on surfaces within the sodium pool, there is little potential for the release of a significant plutonium quantity in a form which could be transported through the containment atmosphere and released from the building. To further support this judgment, possible plutonium release by carryover has been considered.

Recent studies by Jordan and Ozawa[D-4] were applied in estimating the possible magnitude of plutonium release which might occur as a result of physical entrainment and sodium/plutonium carryover.

The Jordan and Ozawa studies measured the release of various quantities of uranium dioxide powder (20μ median diameter) which was suspended in about 100 g of sodium and the mixture heated to 500-to-900°C. The sodium and fuel which was carried over was transported through a heated pipe to a cold trap and filter arrangement where the sodium was condensed, and the uranium content was measured. The results of these experiments were expressed in terms of a decontamination factor, or the ratio of fuel material in the sodium to fuel material carried over. Decontamination factors of 1 to 5×10^3 were reported and found to be insensitive to sodium evaporation rates between 0.3 kg/m^2-hr and 85 kg/m^2-hr.

The more conservative decontamination factor of 1×10^3 from these experiments was applied to estimate the possible carryover of plutonium during the sodium boiloff period.

Quantitative calculations were performed to assess the possible significance of plutonium release under the conditions of two accident sequence cases analyzed in the present study.

Case 658 was selected to evaluate the in-vessel case. This case not only has the highest sodium boiloff rate but also a concurrent volume vent rate that is significantly larger than any in the other cases.

Case 683 was selected to represent the ex-vessel cases. The bases for this selection were similar to those for Case 658.

It was assumed that, in either case, approximately 5 percent of the core might be in sufficiently finely divided form for potential carryover. The conservative value of the experimental decontamination factors, 1×10^3, was then applied, in conjunction with the sodium boiloff rate as calculated by CACECO. On this basis it was calculated that the peak release rate of PuO_2 from the reactor vessel for Case 658 would be about 2.1 g per hour. The peak rate for the ex-vessel case (Case 683) would be about 0.88 g of PuO_2 per hour.

The release values for these cases were applied as plutonium source terms to COMRADEX calculations of offsite doses, using radionuclide fallout and leakage values which were calculated in previous runs for these accident sequences. The results were minor increases in calculated bone doses. The additional bone dose in Case 658 was about 0.44 rem, or roughly 26 percent of the bone dose calculated as a result of the initial expulsion. For Case 683, the bone dose increase was 0.22 rem, or about 10 percent of the initial amount. Since these contributions to the bone dose are small, and the bone dose is already insignificant compared to the thyroid dose contribution, the conclusion is supported that plutonium release during sodium boilup is not of importance.

D.2 Post-Sodium Boilup Phase

The radiological analyses in this study did not include the effect of any radioactivity release in the containment building after the sodium boiled dry. This was based on the judgment that no additional radioactive materials would be volatilized or released in sufficient quantity to be predominant in assessing offsite doses.

D.2.1 Fission Product Release

Of the cases studied, the earliest time at which sodium boil-dry occurred was 430 hours, in Case 683. From this point on, the temperature of the fuel-steel-concrete pool increases until it reaches a maximum of about 4400°F (2427°C) at about 1,050 hours. Following this peak, the temperature of the pool begins to decrease. Thus, it is conservative to consider the possible release of fission products remaining in the molten fuel-concrete mixture at the maximum temperature calculated.

As fuel temperature increased above the sodium boiling point, the potential volatilization of additional fission products would increase. The greatest potential would be for the remaining elements of the group identified by ANL[D-1] as volatile; specifically, tellurium, indium, antimony, silver, and tin. None of these materials would boil, and evaporation would be slow, as indicated by the small vapor fractions at 2500°K. The radioactive inventories of isotopes of these elements remaining at 430 hours, and the F-factors for each are listed in Table D-4.

The most volatile of the remaining fission products, and that with the largest remaining inventory among the more volatile materials, is tellurium. The tellurium inventory is an order of magnitude lower than the quantity of other elements already released, such as iodine. Therefore, it is concluded that additional release of volatile fission products is not of major importance.

D.2.2 Plutonium Release

There is a possibility that release of plutonium from a concrete-fuel-steel mixture could occur during the post-boilup phase by gas sparging. The gas source is water vapor released from concrete below the pool.

Because of the vertical depth of the reactor cavity from which fuel particles would have to escape, it seems unlikely that significant concentrations could be sparged from the pool into the containment building. However, the technique of Parsly and Fontana[D-5] was applied as an assessment of the potential order of magnitude of such an effect.

TABLE D-4

INVENTORY AND DOSE CONVERSION FACTORS OF LESS VOLATILE ELEMENTS (430 hours)

Isotope	Activity In Core At 480 Hrs (curies)	Critical Organ	"F" Value (REM/Ci Inhaled)
Ag 111	1.7×10^5	Lung	3.3×10^4
In *115	5.0×10^2	Lung	6.5×10^2
Sn 123	9.2×10^4	Lung	3.1×10^5
Sn 125	7.7×10^4	Lung	9.7×10^4
Sb 125	7.0×10^4	Lung	2.3×10^4
Sb 127	4.2×10^4	Lung	3.1×10^4
Te *125	1.2×10^4	Lung	5.6×10^4
Te *127	1.5×10^5	Lung	1.8×10^5
Te 127	1.5×10^5	Lung	1.5×10^3
Te *129	6.7×10^5	Lung	2.3×10^5
Te 129	4.3×10^5	Lung	6.3×10^2
Te 132	2.3×10^5	Lung	4.4×10^4

Their calculations assumed that the gas resulted from concrete heating and decomposition. Distribution coefficients for fission products and fuel were calculated by Parsly and Fontana from the data of Gabelnick and Chasanov[D-6] and a differential material balance was written as:

$$c = c_o \exp\left(-\frac{H\ V_G}{V_L}\right),$$

where

c = final concentration

c_o = initial concentration

H = distribution coefficient = concentration in gas/concentration in liquid

V_G = volume of gas which has bubbled through the melt

V_L = volume of melt.

Thus, the fraction retained is

$$\frac{c}{c_o} = \exp\left(-\frac{H\ V_G}{V_L}\right)$$

and the fraction removed is

$$\frac{c_o - c}{c_o} = 1 - \exp\left(-\frac{H\ V_G}{V_L}\right)$$

Parsly and Fontana calculated a distribution coefficient, H, of 2.64×10^{-7} for plutonium.

The volume of heated concrete which would contribute vapor was estimated to be about 29,000 ft^3, and the water vapor from this amount of concrete which would contribute to the sparging was estimated to be about 1.6×10^7 ft^3 of steam. This quantity of water vapor was assumed to pass through the molten concrete-fuel pool whose volume was 8,150 ft^3. Substituting these values into the Parsly and Fontana expression, a release fraction of 5×10^{-4} was obtained.

This represents an average PuO_2 release rate of 0.06 g/hr from the pool to the reactor cavity atmosphere over the 5,700 hour period in which concrete penetration took place.

This release rate is at least an order of magnitude less than that evaluated for the boilup phase in paragraph D.1.2 above. Also, it seems unlikely that a major fraction of any plutonium would be transported out of the reactor cavity and leaked from the containment building.

Considering these factors and the long time after the postulated accident at which the post-boilup phase could be applicable, it is concluded that post-boilup plutonium release is not predominant in assessing post-accident off-site radiological consequences.

References

D-1 L. Baker, et al., Post Accident Heat Removal Technology, ANL/RAS 74-12 (July 1974).

D-2 A. W. Castleman, "LMFBR Safety, I. Fission-Product Behavior in Sodium," Nuclear Safety, Vol. 11, No. 5, Sept.-Oct. 1970.

D-3 Radiological Assessment Models LMFBR Program, Sixth Quarterly Report (December, 1975 - February, 1976), GEAP-14034-6.

D-4 S. Jordan and Y. Ozawa, "Fuel Particle and Fission Product Release from LMFBR Core Catcher, Kernforschungszentrum, Karlsruhe Laboratorium für Aerosolphysik und Filtertechnik", ANS/ENS, Conference on Fast Reactor Safety and Related Physics, Chicago, October 1976.

D-5 L. F. Parsly, Jr., and M. H. Fontana, Estimations of Fission Product Release from Melt During Concrete Penetration, Appendix G to Reactor Safety Study, WASH-1400, October 1975.

D-6 S. D. Gabelnick and M. G. Chasanov, A Calculational Approach to the Estimation of Fuel and Fission Product Vapor Pressures and Oxidation States to 6000°K, ANL-7867, October 1972.

APPENDIX E

STRUCTURAL ANALYSIS

1.0 INTRODUCTION

1.1 Scope

This appendix predicts the time to failure for various sections and components in the FFTF containment building reactor cavity under the most severe Post Accident Heat Removal (PAHR) conditions following a Hypothetical Core Disruptive Accident (HCDA). These estimated times to failure then serve as input to more extensive calculations of the total effects of the various postulated PAHR sequences of events.

1.2 General Design Criteria and Description

The major structural components that comprise the FFTF reactor cavity and the structures contained within the cavity are made of reinforced concrete and steel. The loadings due to PAHR conditions are dead weight and thermal stresses from elevated temperatures. The steel structures are considered to fail when the calculated stress exceeds the ultimate strength at temperature or when the creep damage fraction, $\Sigma({}^{t}i/{}^{T}d)$, reaches a value of 1.0. Where the failure of a reinforced concrete (R/C) element is identifiably due to tension failure in the reinforcement, e.g., hoop tension in the circular cavity wall, the time to failure is determined as for steel structures. For other loading conditions and elastic analysis, failure is assumed to occur when the calculated stresses are equal to a fraction of the yield strength of the reinforcing steel at temperature, or of the ultimate compressive strength of the concrete at temperature. For ultimate strength analysis, failure is assumed to occur when a fraction of the load capacity, based upon the yield strength of the rebar and the ultimate compressive strength of the concrete at temperature, is equal to the applied load. The "fraction" referred to above is intended to account for long-term loading effects and is taken as 0.85 maximum for both types of analyses.

The reactor cavity is a circular cylindrical pit with an R/C wall, a steel cover plate (the reactor head), and an R/C floor slab. The inside diameter is approximately 36 feet and the height approximately 48 feet. The stainless steel reactor vessel is suspended from an R/C ledge built integrally with the wall at the top and is inside a stainless steel guard vessel which rests on the floor of the cavity. The reactor cavity shield (shield collar), another major structure, is a series of wedge-shaped concrete blocks forming a circular ring between the guard vessel and the cavity wall near the top of the reactor vessel. These blocks are supported on steel beams cantilevered from the wall. All concrete surfaces interior to the cavity, including all sides of the reactor shield blocks, are lined with structural grade steel plates. These liner plates are vented by a system of steel tubes to prevent development of high pressures behind the liners due to formation of steam from the water in the concrete and the high temperatures following a hypothesized sodium spill. Figure E-1 shows a cross section of the reactor cavity, indicating the primary structural elements.

2.0 SUMMARY OF RESULTS AND DISCUSSION

2.1 Summary of Results

The calculated times to failure for the appropriate loading conditions are given in the table below. The critical loading conditions are sodium boiloff from the reactor vessel, a creep rupture failure of the reactor vessel support arms at 384 hours after the HCDA, and a sodium spill from the reactor vessel into the reactor cavity 3 hours after the HCDA. The time to failure listed is the time, in hours, after the HCDA.

Item	Load Condition	Calculated Time To Failure, hrs
Reactor Vessel Head	Sodium Boiloff	8000
Reactor Vessel Support Arms	Sodium Boiloff	380-390
	3 Hr Sodium Spill	9800
Reactor Support Ledge	3 Hr Sodium Spill	1000 (3)
Reactor Cavity Wall	3 Hr Sodium Spill	10,000
Reactor Cavity Floor Slab	3 Hr Sodium Spill	> 1000
	Reactor Vessel Drop at T = 384 Hr	600 (1)
Reactor Cavity Shield	3 Hr Sodium Spill	(2)

(1) Failure is defined as cracking of the concrete, allowing liquid sodium to leak into the subcavity. It is assumed that the floor slab liner has been ruptured.

(2) The reactor cavity shield cannot fall to the bottom of the reactor cavity because of geometric interferences.

(3) For the sodium boiloff case, the load on the support ledge is reduced at 390 hrs by an amount equal to the weight of the vessel and its contents. This load reduction is estimated to extend ledge failure time to about 1,500 hours.

The reactor guard vessel is omitted from the above listing because there are no significant loads on it. The main support structure is omitted because a cursory analysis showed it to be much less critical than any of the other elements.

2.2 Discussion

The calculations for the steel structures are relatively straightforward because of the well defined mechanical properties and the relatively simple loading conditions. The loading conditions for the reinforced concrete structural elements are also relatively simple, however, the behavior of the bimaterial composite and the mechanical properties of the concrete are not so well defined for the elevated temperatures under consideration (in the order of 1000°F). An attempt has been made to maintain conservative approaches in the analysis and in the determination of the proper material properties to account for the uncertainties involved. These conservatisms include ignoring the high room temperature strengths of the poured concrete over the specified minimum. It would be desirable, though, to have more high-temperature data, particularly for the ordinary concrete in the cavity floor slab.

Reactor Vessel Head and Reactor Vessel Support Arms

These two steel structures fall under the "relatively straightforward" category. The time to failure for the support arms, loaded in direct tension, defines one of the critical load conditions. The times to failure are determined from the accumulated creep damage.

Reactor Support Ledge

The analysis of the reactor support for the PAHR conditions follows the procedures for the earlier analysis, by others, for the HCDA conditions. The critical section is then one where diagonal tension governs the ultimate load capacity. The time to failure is determined from the accumulated creep damage, assuming that only the reinforcing steel is resisting the applied loads.

Reactor Cavity Wall

The critical loading for the reactor cavity wall is a hydrostatic pressure from the liquid sodium pool in the cavity following the hypothesized spill at 3 hours after HCDA. This load is resisted by the hoop reinforcement in the wall and time to failure is estimated based upon accumulated creep damage.

Reactor Cavity Floor Slab

Failure of the reactor cavity floor slab is defined as cracking of the concrete, allowing liquid sodium to enter the subcavity; it is assumed that the steel liner plate is ruptured. The critical section for the slab is a near-vertical shear crack at the support ledge. The time to failure is calculated from a factored ultimate load capacity.

Reactor Cavity Shield

The reactor cavity shield is prevented from falling to the bottom of the cavity during the critical 3-hour spill condition because of geometrical interferences between the individual wedges. The capacity of the supporting system to support the loads accompanying this binding of the blocks has been checked and found to be adequate.

3.0 SYSTEM DESCRIPTION AND BASIS OF DESIGN

3.1 Applicable Documents

The basic document describing the PAHR events initially used for this report is listed below. The information given in the document has been supplemented and updated with more recent, but as yet unpublished, CACECO computer analyses. Where such data is used in the structural analyses in this report, it is reproduced and referenced by the CACECO case number.

> Analyses of FFTF Postulated Failure of In-Vessel Post-Accident Heat Removal, HEDL-TI-76028, Hanford Engineering Development Laboratory, June 1976.

3.2 General Description

The FFTF reactor cavity is essentially a circular reinforced concrete pit containing the FFTF reactor and located in the center of the reactor containment building. The inside diameter of the pit is 36 feet, except near the bottom where the diameter is 32 feet, and the walls are a minimum of 4 feet thick. The height of the cavity is approximately 48 feet, top of floor slab to top of reactor head. The reinforced concrete floor slab is 3.25 feet deep and covers a circular subcavity 21 feet in diameter. An inward projecting rim, or ledge, at the top of the reactor cavity wall supports the main support structure, a heavy "Z" shaped steel ring, which in turn supports the steel reactor head and reactor vessel. The cavity wall and support ledge are reinforced magnetite concrete. The cavity floor slab is reinforced ordinary concrete.

The structural analyses in this report cover the main structural elements contained within the cavity as well as the cavity itself. These additional items are the reactor vessel and the reactor cavity shield. The reactor vessel is suspended from a number of support arms built integrally with the vessel. The reactor vessel contains the reactor internals and approximately 600,000 pounds of liquid sodium. The reactor guard vessel, which stands on the floor of the cavity, surrounds the reactor vessel, but provides no support to the vessel and is not considered a major structural element. The reactor cavity shield is a series of wedge-shaped concrete blocks forming a circular ring just under the support ledge. These blocks are supported on steel beams cantilevered from the cavity wall. The reactor cavity shield blocks are ordinary concrete, unreinforced.

All concrete surfaces interior to the cavity, including all sides of the reactor shield blocks, are lined with steel plate. These liners form a continuous sealed surface. The liners are vented through a system of steel tubes to prevent development of high pressure behind the liners due to the formation of steam from the water in the concrete and the high temperatures following a sodium spill. The analysis of the liners is covered in another report.

3.3 Design Criteria

The loadings due to the PAHR conditions are deadweight and thermal stresses from elevated temperatures. The object of the analyses in this report is to estimate the times to failure of the major structural components in the FFTF reactor cavity.

The steel structures are considered to fail when the calculated maximum direct stress exceeds the ultimate strength at temperature or when the creep damage fraction, $\Sigma({}^{t}i/{}^{T}d)$, reaches a value of 1.0. The materials properties data for the steels used are taken from Section III of the ASME BPVC (Code Case 1592-4), from the LMFBR Materials Handbook, and from HEDL internal memos. These data are referenced in the analyses where used.

Where the failure of an R/C element is the tension failure of the reinforcement, e.g., hoop tension in the circular cavity wall, the time to failure is determined as for steel structures. For other loading conditions and elastic analysis, failure is assumed to occur when the calculated stresses are equal to a fraction of the yield strength of the reinforcing steel at temperature or of the ultimate strength of the concrete at temperature. For ultimate strength analysis, failure is assumed to occur when a fraction of the load capacity, based upon the yield strength of the rebar and the ultimate strength of the concrete at temperature, is equal to the applied load. The "fraction" referred to is intended to account for long-term loading and is taken as 0.85, maximum, for both types of analysis. The mechanical properties of the reinforcing steel are taken from HEDL internal memos. The mechanical properties for the magnetite and ordinary concrete are based upon the specified minimum ultimate compressive strength. Ultimate strength and modulus of elasticity with temperature are based upon published data and some HEDL testing. It is assumed that the room temperature relationship between shear strength and compressive strength given in the ACI Building Code holds at elevated temperatures.

3.4 Design Loads

The design loads are the deadweight loads and the thermal gradients accompanying the various PAHR conditions. The three critical conditions for these analyses are as follows:

(1) Sodium boiloff from the reactor vessel.

(2) A creep rupture of the reactor vessel support arms at 384 hours after the HCDA which follows from (1) above and which results in the liquid sodium remaining in the vessel at that time to spill into the reactor cavity.

(3) A postulated rupture of the reactor vessel at 3 hours after the HCDA which spills 619 thousand pounds of liquid sodium into the reactor cavity.

It is postulated for cases (2) and (3) above and for the analysis of the reactor cavity floor slab that the liner plate on the slab is ruptured. The result is a flow of sodium under the liner and direct contact between the liquid sodium and the concrete structure. The result of the reaction between the sodium and the concrete is taken to be limited to a two-inch penetration, i.e., the top two inches of the slab are considered ineffective in carrying the applied loads.

3.5 Stress and Strain Limits

3.5.1 Steel

The steels used in the reactor cavity structures are listed below along with the corresponding room temperature yield and ultimate strength.

Steel	Structure	U.S. (KSI)	U.S. (KSI)
ASTM A36	Plate and Structural Shapes	36	58
ASTM A615, Gr 60	Reinforcing Bars	60	90
SA-508, Cl 2	Reactor Head	50	80
304 S. S.	Reactor Vessel	30	70

The time- and temperature-dependent properties are given and referenced where used in the analyses.

3.5.2 Concrete

Two types of concrete are used in the reactor cavity. A magnetite aggregate concrete is used in the cavity wall including the support ledge. Concrete using "ordinary" aggregate is used in the floor slab and in the reactor cavity shield. The unit weights of these concretes are 220 pcf and 150 pcf, respectively. The room temperature ultimate compressive strength for both types of concrete is taken as 5,000 psi, the specified minimum strength. The actual strengths are higher than this value. Reference 15 indicates 90-day compressive strengths for the magnetite concrete as high as 9,210 psi.

A literature search was made to determine the high-temperature properties of concrete. The results show that the data obtained from different tests by different investigators vary widely. Some of these data are summarized on Figures E-2 and E-3 which show the curves for the variation of ultimate strength and modulus of elasticity used in the analyses. These curves were developed by plotting through the points of Reference E-1 and then compressing these curves along the temperature axes to approach a lower bound for the other data and, for the variation of ultimate strength, to pass through the minimum data point for magnetite concrete from the HEDL tests described in Appendix B of reference E-2. The single data point for ordinary concrete, based on a single specimen from the HEDL tests, is somewhat questionable because the specimen was severely cracked before testing. More testing of the particular concrete used in the FFTF application would be helpful.

A few qualitative conclusions were determined from the literature search, which is described more fully in Appendix A of reference E-2. These are as follows:

(1) The proportion of the original strength of the concrete which is retained at an elevated temperature is increased if the concrete is loaded in compression during testing.

(2) The proportion of the original strength of the concrete which is retained after the concrete is raised to a higher temperature is greater at the elevated temperature than after cooling.

(3) The same is true for the modulus of elasticity.

(4) A long-term soak at elevated temperatures may cause further deterioration in the strength of the concrete from that associated with the initial rise in temperature.

The concrete in the FFTF reactor cavity will be stressed in compression during heating and, during the critical time period, the loads are applied while the concrete is hot. These two beneficial effects, items (1), (2), and (3), above, are not considered in the analyses. The detrimental effect of item (4), above, is considered in the analyses by application of a strength reduction factor equal to or less than 0.85, based on the information in References E-3 and E-4.

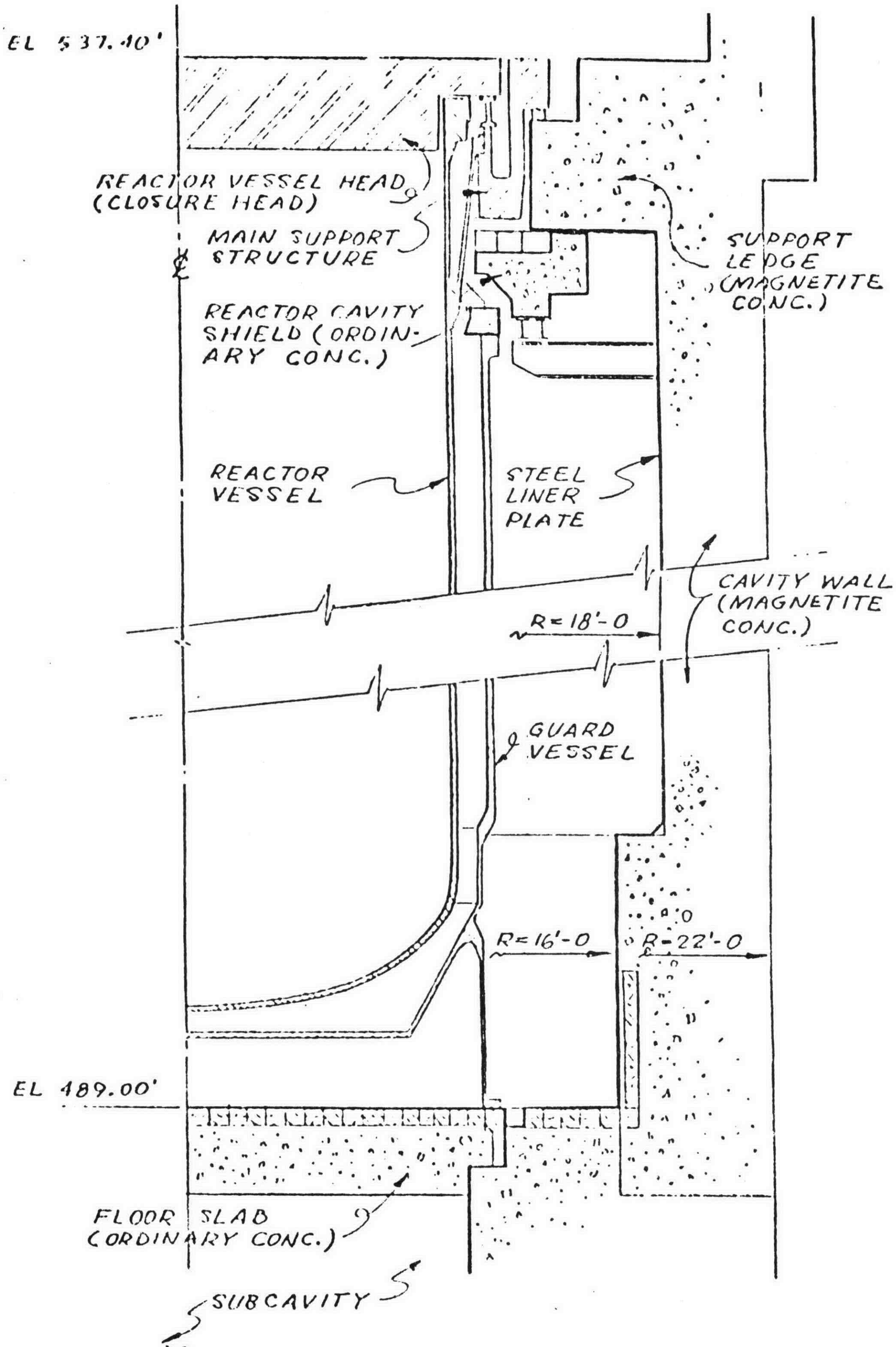


FIGURE E-1. Reactor Cavity.

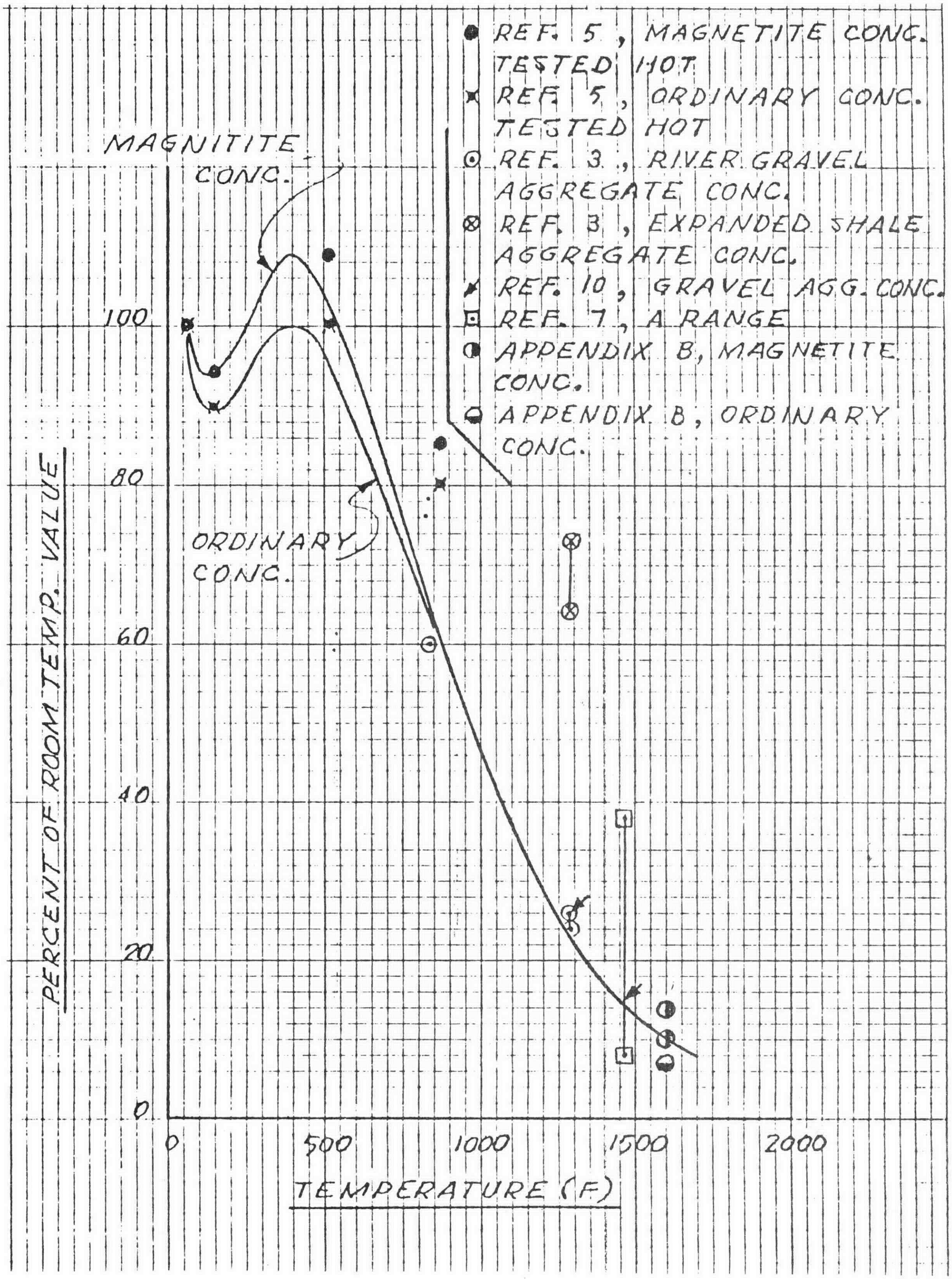


FIGURE E-2. Variation of Ultimate Strength of Concrete with Temperature.

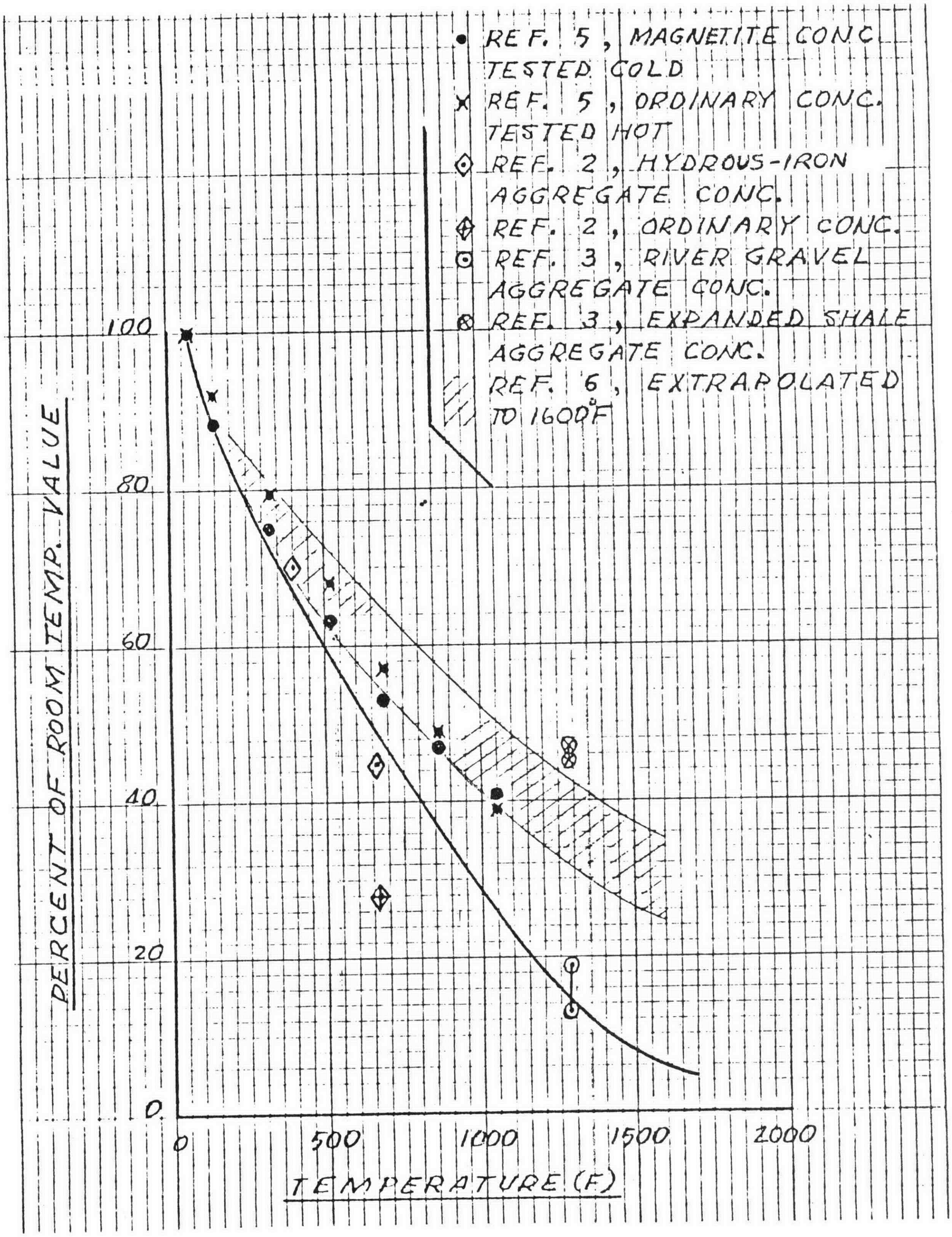


FIGURE E-3. Variation of Modulus of Elasticity of Concrete with Temperature.

4.0 REFERENCES

E-1 Ohgishi, S., S. Miyasaha, and J. Chida, "On Properties of Magnetite and Serpentine Concrete at Elevated Temperatures for Nuclear Reactor Shielding," Paper No. SP 34-57, Special Publication SP-34, American Concrete Institute, Detroit, 1972.

E-2 A. O. Rock & L. M. Polentz, Structural Analysis of FFTF Reactor Cavity for Post Accident Heat Removal Conditions, HEDL-TC-801, March 1977.

E-3 D. Linse, "Strength of Concrete Under Biaxial Sustained Load," Paper No. SP 34-17, Special Publications SP-34, American Concrete Institute, Detroit, 1972.

E-4 Stockl, S., "Strength of Concrete Under Uniaxial Sustained Loading," Paper No. SP-34-16, Ibid.

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