Westinghouse Electric Corporation
Water Reactor Divisions
Nuclear Technology Division
Box 355
Pittsburgh Pennsylvania 15230

March 31, 1982
AW-82-21

Mr. James R. Miller, Chief
Standardization & Special
Projects Branch
Division of Licensing
U. S. Nuclear Regulatory Commission
7920 Norfolk Avenue
Bethesda, Maryland 20014

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: Response to Questions on WCAP-9561, "Bart-Al: A Computer Code for the Best Estimate Analysis of Reflood Transients" (Proprietary)

REF: Westinghouse Letter No. NS-EPR-2574, Rahe to Miller, dated March 31, 1982

Dear Mr. Miller:

The proprietary material being transmitted by the referenced letter supplements the proprietary material previously submitted as WCAP-9561 in January 1980. Further, the affidavit submitted to justify the material previously submitted, AW-77-18, was approved by the Commission on October 28, 1977, and is equally applicable to this material.

Accordingly, withholding the subject information from public disclosure is requested in accordance with our previously submitted affidavit and application for withholding, AW-77-18, dated April 6, 1977, a copy of which is attached. The proprietary affidavit which accompanied the approved material and was submitted to the Commission April 6, 1977 is not attached hereto.

Correspondence with respect to the proprietary aspects of this application should reference AW-82-21 and should be addressed to the undersigned.

Very truly yours,

Robert A. Wiesemann

/bek
Attachment

Robert A. Wiesemann, Manager
Regulatory & Legislative Affairs

cc: E. C. Shomaker, Esq.
Office of the Executive Legal Director, NRC

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Robert A. Wiesemann, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Corporation ("Westinghouse") and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

Robert A. Wiesemann, Manager
Licensing Programs

Sworn to and subscribed
before me this 20 day
of April 1977.

Notary Public

(1) I am Manager, Licensing Programs, in the Pressurized Water Reactor Systems Division, of Westinghouse Electric Corporation and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing or rule-making proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Water Reactor Divisions.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.790 of the Commission's regulations and in conjunction with the Westinghouse application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse Nuclear Energy Systems in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

(g) It is not the property of Westinghouse, but must be treated as proprietary by Westinghouse according to agreements with the owner.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition in those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information is not available in public sources to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is attached to Westinghouse Letter Number NS-CE-1403, Eicheldinger to Stolz, dated April 6, 1977. The letter and attachment are being submitted in support of the Westinghouse emergency core cooling system evaluation model.

Public disclosure of the information sought to be withheld is likely to cause substantial harm to the competitive position of Westinghouse, taking into account the value of the information to Westinghouse, the amount of effort and money expended by Westinghouse in developing the information, and considering the ways in which the information could be acquired or duplicated by others.

Further the deponent sayeth not.

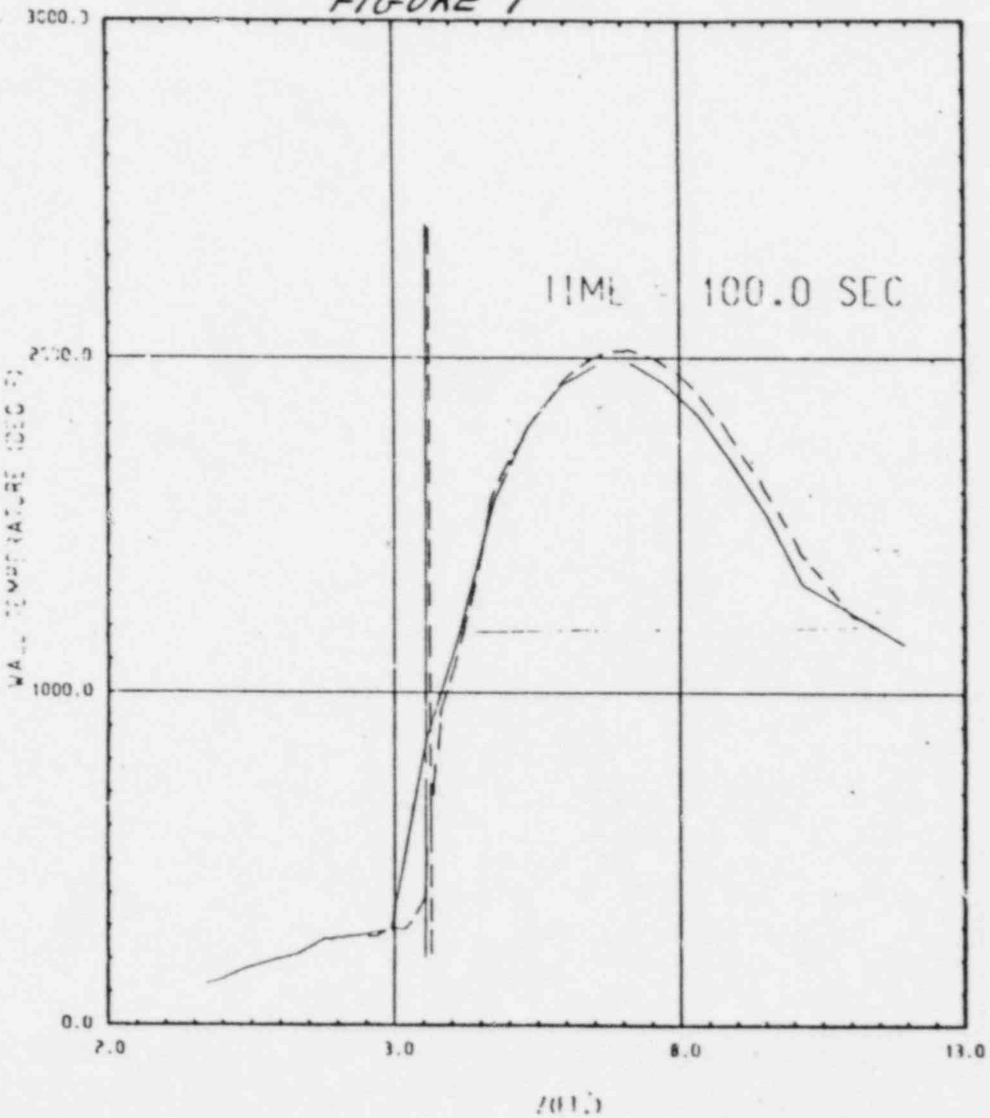
SECTION 2.0

1.) How sensitive are the BART results to axial mesh size?

To investigate BART sensitivity to mesh size, the BART calculation for run 32333 (see response to Question 4, Section 6.0) was repeated with the axial mesh size reduced by a factor of two.

Figure 1 - 3 show that there is an overall increase in calculated temperature of about 100°F. Figures 4 to 7 show that the predition still compares well with data.

FIGURE 1

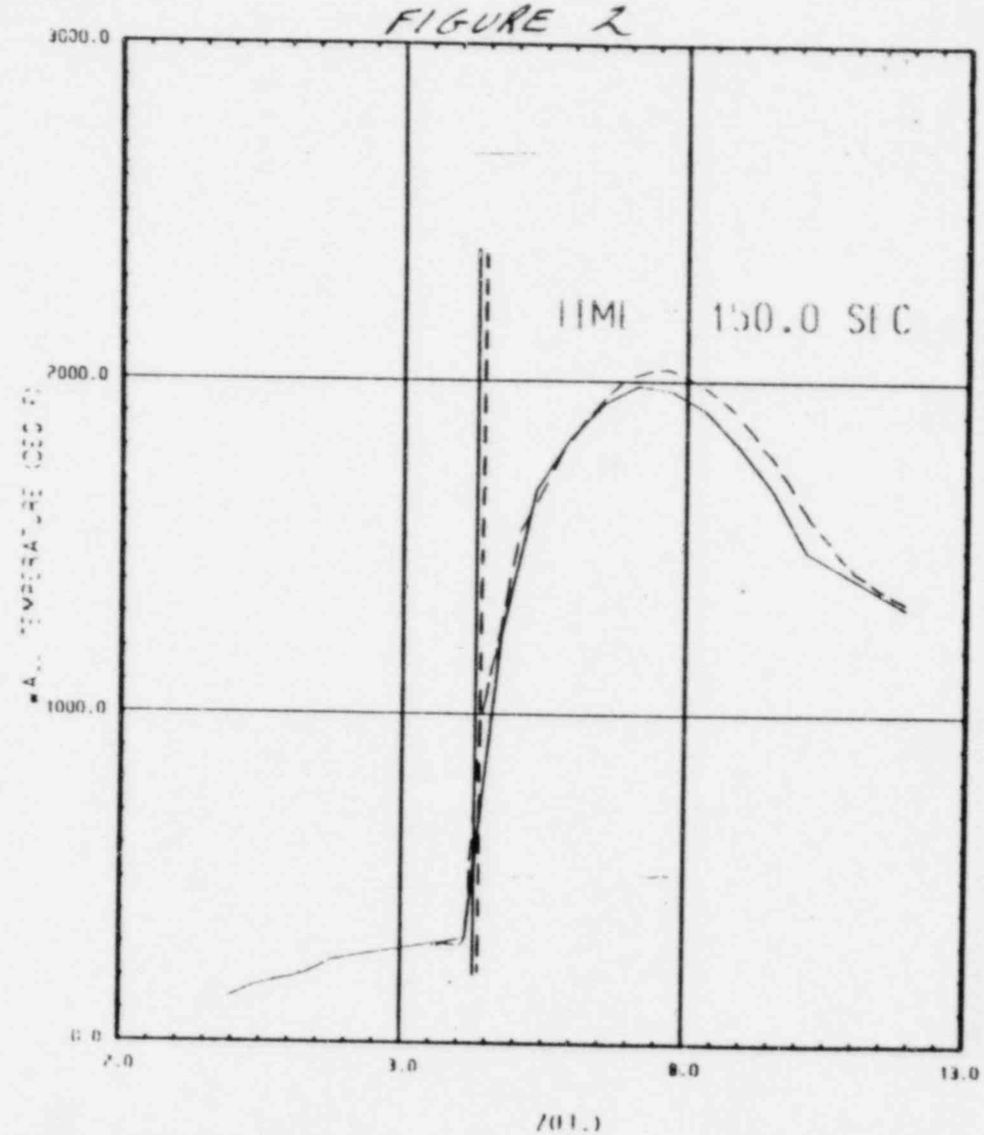


FLECHT 32333 P40

BARIA1

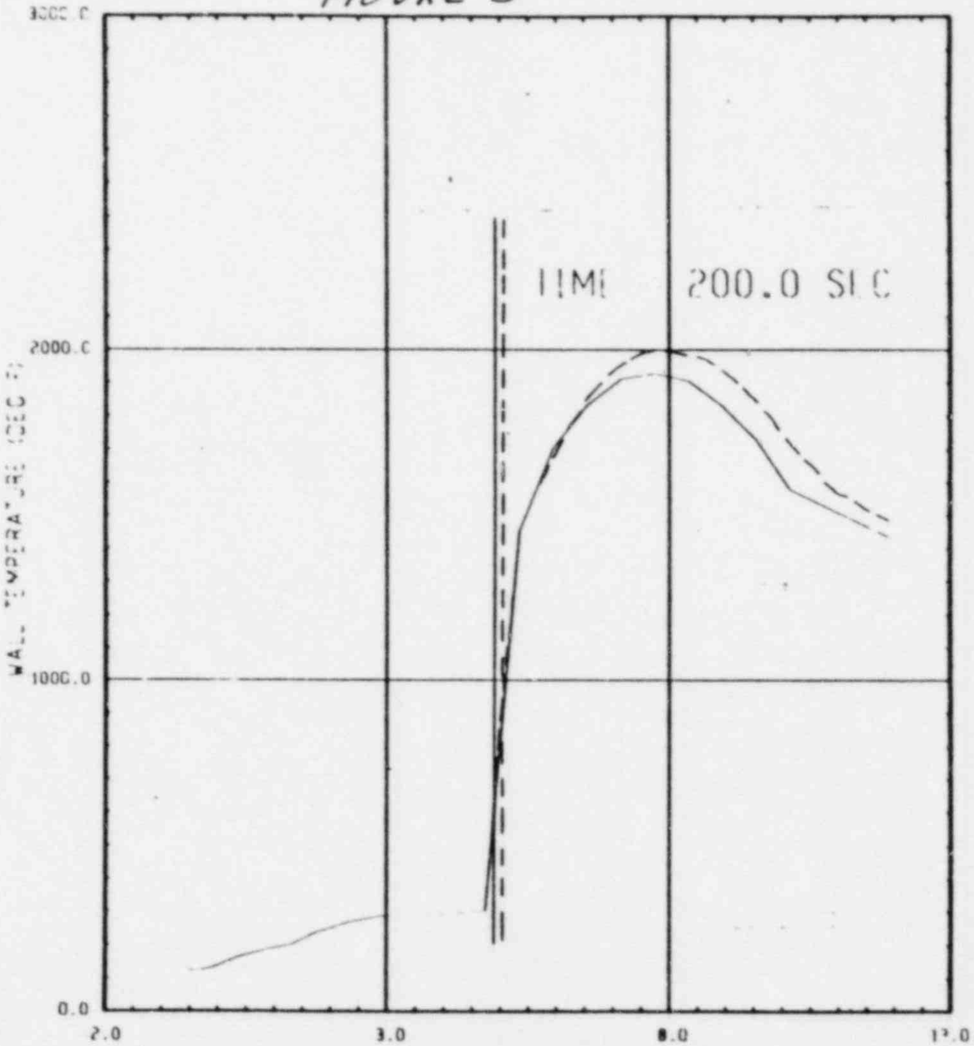
- - - - - - FINE MESH

FIGURE 2



FINE MESH

FIGURE 3



FLECHT 32333 P40

BARTA1

– – – – – FINE MESH

FIGURE 4

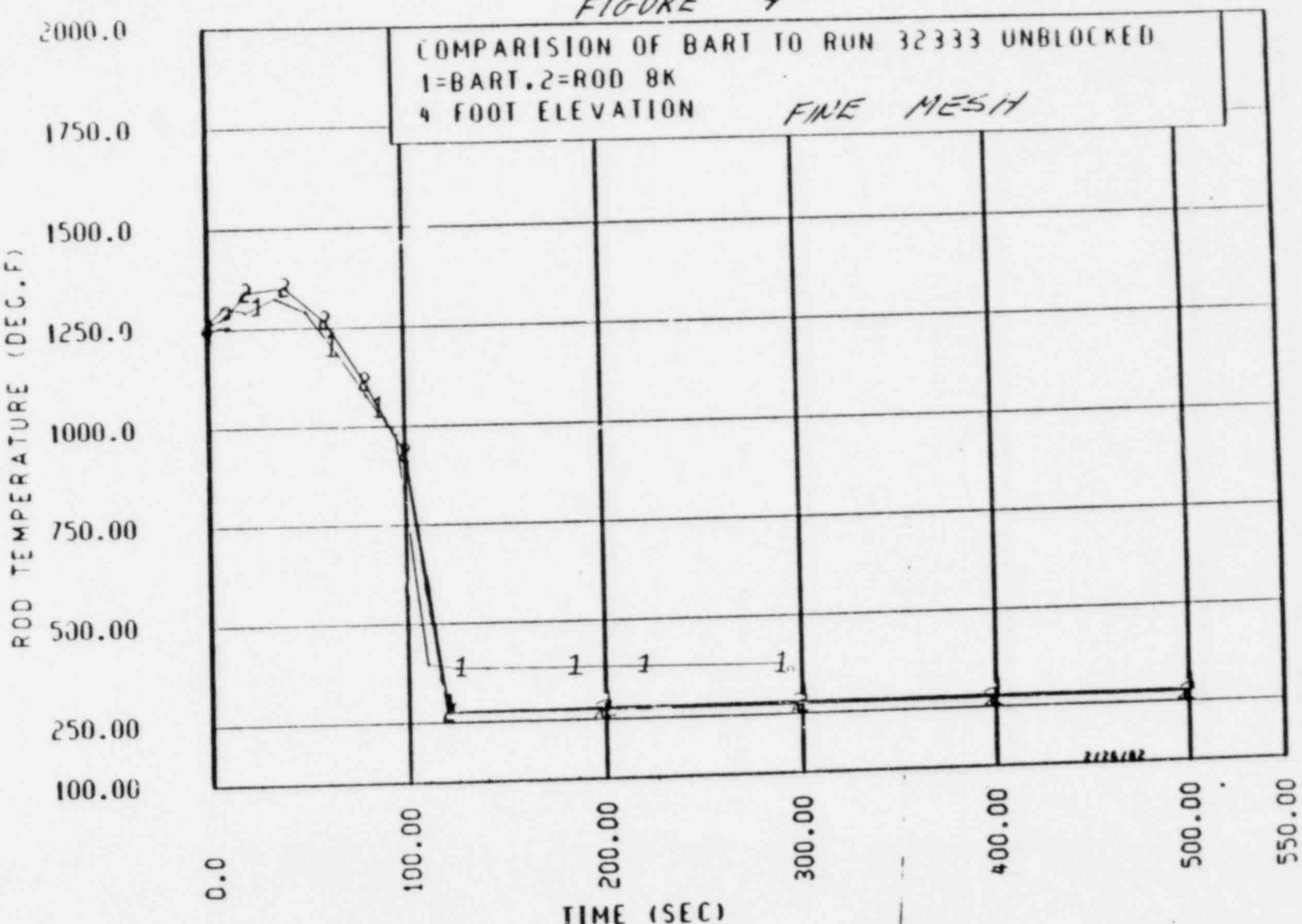
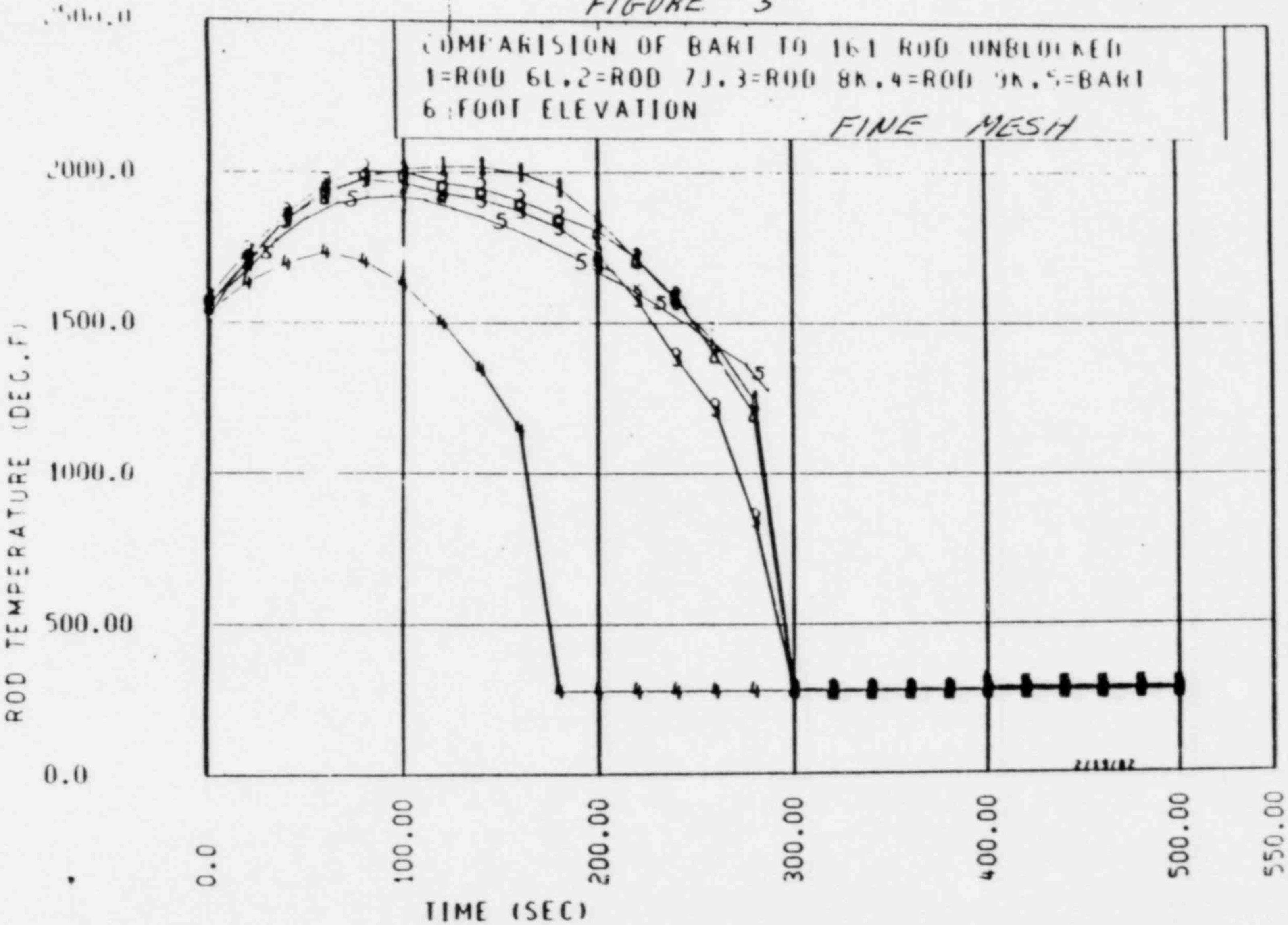

COMPARISION OF BART TO RUN 32333 UNBLOCKED
1=BART.2=ROD 8K
4 FOOT ELEVATION
FINE MESH
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
100.00
ROD TEMPERATURE (DEG.F)
0.0
100.00
200.00
300.00
400.00
500.00
550.00
TIME (SEC)

FIGURE 5



COMPARISION OF BART TO 161 ROD UNBLOCKED
1=ROD 6L,2=ROD 7J,3=ROD 8K,4=ROD 9K,5=BART
6 FOOT ELEVATION
FINE MESH
2000.0
1500.0
1000.0
500.00
0.0
ROD TEMPERATURE (DEG.F)
0.0
100.00
200.00
300.00
400.00
500.00
550.00
TIME (SEC)

FIGURE 6

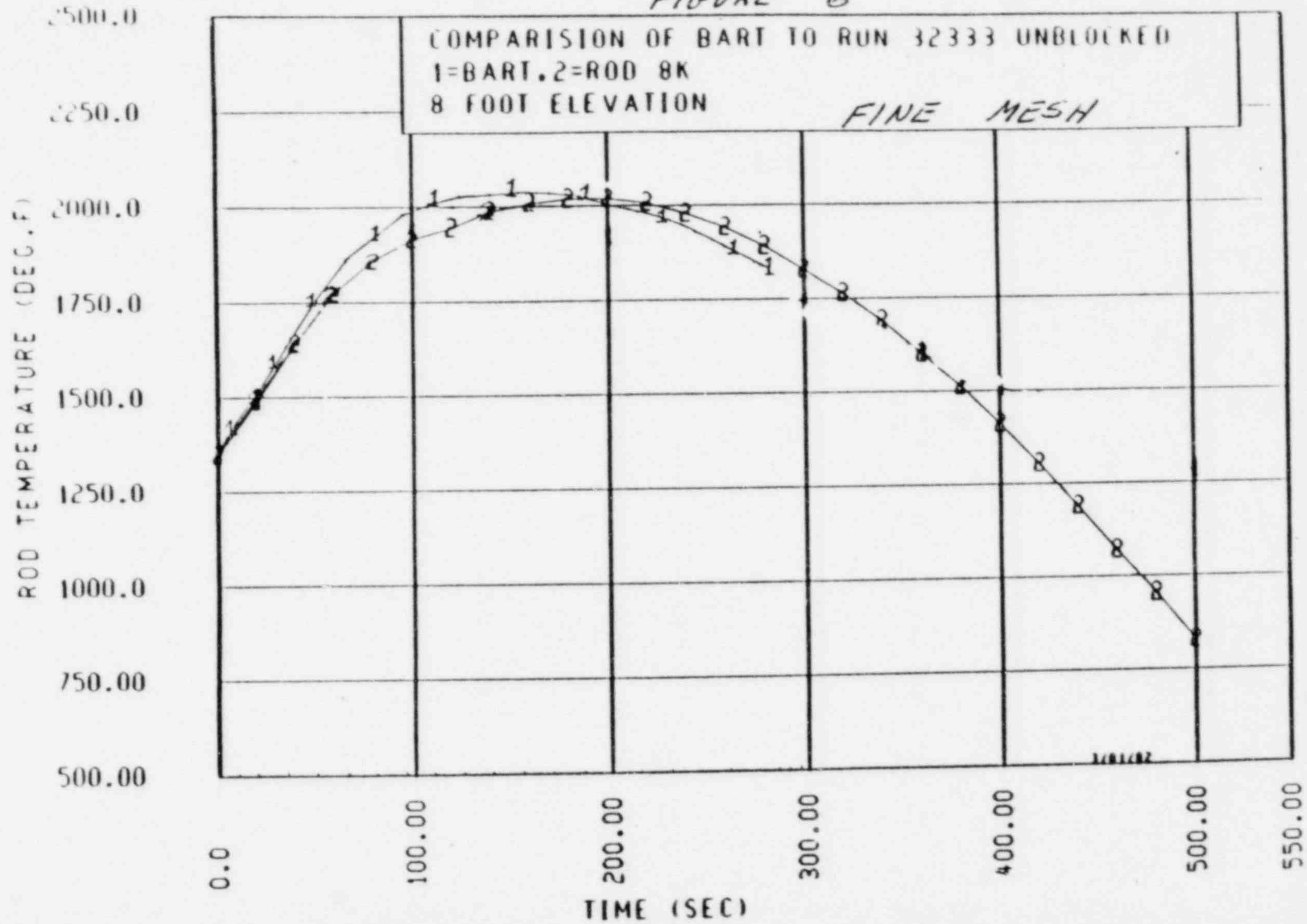
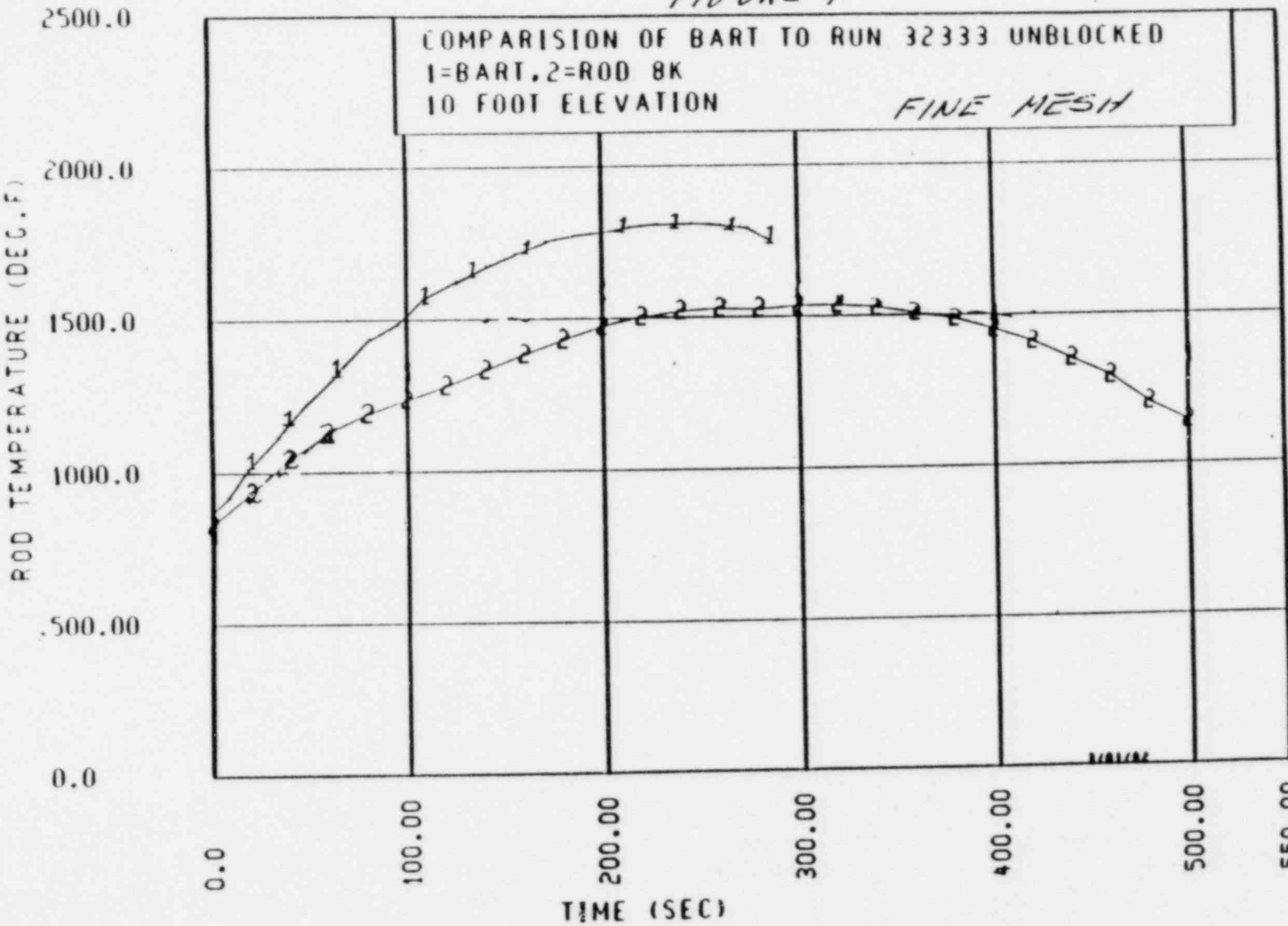

COMPARISION OF BART TO RUN 32333 UNBLOCKED
1=BART.2=ROD 8K
8 FOOT ELEVATION
FINE MESH
ROD TEMPERATURE (DEG.F)
2500.0
2250.0
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
0.0
100.00
200.00
300.00
400.00
500.00
550.00
TIME (SEC)

FIGURE 7


COMPARISION OF BART TO RUN 32333 UNBLOCKED
1=BART,2=ROD 8K
10 FOOT ELEVATION
FINE MESH
ROD TEMPERATURE (DEG.F)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
0.0
100.00
200.00
300.00
400.00
500.00
550.00
TIME (SEC)

SECTION 2.0

3) SEE ATTACHMENT 1

4) SEE ATTACHMENT 1

6) SEE ATTACHMENT 1

SECTION 2.2

1) SEE ATTACHMENT 2

5) SEE ATTACHMENT 2

SECTION 3.3.1

8) What is the u in equation 3.3-21?

The u in equation 3.3-21 is the liquid velocity (see Attachment 2).

SECTION 3.3.2

1) The thermal and hydraulic modeling is referred to as "near the quench front." Quantify this statement.

Attachment 2 describes how the calculations are performed near the quench front.

SECTION 3.3.2

3) The local vapor flux j_{yi} is treated in the same way as the global vapor flux in that $j_{yi} = F_1 \alpha_i$. Does the vapor film generation enter into this α_i and hence into j_{yi}?

Equation 3.3-26 is used below the quench region, where the flow regime is bubbly churn turbulent. As described in Attachment 2, fluid flow calculations in the quench model are terminated at the beginning of the vapor film.

SECTION 3.3.2

4) Why is ΔZ_i in euation 3.3-30 not time dependent? Does this infer that the isotherm spacing is constant?

Equation 3.3-30 is in error. The correct derivation appears below:

$$\frac{d}{dt}\left[\rho\epsilon_i(z_i - z_{i-1})H_i\right] = \rho(U_{i-1} - V_{i-1})\epsilon_{i-1}H_{i-1} - \rho(U_i - V_i)\epsilon_i H_i + q_i'''(z_i - z_{i-1}) \quad (1)$$

The liquid continuity equation is:

$$\frac{d}{dt}\left[\rho\epsilon_i(z_i - z_{i-1})\right] = \rho(U_{i-1} - V_{i-1})\epsilon_{i-1} - \rho(U_i - V_i)\epsilon_i \quad (2)$$

where $\epsilon_i = (1 - \alpha_i)$

Assume the liquid density is constant.

Equation 1 becomes:

$$\epsilon_i(z_i - z_{i-1})\frac{dH_i}{dt} + H_i\frac{d}{dt}\epsilon_i(z_i - z_{i-1})$$

$$= (U_{i-1} - V_{i-1})\epsilon_{i-1}H_{i-1} - (U_i - V_i)\epsilon_i H_i \quad (3)$$

$$+ q_i'''(z_i - z_{i-1})/\rho$$

Substitute equation 2 into equation 3:

$$\epsilon_i (Z_i - Z_{i-1}) \frac{dH_i}{dt} = (U_{i-1} - V_{i-1}) \epsilon_{i-1} H_{i-1}$$

$$\cancel{- (U_i - V_i) \epsilon_i H_i} - (U_{i-1} - V_{i-1}) \epsilon_{i-1} H_i$$

$$\cancel{+ (U_i - V_i) \epsilon_i H_i} + q''' (Z_i - Z_{i-1}) / \rho$$

$$\epsilon_i (Z_i - Z_{i-1}) \frac{dH_i}{dt} = (U_{i-1} - V_{i-1}) \epsilon_{i-1} (H_{i-1} - H_i)$$

$$+ q_i''' (Z_i - Z_{i-1}) / \rho$$

SECTION 3.3.3

3) Is it significant that there is no reduction of the bubble dimension in the condensation model in equation 3.3-38?

It is true that condensing bubbles will reduce in volume as they flow through the liquid. However, new bubbles are continually being formed on the rod. An accurate bubble model would have to track the change in volume of each individual bubble. As described in Attachment 2, a mean bubble size is used to represent the entire bubble population.

SECTION 3.3.3

4) The expression q''_{nb} does not appear in Section 3.3.4. Is q''_{nb} actually the value Q determined by integrating up the elevation of the control volume. If so, should not q'' in that integral be a function of Z. Clarify the definition of q''_{nb}.

See Attachment 2.

SECTION 3.3.3

5) Which α is the α of equation 3.3-83?

α_i is calculated using equation 3.3-27.

SECTION 3.3.3

6) Is it not clear that the heat fluxes of 3.3-39 function over the same areas. Do forced convection and nuclear boiling occur over the same surface? If so, how?

See Attachment 2.

SECTION 3.3.3

7) Is the condensation model euqation 3.3-38, what if any mechanism accounts for the bubbles getting smaller as they condense?

A mean bubble size is assumed as representative of the bubble population in the channel.

SECTION 3.3.4

1) It appears that Region IV was omitted from table 3.3-2. Should it be included? If not, explain why?

See attached page for corrected table 3.3-2.

TABLE 3.3-2

HEAT TRANSFER CORRELATIONS USED NEAR QUENCH FRONT

Region	Heat Transfer Mechanism	Correlation	Reference
	Single phase forced convection	$Nu = .023\ Re^{.8}\ Pr^{.4}$ Re>2000 $Nu = 10$ Re<2000	8
I	Nucleate Boiling	$h_{NB} = \left[\dfrac{C_{p\ell}\ \Delta T}{.013\ H_{\ell v}}\right]^{3} \dfrac{\mu_\ell\ H_{\ell v}}{P_r^{5.1}\ L}$	32
II		where $L = \left[\dfrac{\sigma}{\Delta\rho g}\right]^{0.5}$	
III	Nucleate or transition boiling	Minimum of h_{NB} above and: $h = q''_{max}\ e^{(1 - B\Delta T)}B$ where: $q''_{max} = .15\ \rho_v\ H_{\ell v} \left[\dfrac{\sigma\Delta\rho g}{\rho_v^2}\right]^{.25}$	20
IV	Film boiling	$h_{fb} = .62 \left[\dfrac{K_v^{3}\ H_{\ell v}\ \rho_v\ \Delta\rho g}{\mu_v\ \Delta T\ L}\right]^{.25}$	22

SECTION 3.3.4

2) More clearly define the boundaries between Region II and Region I.

See Attachment 2 for clarification.

SECTION 3.3.4

3) More clearly define the boundaries between Region II and Region I.

See Attachment 2 for clarification.

SECTION 3.3.4

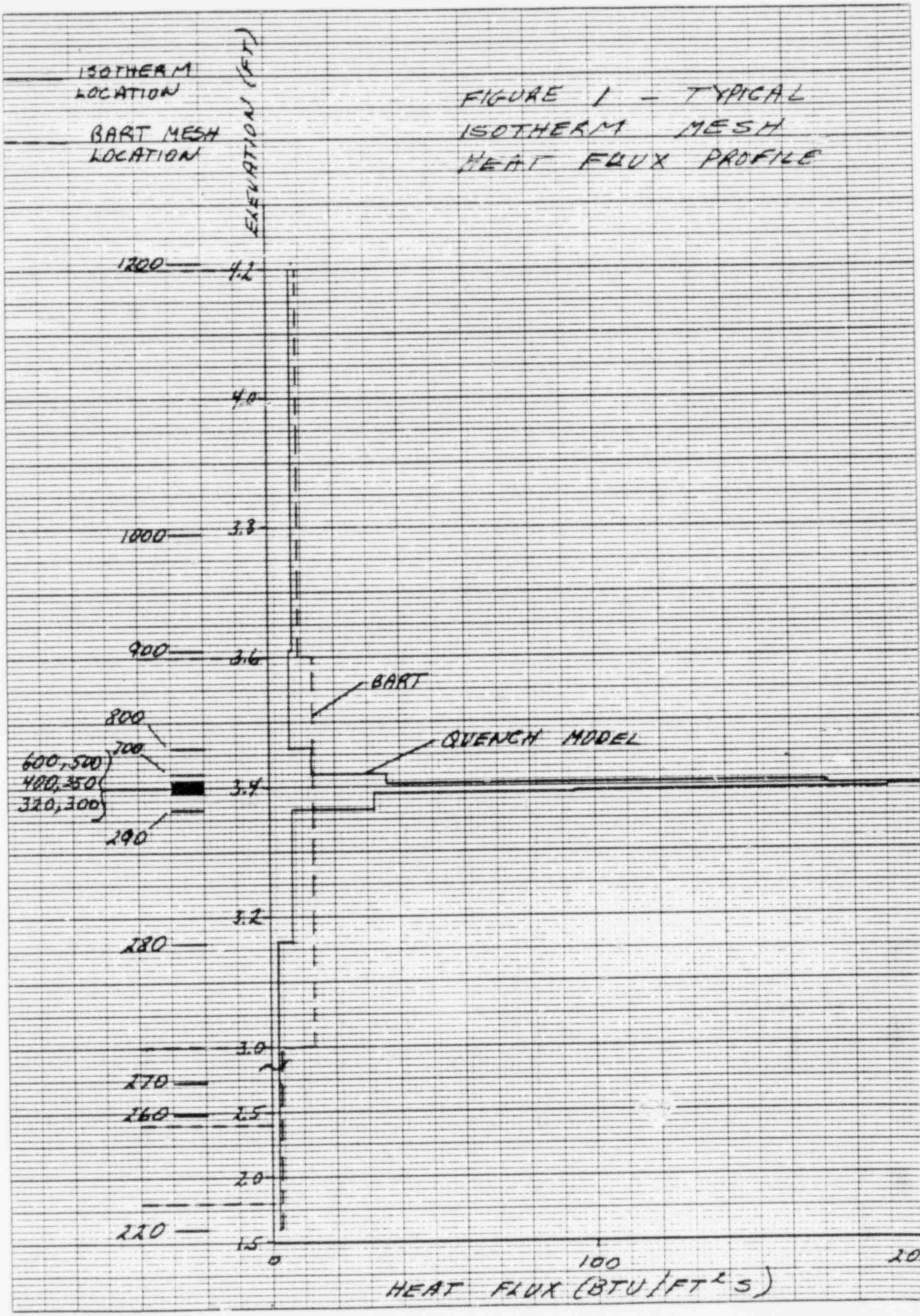
4) It is inferred that the rod Liedenfrost temperature is used to determine a quench region isotherm. How is this temperature determined? How is the minimum rewetted rod surface temperature determined? It appears that one of these is an input value -- how is it determined and what are the effects of variation in this value?

The temperature at which the minimum heat flux occurs on the rod is used to define the location of the quench front. As shown in Figure 3.3-7, this temperature varies with the value of B. It is not an input quantity. The only requirement is that the isotherm mesh define this region reasonably well.

SECTION 3.3.4

5) Due to the general upward propagation of energy released during reflood, doesn't the linearized apportioning of energy favor the quench front advance; e.g., at $Z_q = Z_i$, all the heat is realized into the lower node reducing the subcooling there rather than generating more steam at the quench plane and thereby slowing the advance of the quench plant.

Sufficient detail exists in the isotherm mesh to avoid, the severe distortion suggested above, as can be seen from the attached figure.


ISOTHERM LOCATION
BART MESH LOCATION
FIGURE 1 - TYPICAL ISOTHERM MESH HEAT FLUX PROFILE
ELEVATION (FT)
1200
4.2
4.0
1000
3.8
900
3.6
BART
800
700
600,500
400,350
320,300
290
QUENCH MODEL
3.4
3.2
280
3.0
270
260
2.5
2.0
220
1.5
0
100
200
HEAT FLUX (BTU/FT² S)

SECTION 3.3.4

6) On page 3.3-21, the definition of the "approximate" boundary between Region I and II appears to be missing. Is that the case? If so, what is the definition?

The boundary between region I and II is defined as the point where the heat flux equals or exceeds:

$$q_b'' = \rho_v H_{lv} j_{vb}$$

where

$$j_{vb} = U_{rbb} \alpha_{bb} \quad \text{(see equation 3.3-40)}$$

$$\alpha_{bb} = \frac{\pi D_b^2}{2 \lambda^2} \quad \text{(see equation 3.3-41)}$$

$$U_{rbb} = 1.53 \left[\frac{\sigma \Delta \rho g}{\rho_l^2} \right]^{0.25}$$

SECTION 3.3.4

7.) What happens to the bubbles formed in Region I, page 3.3-21? The implication is that they are swept downstream. How does the condensation model account for them.

The flux of vapor   is determined from eq. 3.3-26. The change in void draction as a result of condensation, the flux of vapor from below, and the flux of vapor leaving the region, is calculated from eq. 3.3-27.

SECTION 5.0

1) Is there any particular reason for not incorporating BART into LOCTA to take advantage of the LOCTA gap conductance calculations as well as eliminate the final stand alone LOCTA calculation?

   Work is currently being performed to incorporate BART into LOCTA, replacing the FLECHT correlation and the steam cooling model, and avoiding the need to run two separate codes.

SECTION 5.0

2.) A comparison of the current and proposed WREFLOOD calculation is not presented. This is needed. In particular a comparison of the entrainment rate.

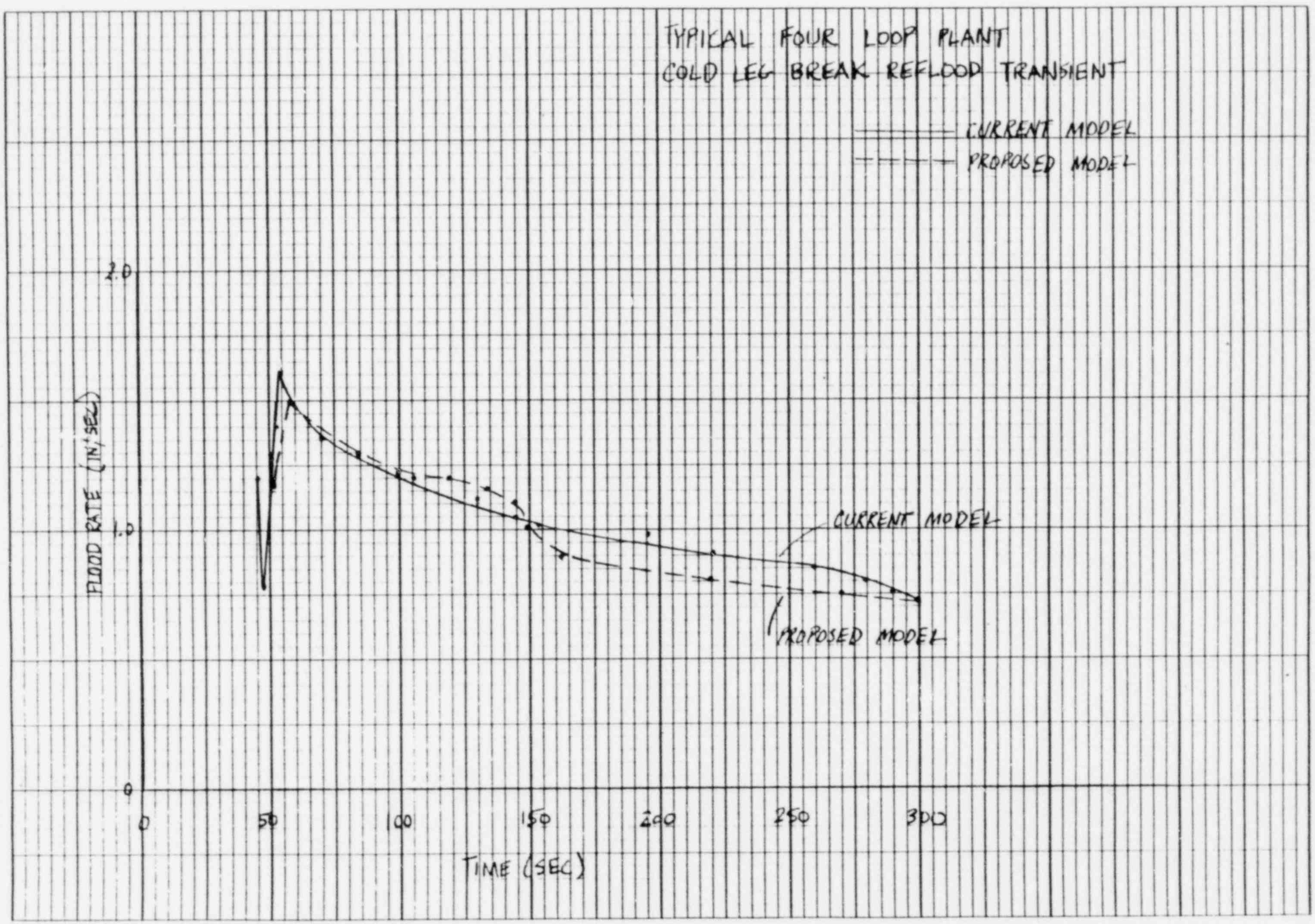
Figures 1 to 3 compare the flooding rate, liquid and quench levels, and entrainment fraction for a typical four loop plant.

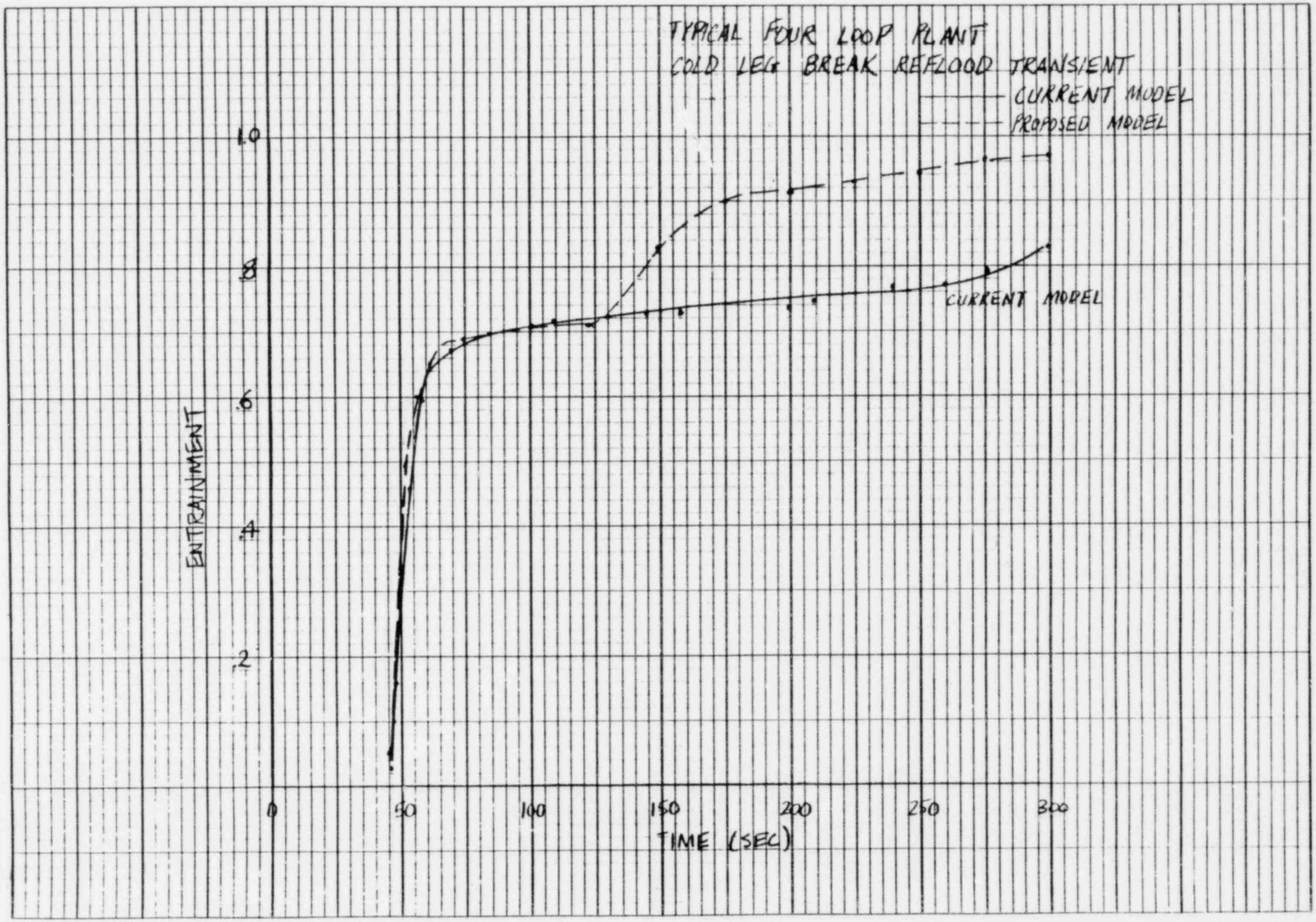
Entrainment is seen to begin slightly earlier in the proposed calculation. This is due to the term:

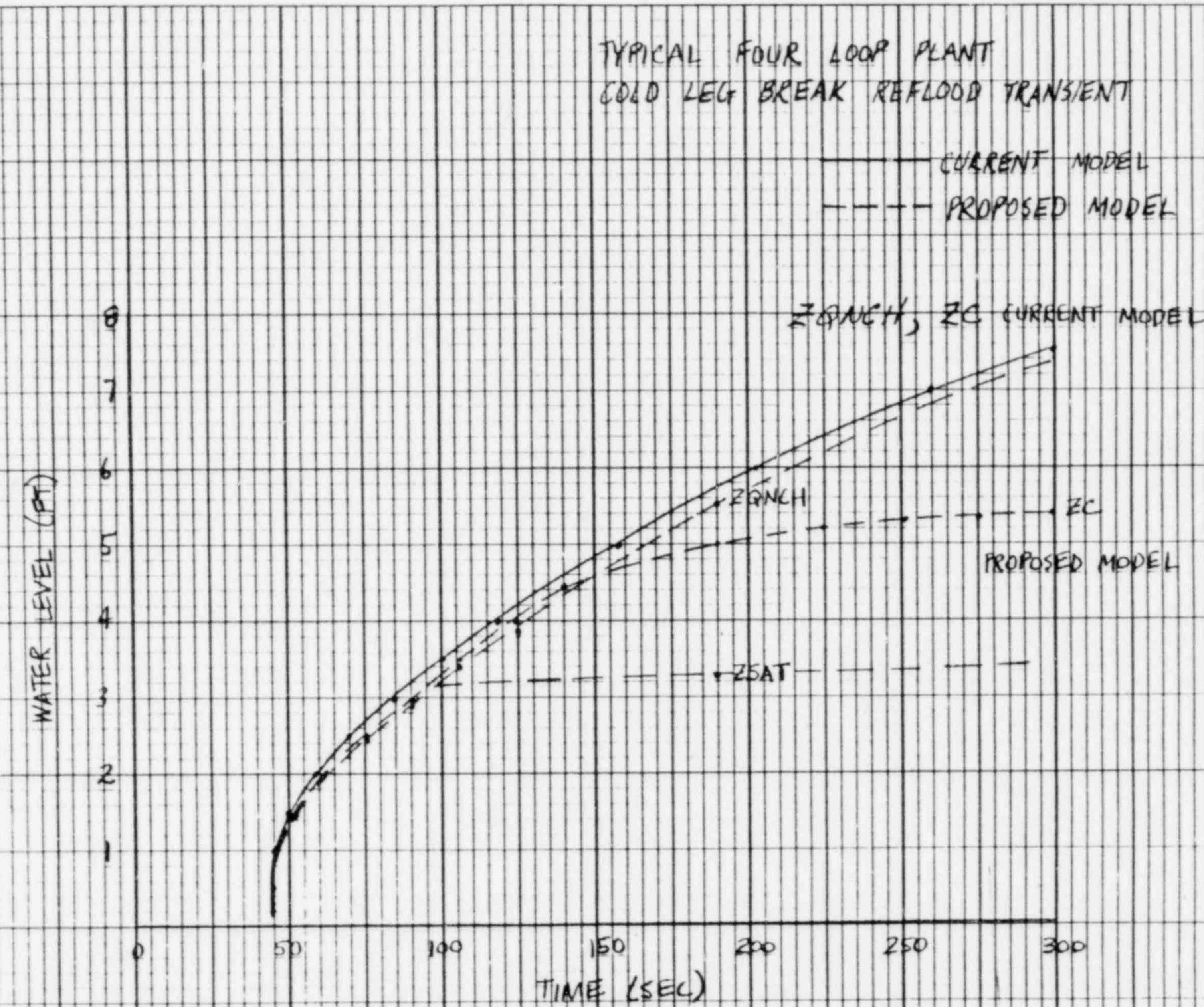
$$Z_{st} = 10. \frac{\overline{V_{IN}} \quad \Delta T_s}{(1000. - T_{SAT})}$$

which has been included in the entrainment correlation. In the current model the earlier entrainment is accounted for by subtracting Z_{st} from the quench front location in the LOCTA calculation [1]. As reflood progresses, boiling commences below the quench front. Subsequently, entrainment is controlled primarily by the movement of this line. The increased entrainment reduces the flooding rate in the proposed model, but this difference tends to disappear because the downcomer driving head remains high due to the lower density in the core.

1. Bordelon, F. M., et. atl "The Westinghouse ECCS Evaluation Model - Supplementary Information", WCAP - 8471 - P - A, April 1975.


TYPICAL FOUR LOOP PLANT
COLD LEG BREAK REFLOOD TRANSIENT
CURRENT MODEL
PROPOSED MODEL
CURRENT MODEL
PROPOSED MODEL
2.0
1.0
0
FLOOD RATE (IN/SEC)
0
50
100
150
200
250
300
TIME (SEC)

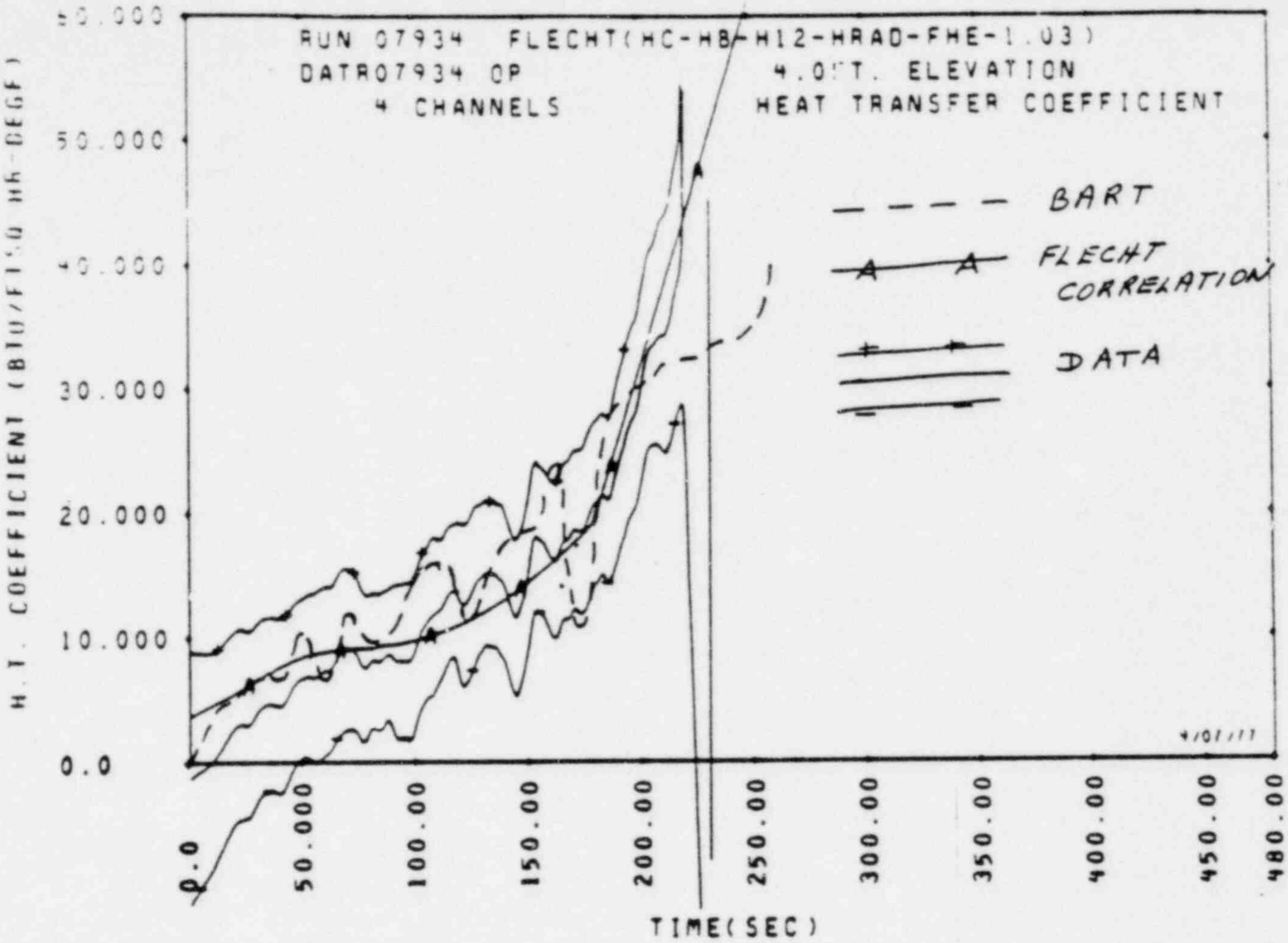

TYPICAL FOUR LOOP PLANT
COLD LEG BREAK REFLOOD TRANSIENT
CURRENT MODEL
PROPOSED MODEL
CURRENT MODEL
ENTRAINMENT
1.0
.8
.6
.4
.2
0
50
100
150
200
250
300
TIME (SEC)


TYPICAL FOUR LOOP PLANT
COLD LEG BREAK REFLOOD TRANSIENT
CURRENT MODEL
PROPOSED MODEL
ZQNCH, ZC CURRENT MODEL
ZQNCH
ZC
PROPOSED MODEL
ZSAT
WATER LEVEL (FT)
TIME (SEC)
0
50
100
150
200
250
300
1
2
3
4
5
6
7
8

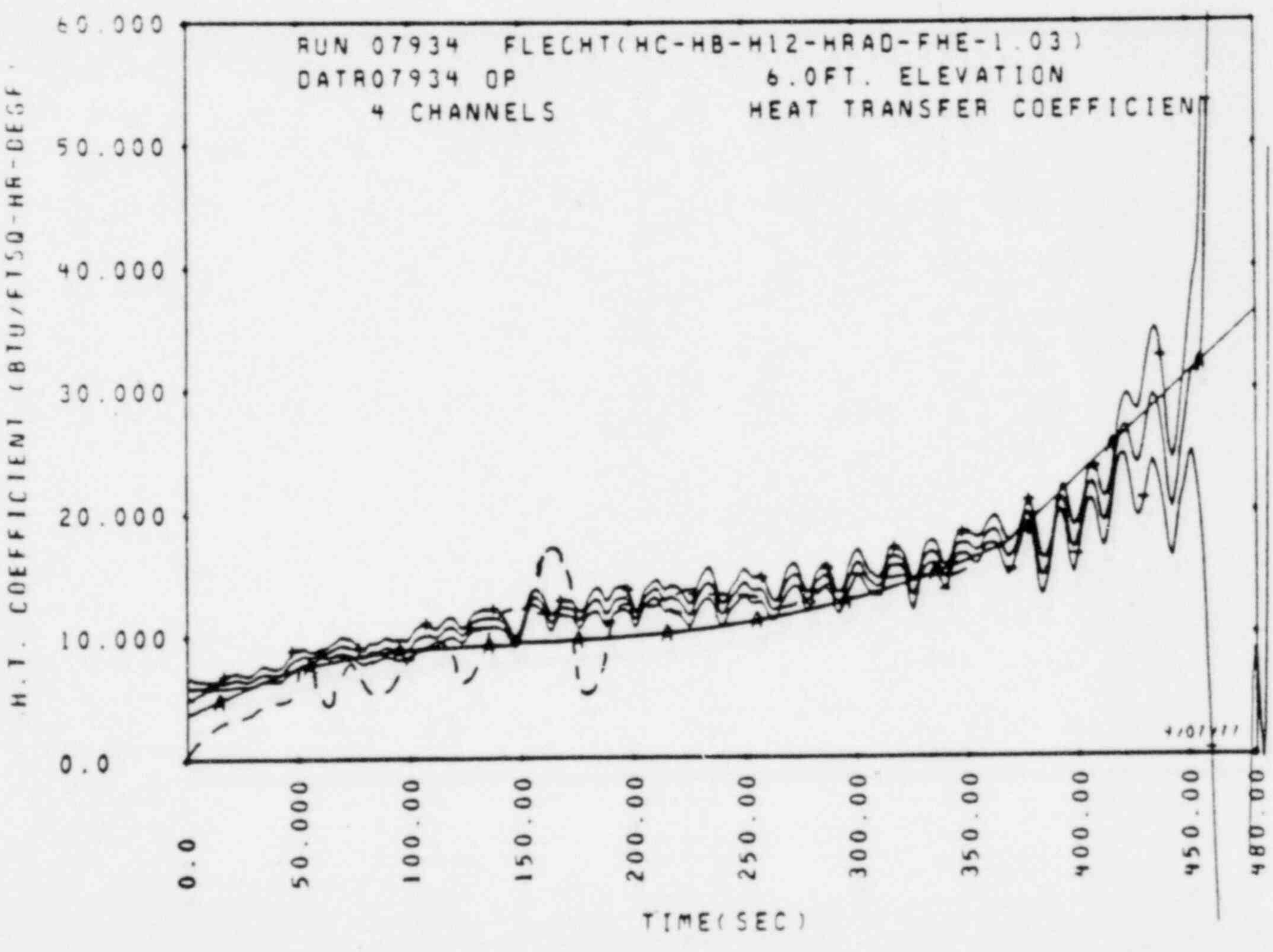
SECTION 5.0

3.) A comparison of the surface heat transfer coefficient from both BART and the current FLECHT correlation should be provided.

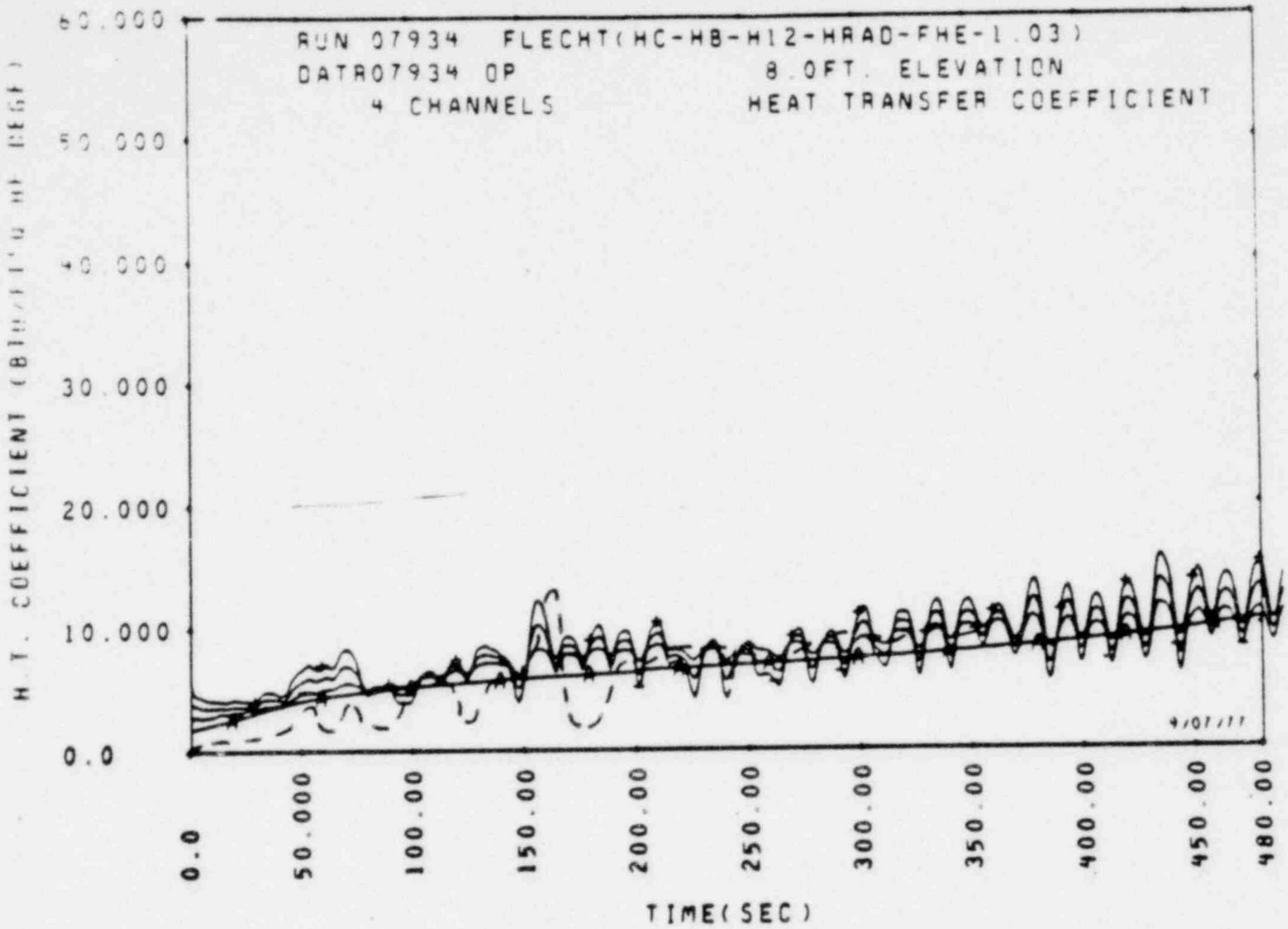
The attached figures compare the BART calculated heat transfer coefficient (---) the FLECHT correlation (~~A A A~~) and data (——) for selected FLECHT cosine tests. It can be seen that BART agrees quite well with the data at all elevations (refer to WCAP 9561 for the test conditions).

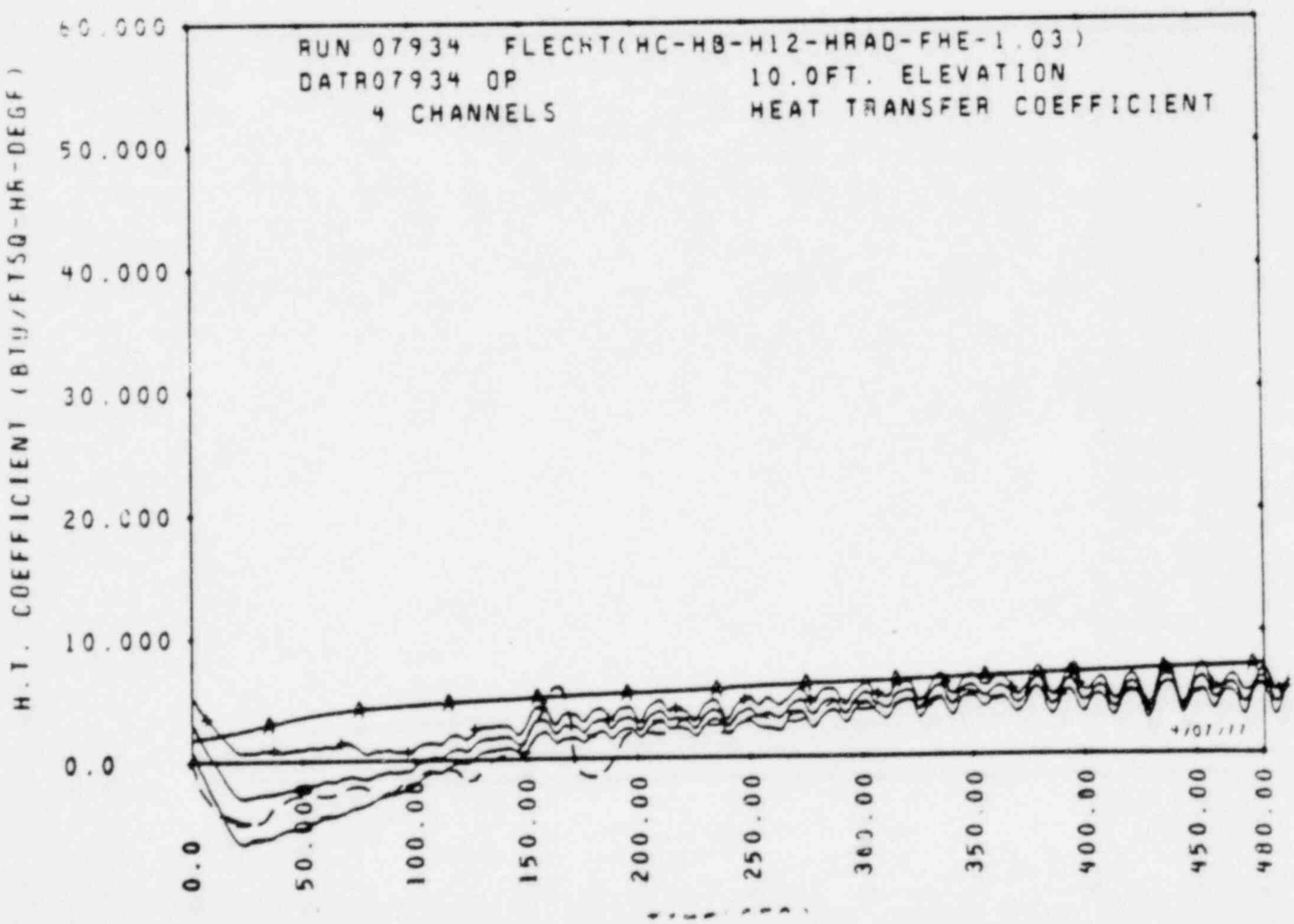


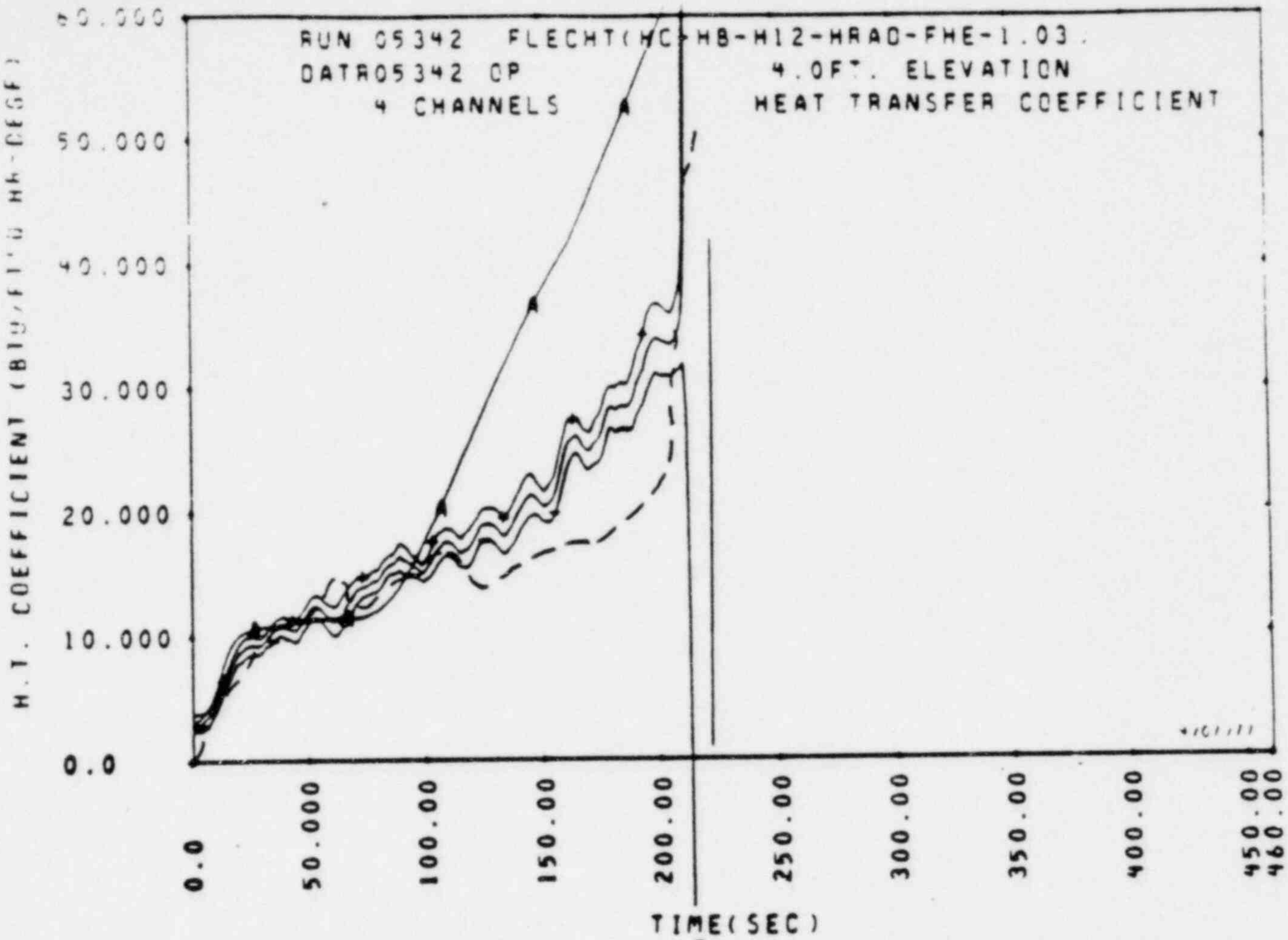
RUN 07934 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR07934 OP
4 CHANNELS
4.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
BART
FLECHT CORRELATION
DATA
H.T. COEFFICIENT (BTU/FTSQ HR-DEGF)
TIME(SEC)

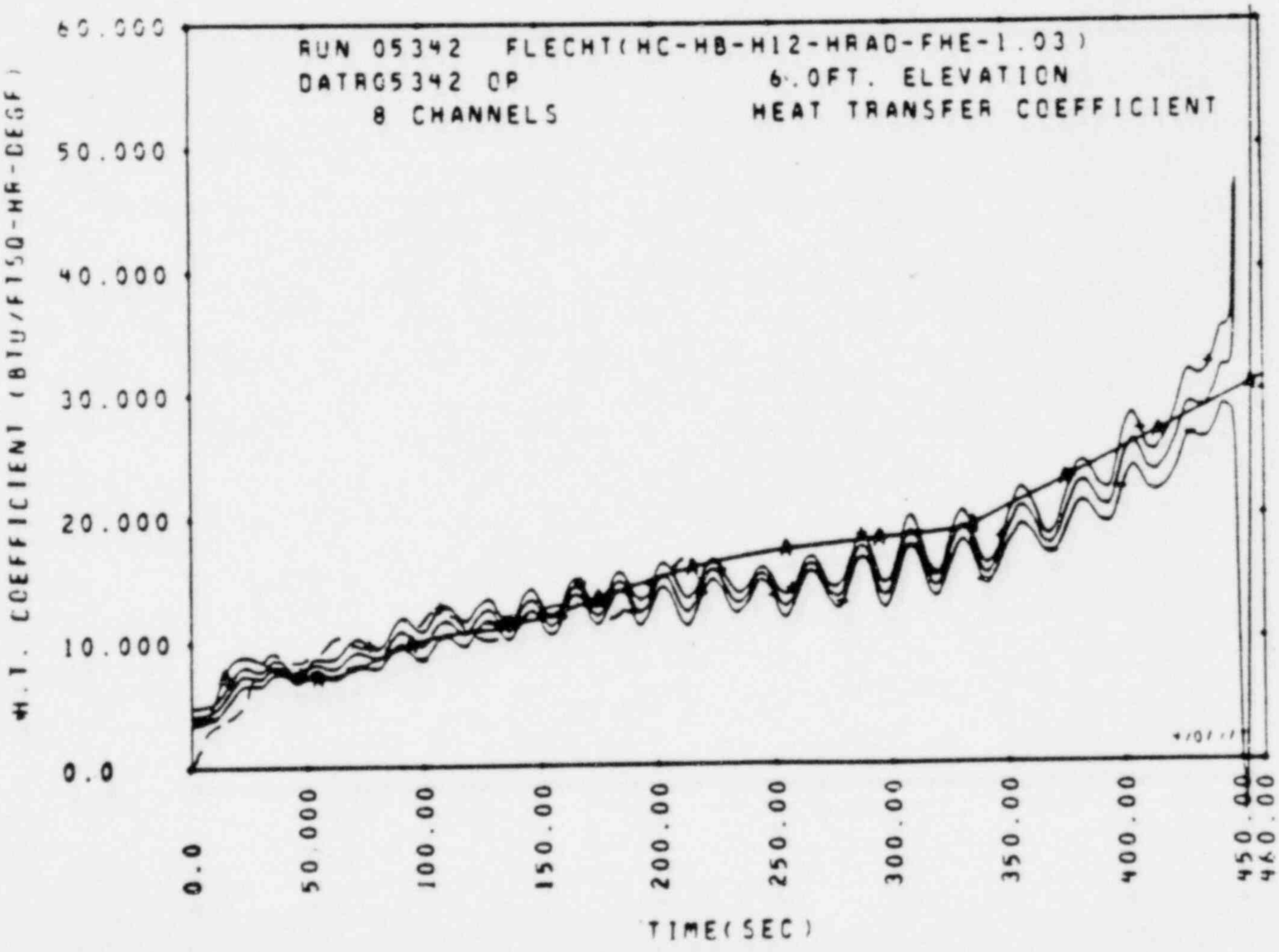


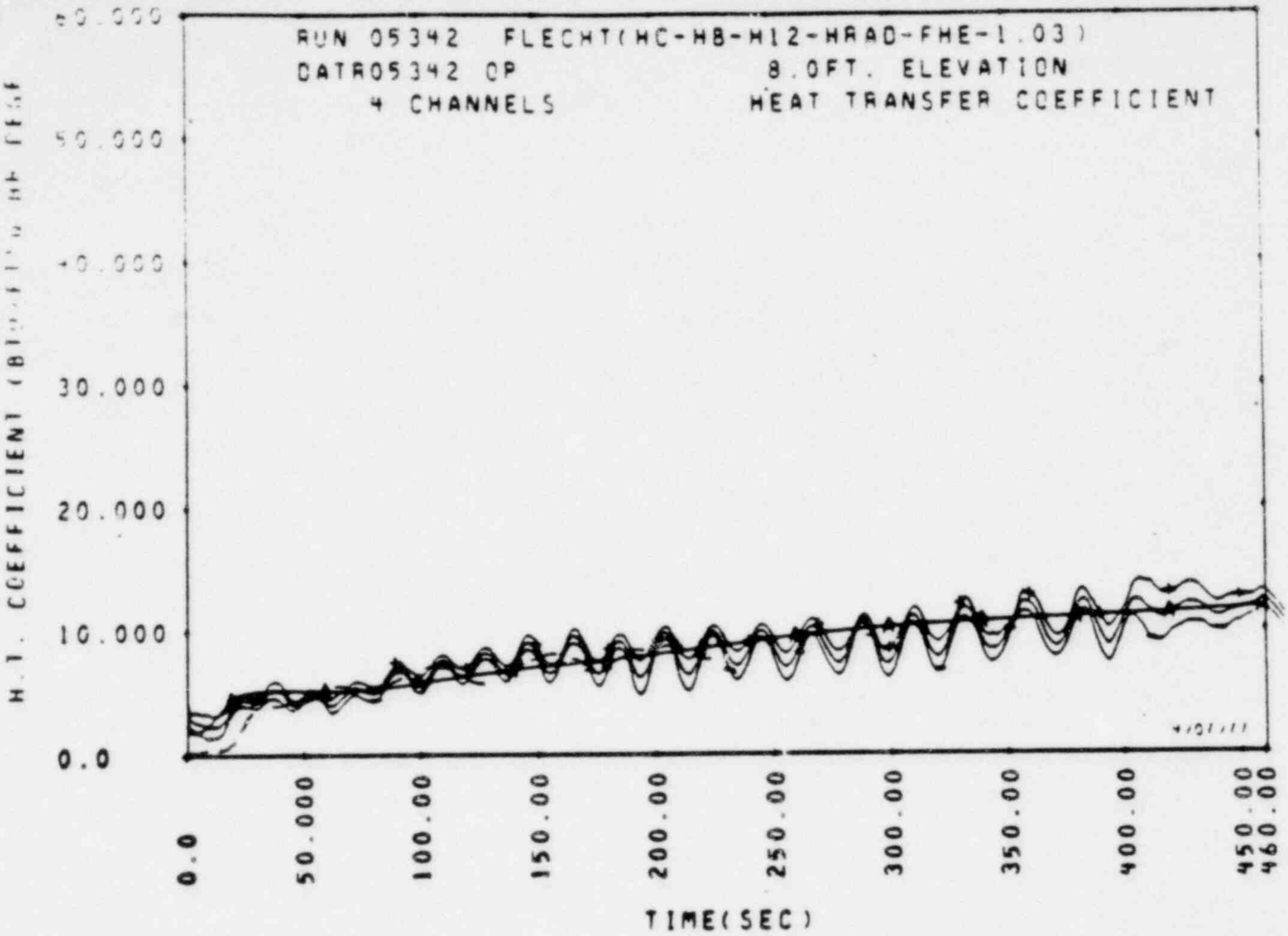
RUN 07934 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR07934 OP
4 CHANNELS
6.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT (BTU/FTSQ-HR-DEGF)
TIME(SEC)


RUN 07934 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR07934 OP
4 CHANNELS
8.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT (BTU/FTSQ-HR-DEGF)
60.000
50.000
40.000
30.000
20.000
10.000
0.0
0.0
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
480.00
TIME(SEC)

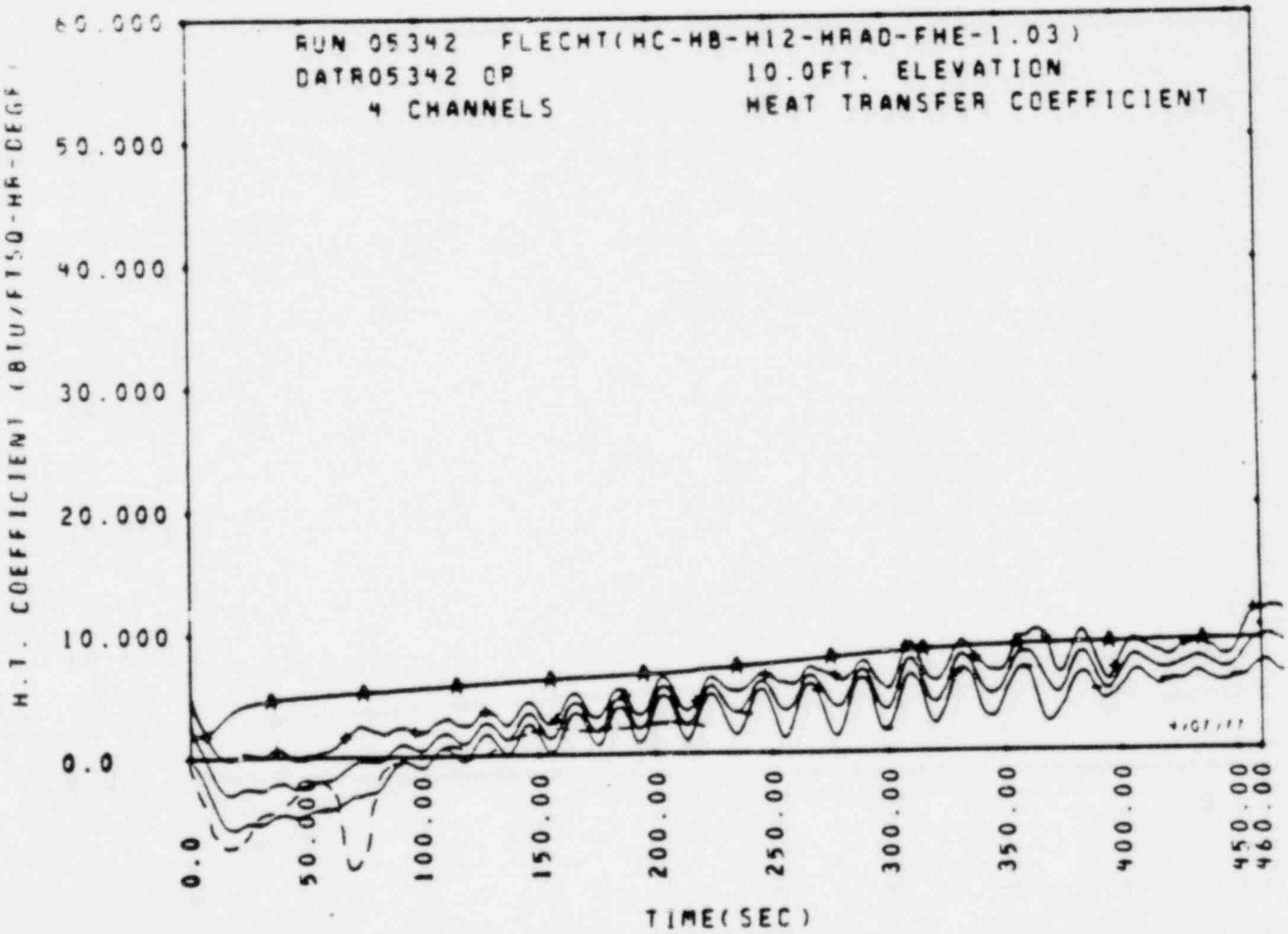

RUN 07934 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR07934 OP
4 CHANNELS
10.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT (BTU/FTSQ-HR-DEGF)
60.000
50.000
40.000
30.000
20.000
10.000
0.0
0.0
50.
100.
150.00
200.00
250.00
350.00
400.00
450.00
480.00


RUN 05342 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR05342 OP
4 CHANNELS
4.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT (BTU/FT²-HR-DEGF)
TIME(SEC)

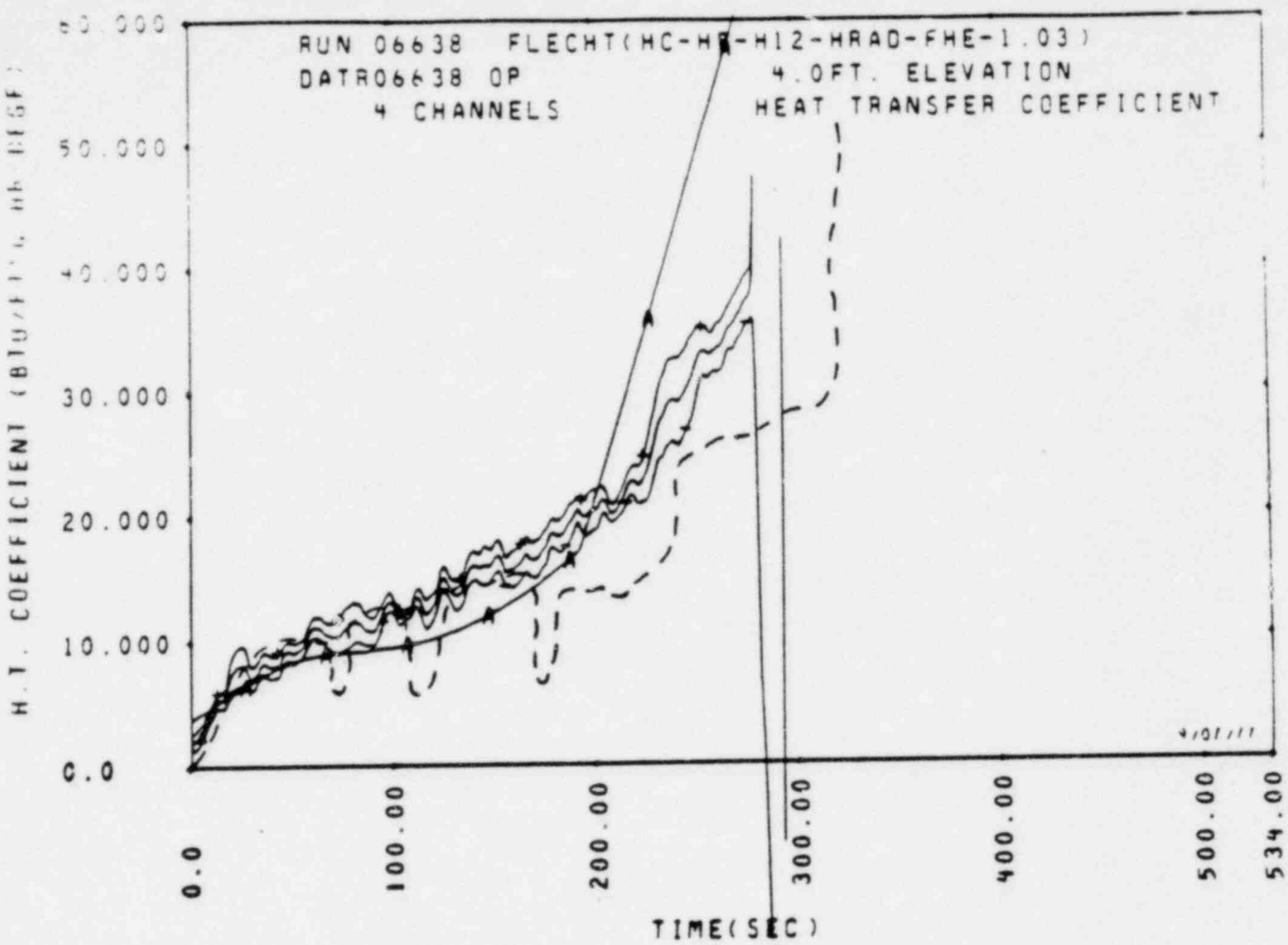

RUN 05342 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATRG5342 OP
8 CHANNELS
6.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT (BTU/FTSQ-HR-DEGF)
TIME(SEC)



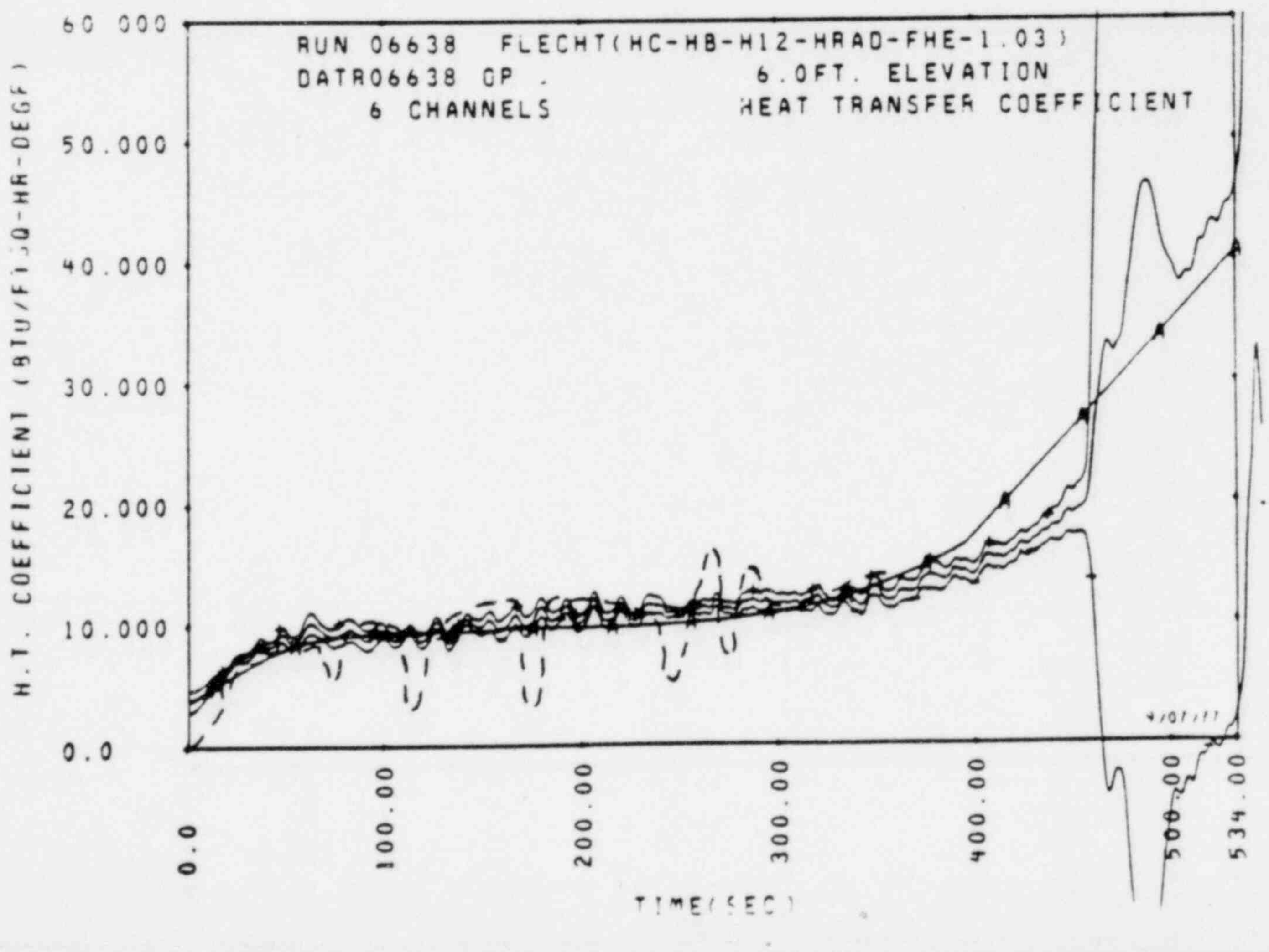
RUN 05342 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR05342 OP
4 CHANNELS
8.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT
0.0
10.000
20.000
30.000
40.000
50.000
60.000
0.0
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
460.00
TIME(SEC)



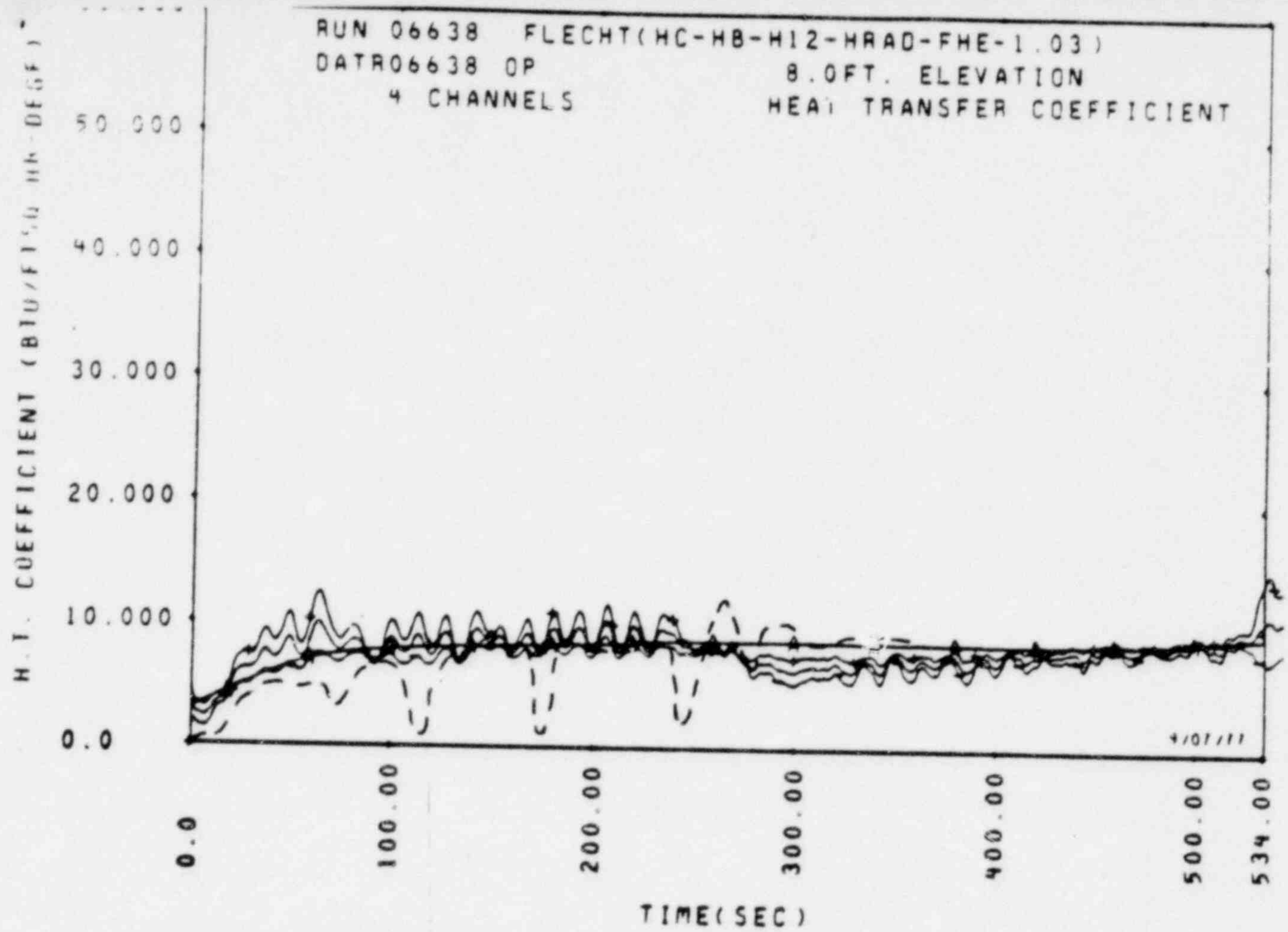
RUN 05342 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR05342 OP
4 CHANNELS
10.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT (BTU/FTSQ-HR-DEGF)
0.0
10.000
20.000
30.000
40.000
50.000
60.000
0.0
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
460.00
TIME(SEC)

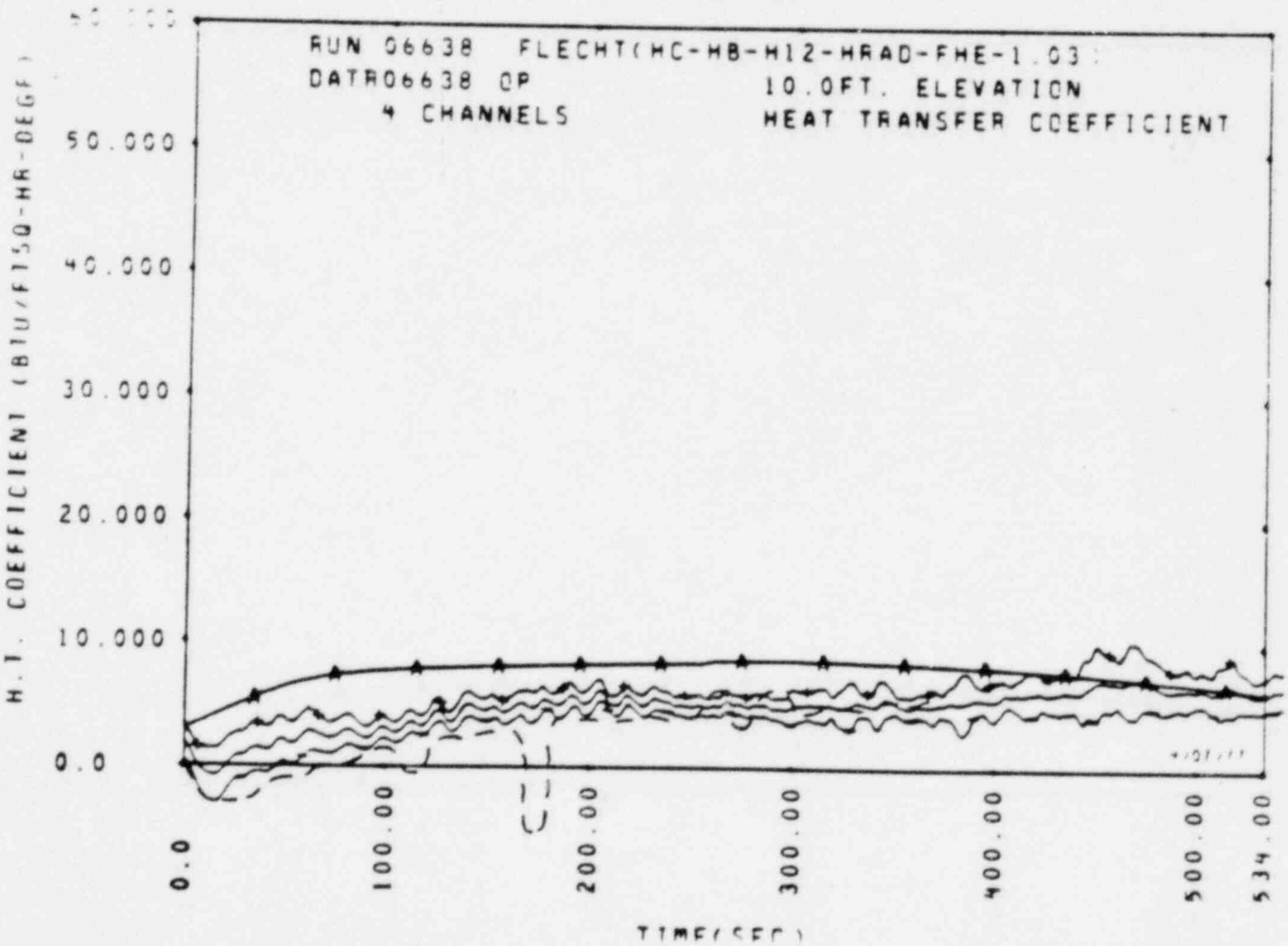


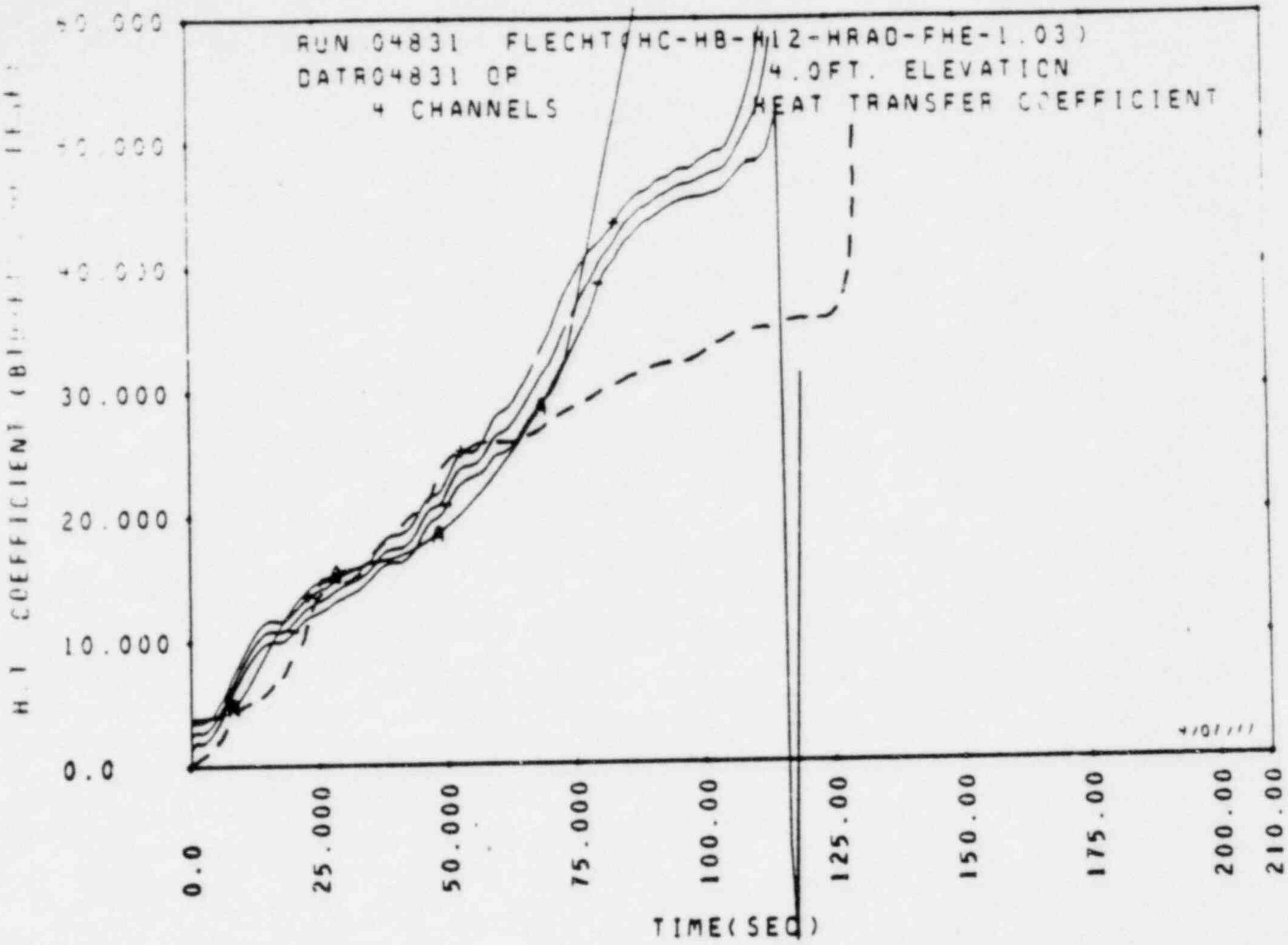
RUN 06638 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR06638 OP
4 CHANNELS
4.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT (BTU/FT²-HR-DEGF)
0.0
10.000
20.000
30.000
40.000
50.000
60.000
0.0
100.00
200.00
300.00
400.00
500.00
534.00
TIME(SEC)

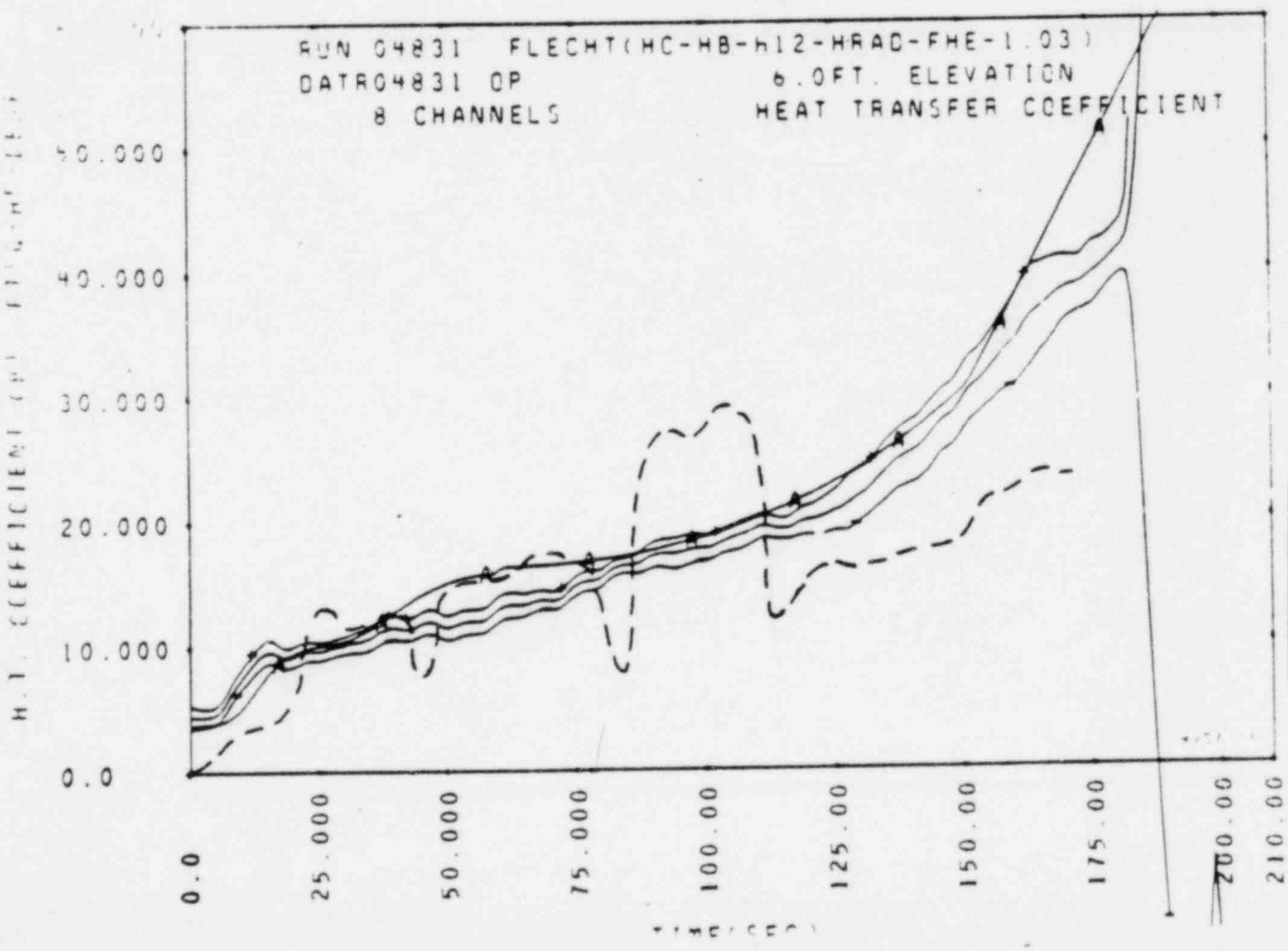


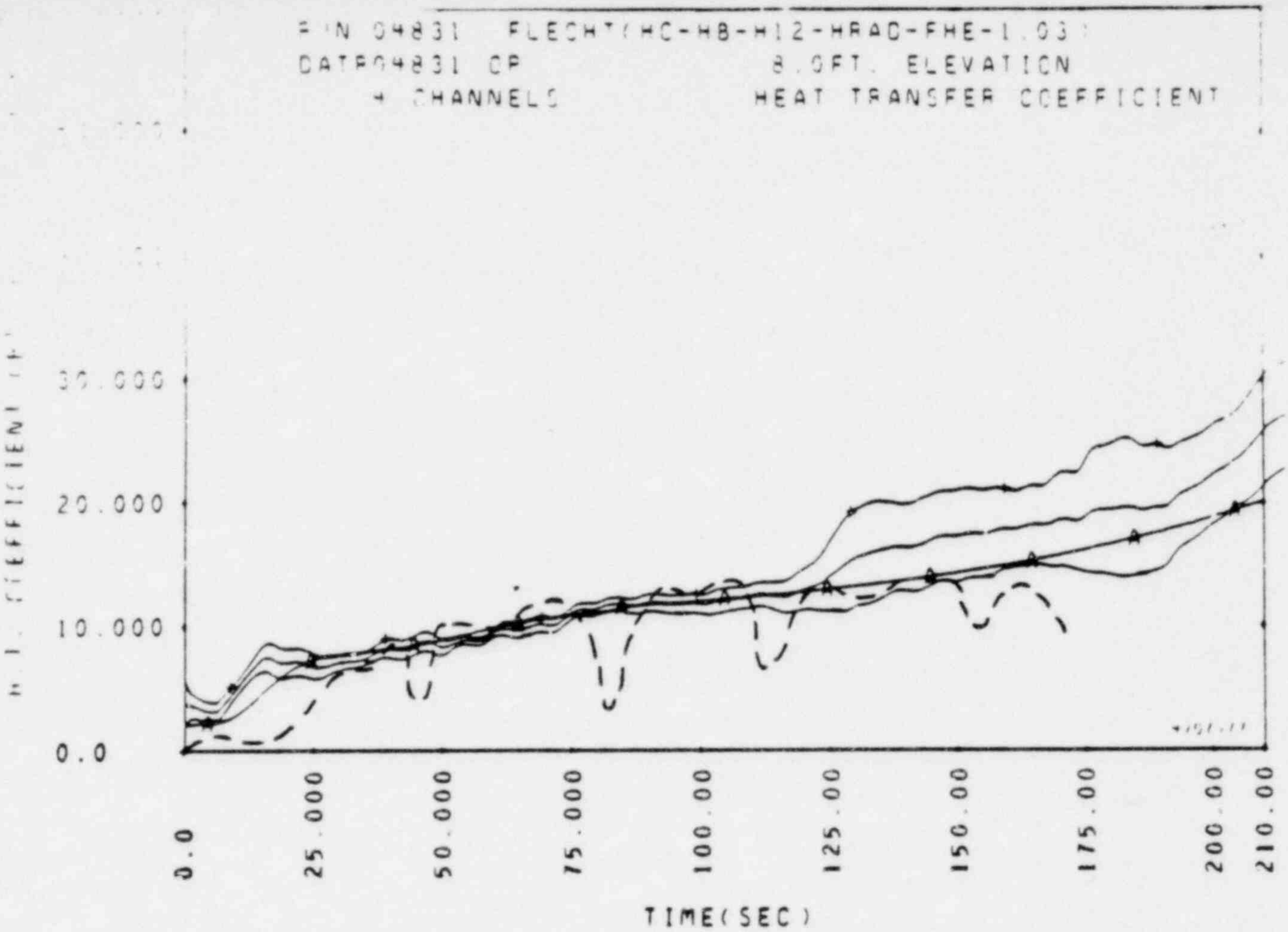
RUN 06638 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR06638 OP .
6 CHANNELS
6.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT (BTU/FT-SQ-HR-DEGF)
0.0
10.000
20.000
30.000
40.000
50.000
60 000
0.0
100.00
200.00
300.00
400.00
500.00
534.00
TIME(SEC)

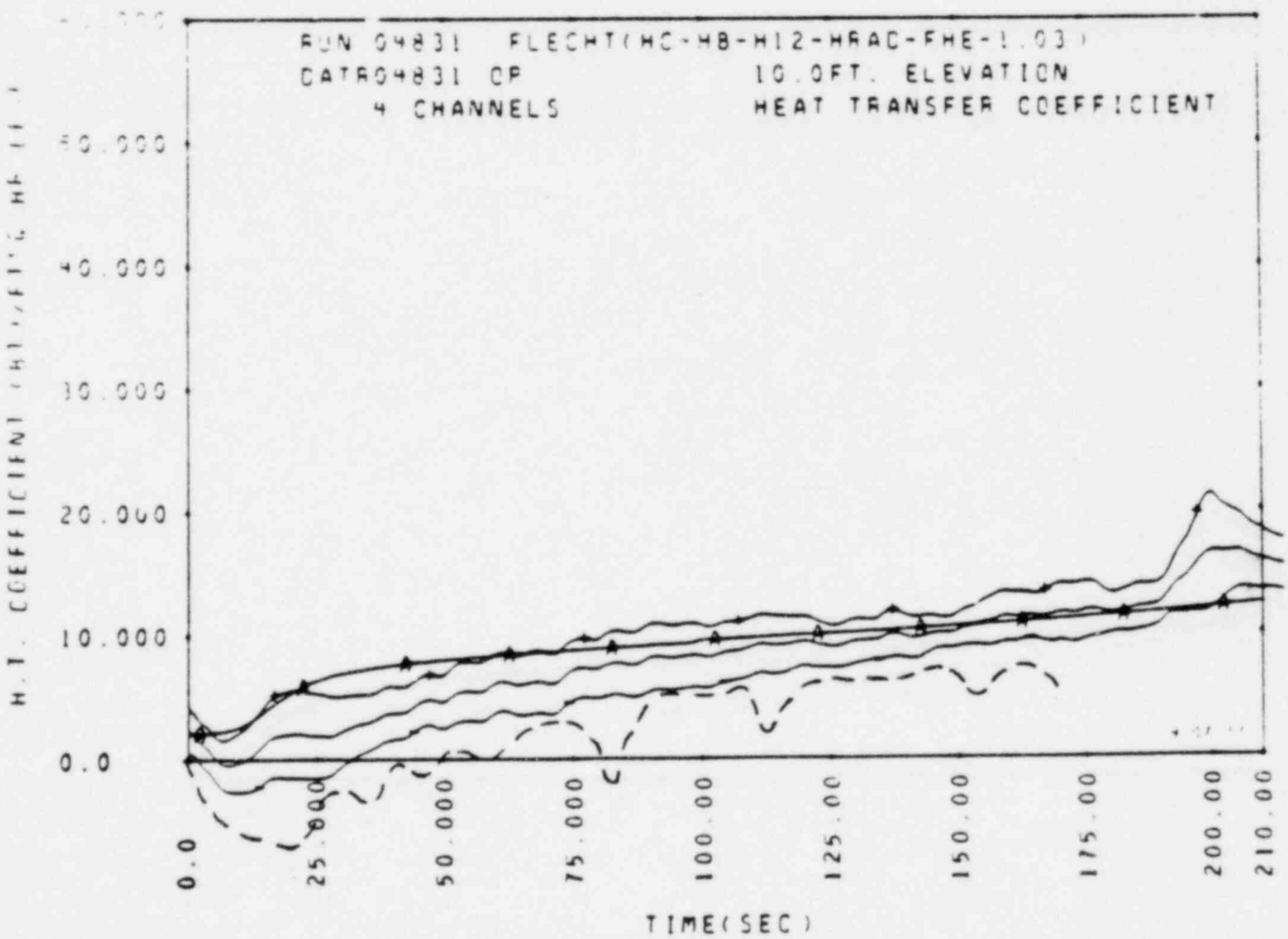

RUN 06638 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR06638 OP
4 CHANNELS
8.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT (BTU/FT SQ HR-DEGF)
50.000
40.000
30.000
20.000
10.000
0.0
0.0
100.00
200.00
300.00
400.00
500.00
534.00
TIME(SEC)


RUN 06638 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR06638 OP
4 CHANNELS
10.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT (BTU/FTSQ-HR-DEGF)
50.000
40.000
30.000
20.000
10.000
0.0
0.0
100.00
200.00
300.00
400.00
500.00
534.00


RUN 04831 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR04831 OP
4 CHANNELS
4.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT (BTU/
0.0
10.000
20.000
30.000
40.000
TIME(SEC)
0.0
25.000
50.000
75.000
100.00
125.00
150.00
175.00
200.00
210.00


RUN 04831 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR04831 OP
8 CHANNELS
6.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT
0.0
10.000
20.000
30.000
40.000
50.000
0.0
25.000
50.000
75.000
100.00
125.00
150.00
175.00
200.00
210.00


RUN 04831 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR04831 CP
4 CHANNELS
8.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT
30.000
20.000
10.000
0.0
25.000
50.000
75.000
100.00
125.00
150.00
175.00
200.00
210.00
TIME(SEC)


RUN 04831 FLECHT(HC-HB-H12-HRAD-FHE-1.03)
DATR04831 CP
4 CHANNELS
10.0FT. ELEVATION
HEAT TRANSFER COEFFICIENT
H.T. COEFFICIENT
50.000
40.000
30.000
20.000
10.000
0.0
25.000
50.000
75.000
100.00
125.00
150.00
175.00
200.00
210.00
TIME(SEC)

SECTION 5

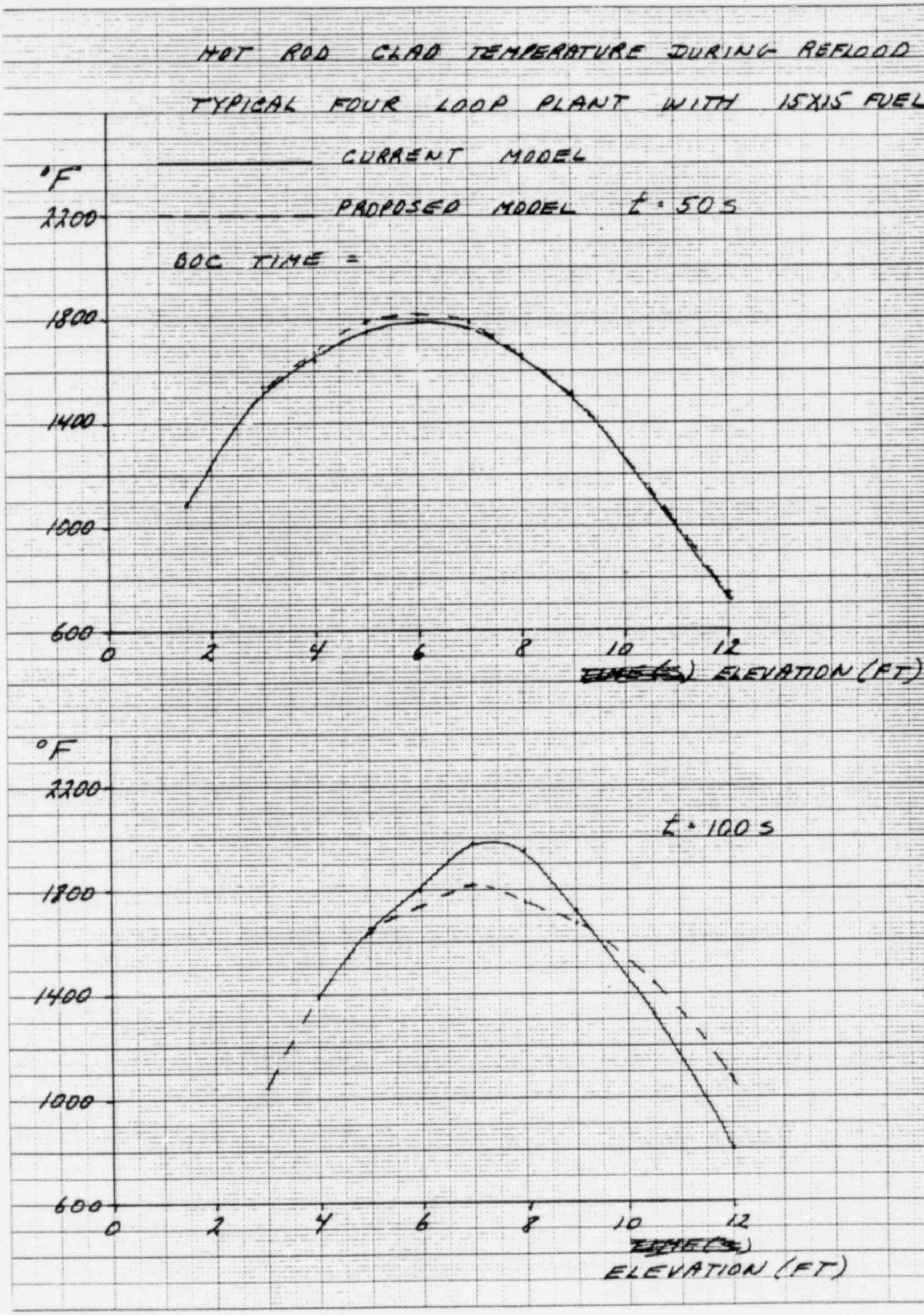
4) Is there any means of comparing the levels of Z_q and Z_s produced by WREFLOOD and BART for the same reflood analysis. The WREFLOOD/BART incompatibaility is not clear. The level calculations in WREFLOOD are done in BART, why not use them?

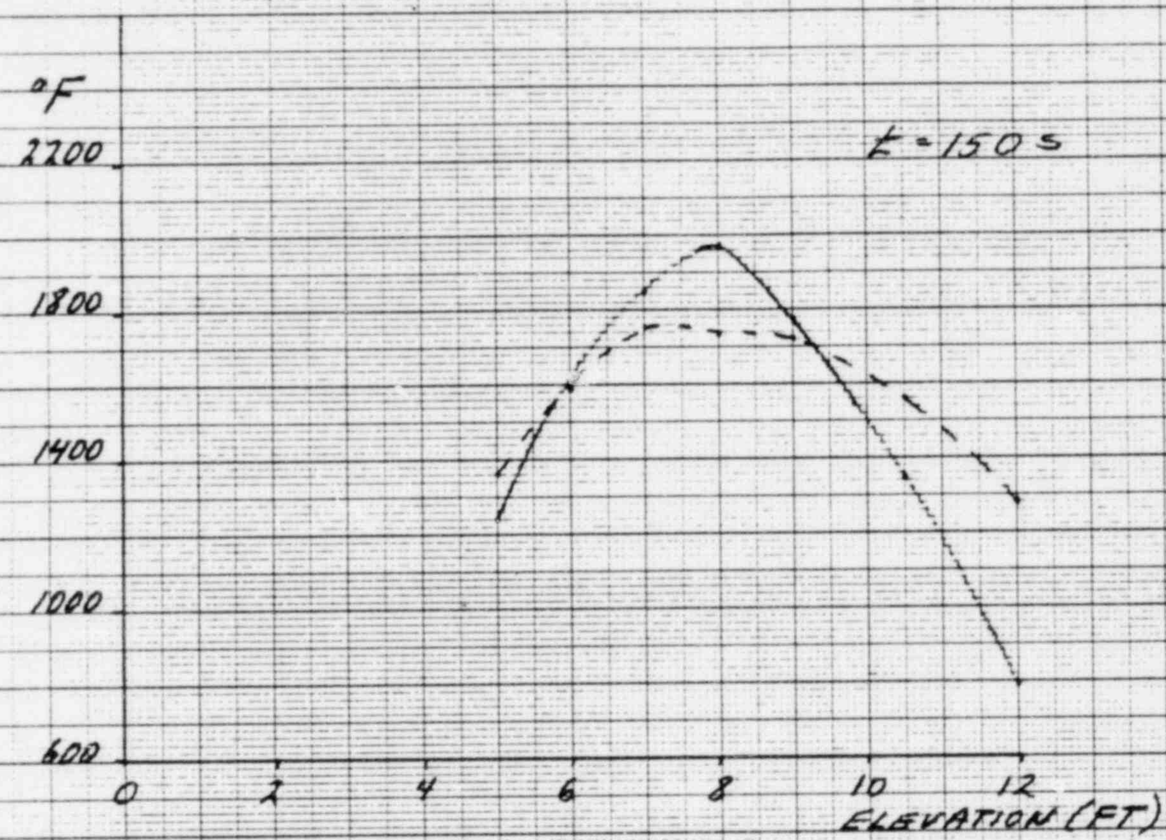
The levels calculated by BART cannot be directly compared with WREFLOOD because BART calculates conditions in the hot assembly, while WREFLOOD calculates conditions in the average assembly.

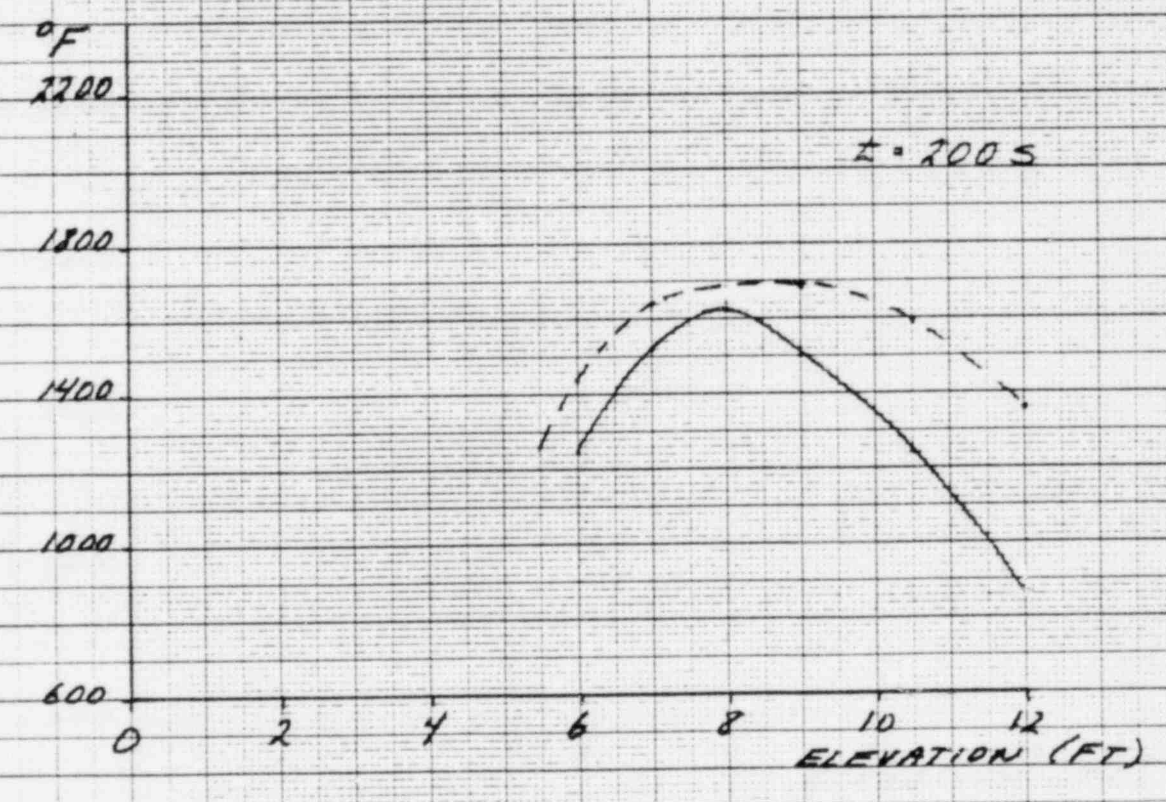
SECTION 5

5.) Provide the comparisons of the peak clad temperatures using both the current ECCS evaluation model package and the proposed model.

Figures 1 to 4 show the hot rod acial temperature distribution from beginning of reflood to turn around for a typical four loop plant. The clad temperatures were calculated using the flooding rates shown in the response to question 2.


HOT ROD CLAD TEMPERATURE DURING REFLOOD
TYPICAL FOUR LOOP PLANT WITH 15X15 FUEL
CURRENT MODEL
PROPOSED MODEL
t = 50 s
BOC TIME =
°F
2200
1800
1400
1000
600
0
2
4
6
8
10
12
~~TIME(S)~~ ELEVATION (FT)
°F
2200
t = 100 s
1800
1400
1000
600
0
2
4
6
8
10
12
~~TIME(S)~~
ELEVATION (FT)


°F
2200
1800
1400
1000
600
t = 150 s
0
2
4
6
8
10
12
ELEVATION (FT)


°F
2200
1800
1400
1000
600
t = 200 s
0
2
4
6
8
10
12
ELEVATION (FT)

SECTION 6.0

1) It was understood that BART required a flooding rate as input. Describe how the BART flooding rate prediction in Figures 6.1 and 6.4 was developed.

   The flooding rates predicted in Figure 6.1 and 6.4 were calculated using the WREFLOOD code. The procedure described in Section 5.1 was used.

SECTION 6

2.) The clad wall temperature comparison graphs in Figure 6.2 and 6.5 do not include elevations or rod identification. A more complete and detailed data presentation is needed.

More detailed and complete versions of the data presented in Figures 6.2 and 6.5 are included in the response to question 3.

SECTION 6

3.) How does one account for the substantial clad surface temperature over-prediction of Figure 6.2 and 6.5?

The major cause of the large clad surface temperature over-predictions of Figure 6.2 and 6.5 is the failure of the WREFLOOD-generated flooding rates to include the large initial injection rates that occured in FLECHT-SET runs 3105B and 2714B. The discrepencies are apparent in Figure 6.1 and 6.4.

To demonstrate this effect, BART was re-run for FS3105B and 2714B. The single modification made to the respective inputs is an "augmented" flooding rate history which includes the high initial flooding rates. This modification is shown graphically on the accompanying versions of Figures 6.1 and 6.4

The improvement in peak clad temperature predictions due to the modified flooding rate profiles is shown in the attached plots of clad temperature. These plots give the same basic information as the less explicit Figure 6.2 and 6.5 in the BART - A1 report.

At the six-foot elevation, graphs are presented for the hottest rod, the average rod (after which the BART calculated rod was modelled and to which the BART rod is most comparable) and the coolest rod. The selections were made from sixteen available thermocouple channels at the six-foot elevation.

At the eight-foot elevation, graphs for all available thermocouple channels are presented.

RUN NUMBER	3105B
CONTAINMENT PRESSURE	59 PSIA
INITIAL CLAD TEMPERATURE	1100°F
PEAK POWER •	0.84 KW/FT
AVERAGE HOUSING TEMPERATURE	306°F
COOLANT TEMPERATURE	157°F
INJECTION RATE	12.3 LBM/SEC FOR 14 SEC VARIABLE TO END

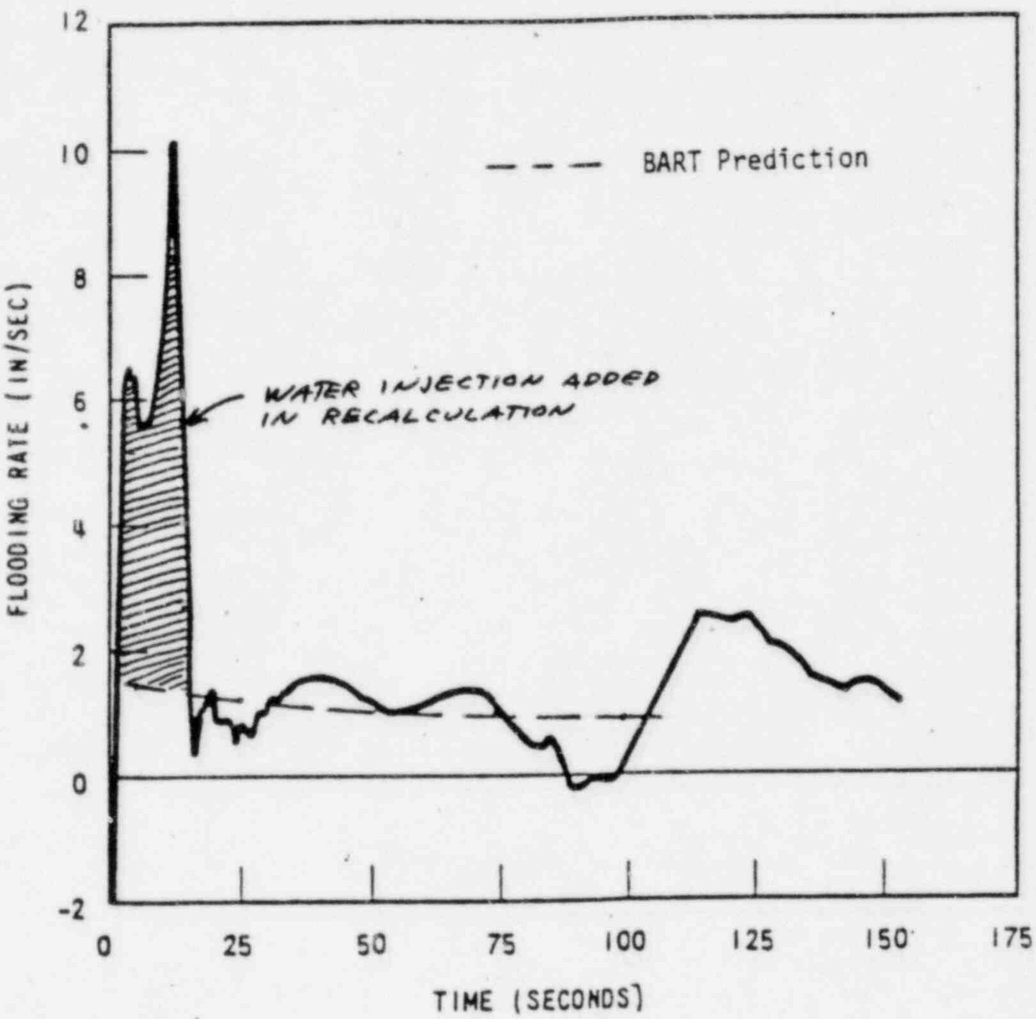
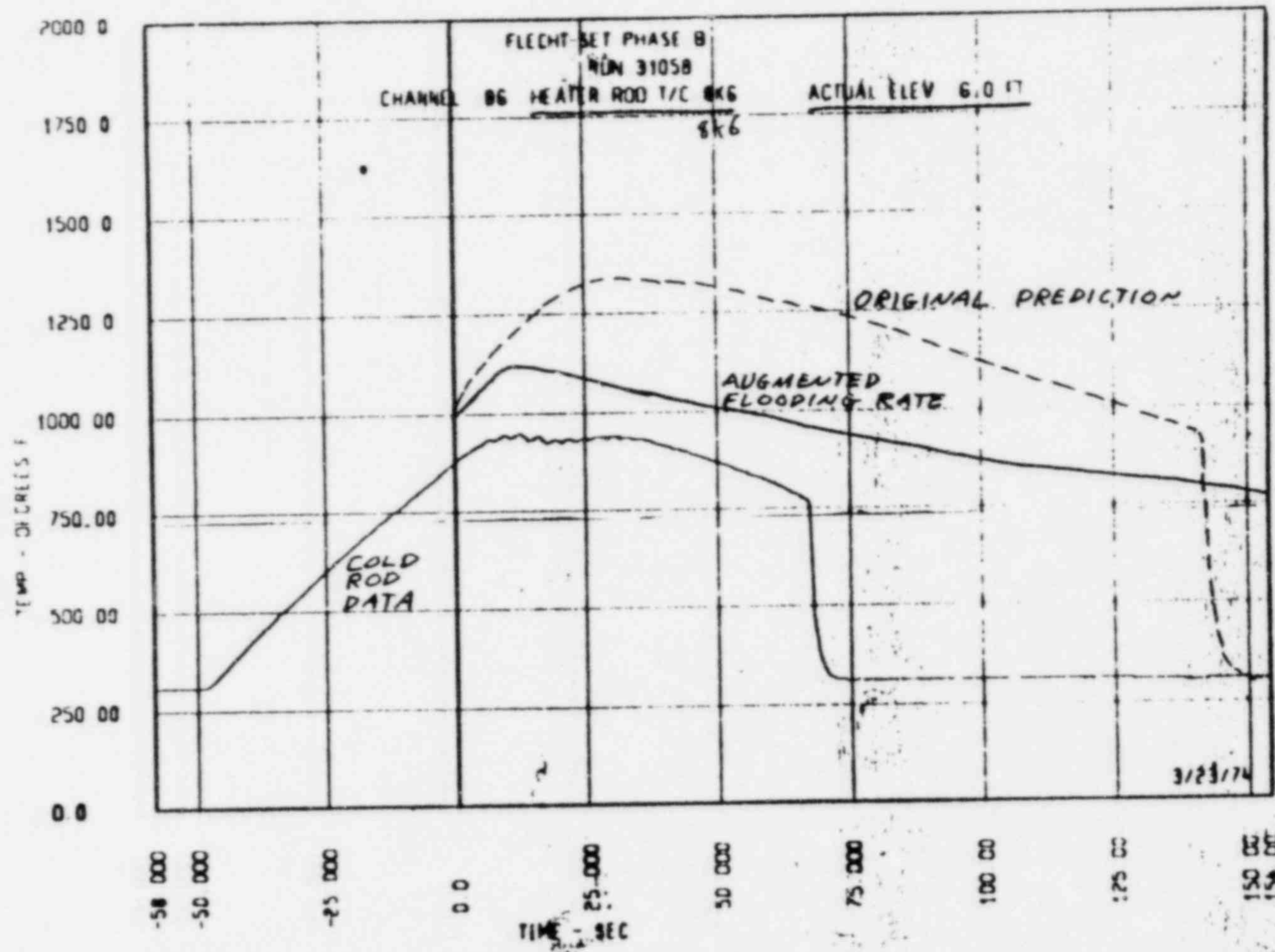


Figure 6-1 Flooding Rate Into Test Section Calculated for Run 3105B Expressed as Inches/Second

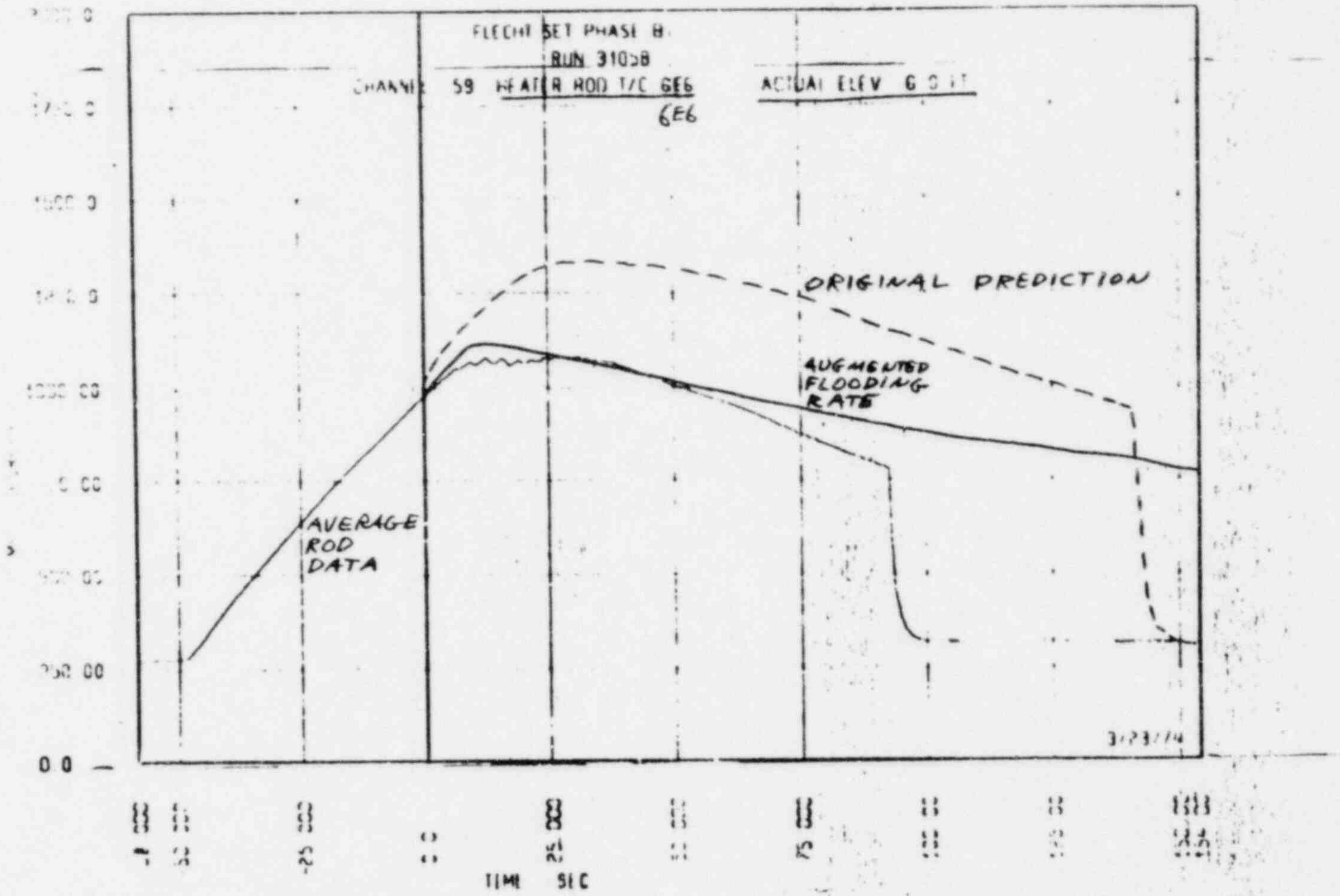


BART PREDICTION VS. F/S 31058
6' ELEVATION

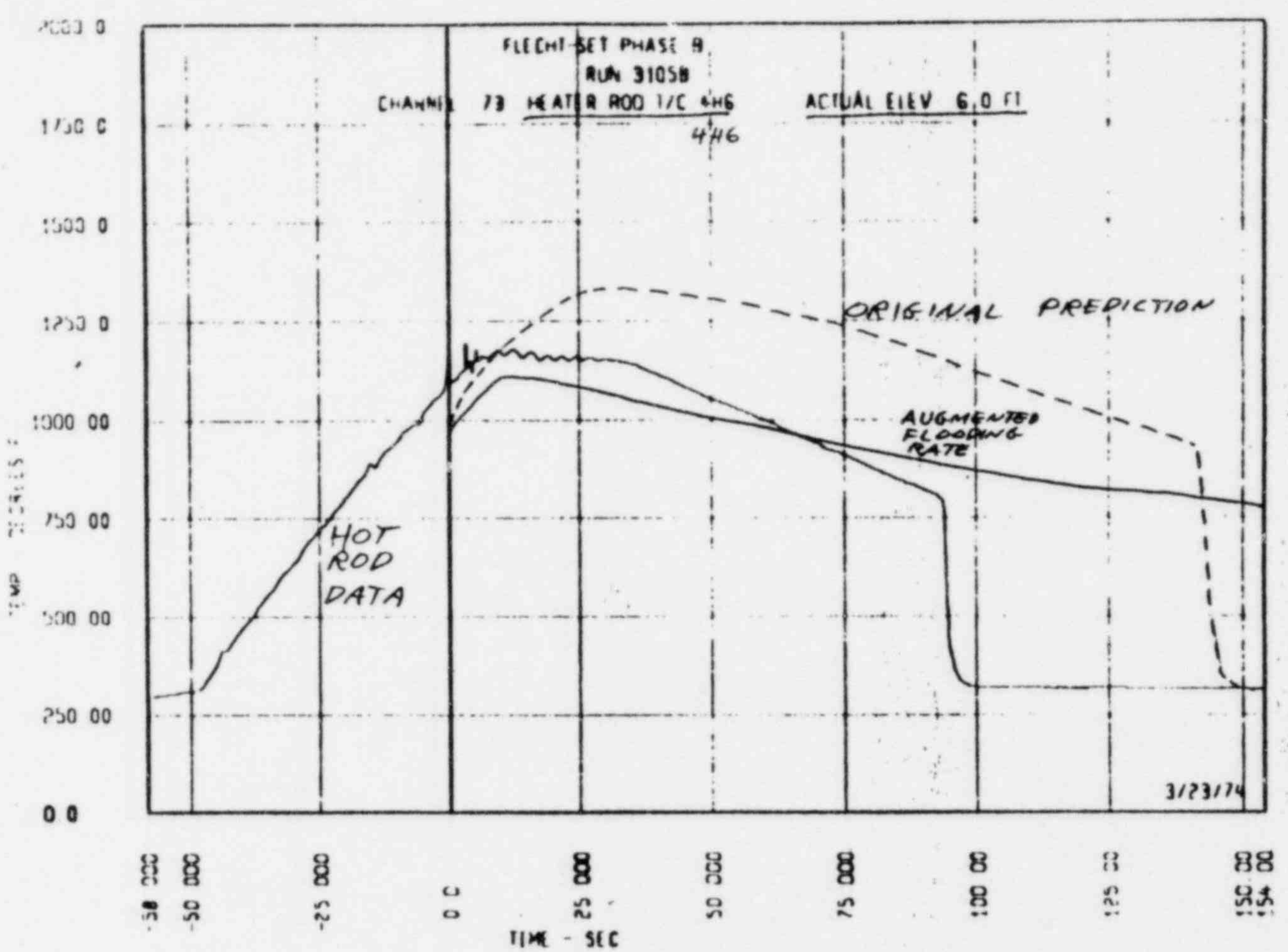
At late times in the transients the inability of BART to calculate rod quenching from the top of the core down retards the temperature drop at unquenched locations along the rod. This effect is more severe at higher elevations.

A discrepency between the accumulator mass depletion and the measured flow totalling 48 pounds at the end of the FS 2714B test has been noted. It translates to a lower calculated flooding rate for the test and a lower input flooding rate for the BART prediction of that test.

As a final exercise, BART was rerun with a flooding rate calculated to include the water unaccounted for in the original test. The further improvement of the BART temperature calculation demonstrates how important an accurate input flooding rate is in determining the accuracy of the entire BART model prediction.

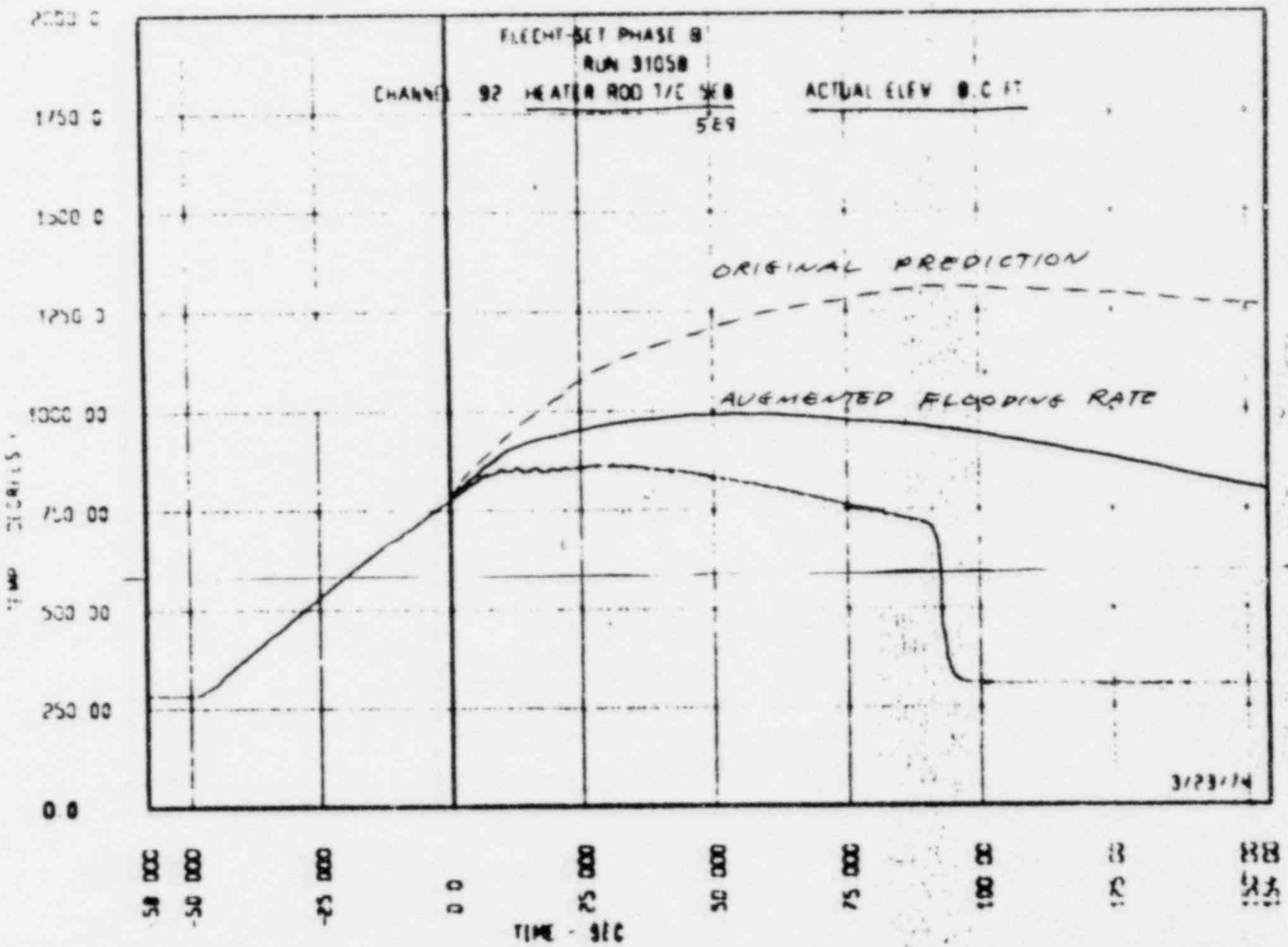


BART PREDICTION VS. F/S 3105B
6' ELEVATION



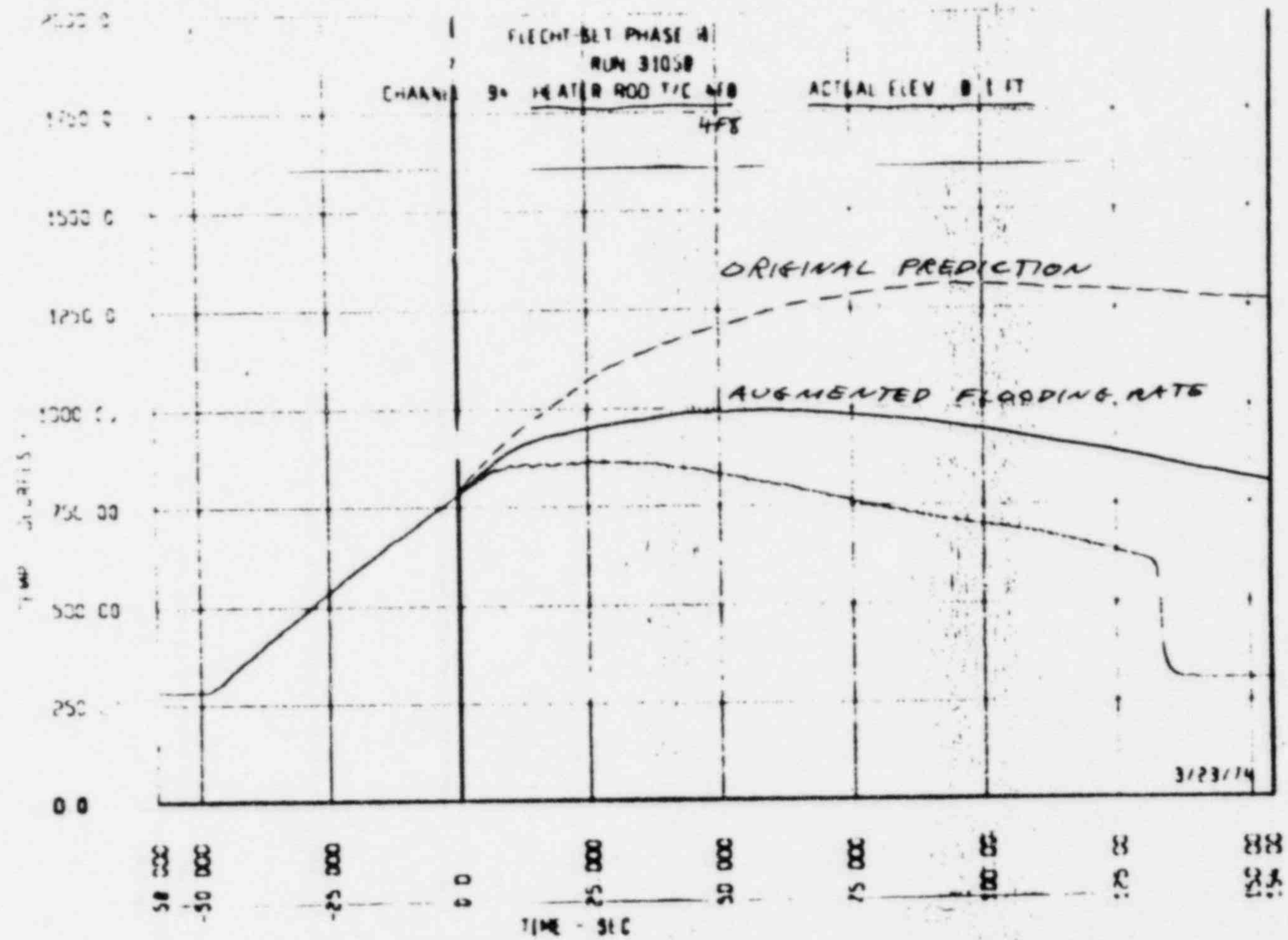
BART PREDICTION VS. F/S 3105B

6' ELEVATION.



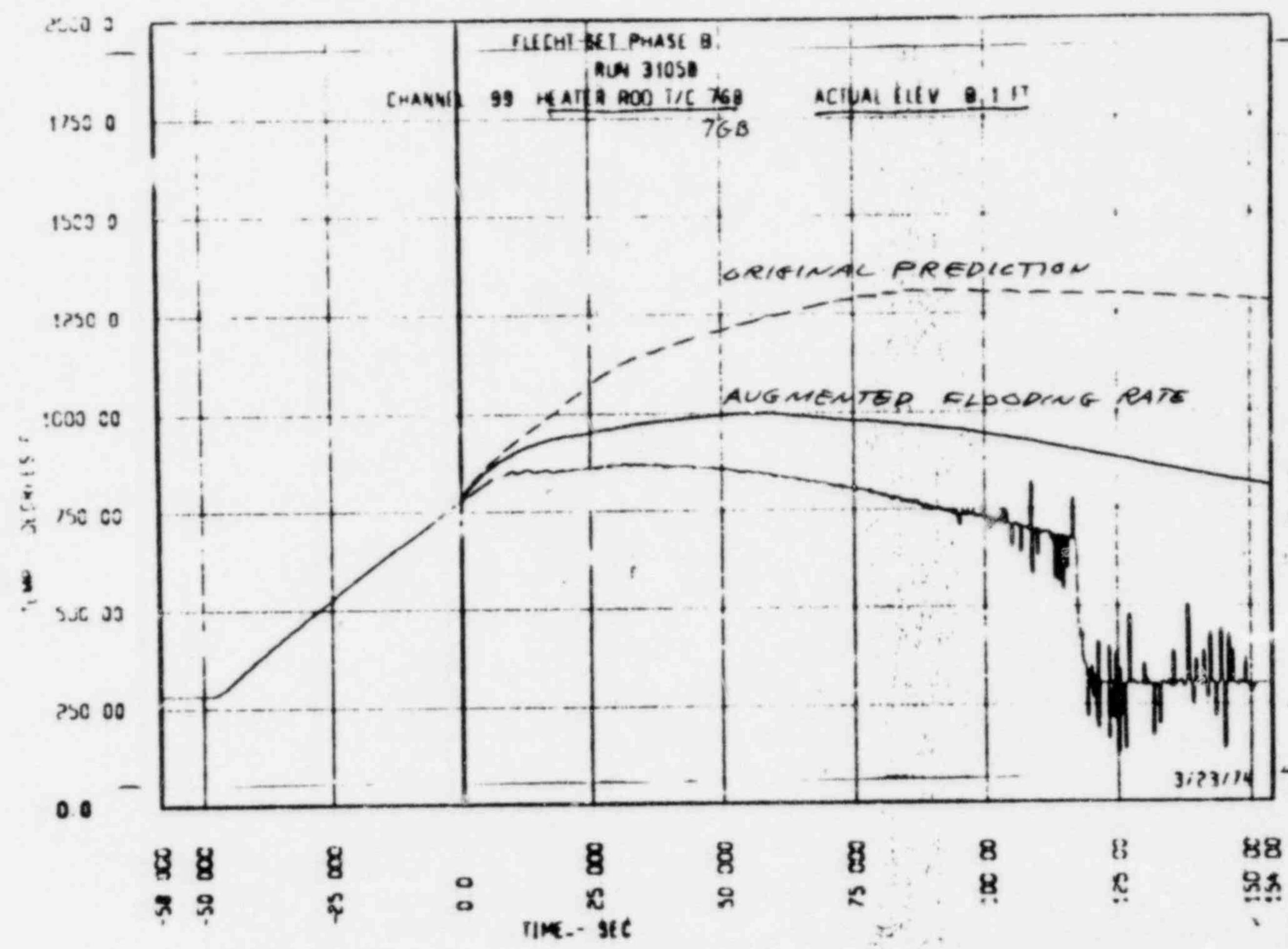
BART PREDICTION VS. F/S 3105B

8' ELEVATION



BART PREDICTION vs. F/S 3105B

8' ELEVATION



BART PREDICTION vs. F/S 3105B

8' ELEVATION

RUN NUMBER	27148
CONTAINMENT PRESSURE	20 PSIA
INITIAL CLAD TEMPERATURE	1100°F
PEAK POWER	0.84 KW/FT
AVERAGE HOUSING TEMPERATURE	249°F
COOLANT TEMPERATURE	153°F
INJECTION RATE	12.2 LBM/SEC FOR 11 SEC VARIABLE TO END

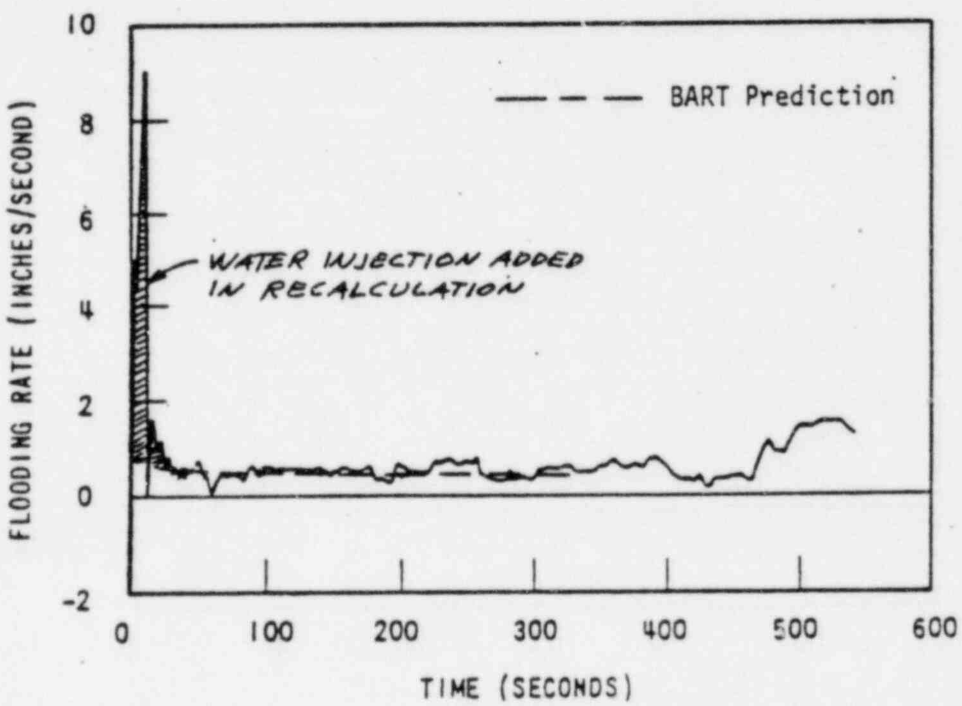
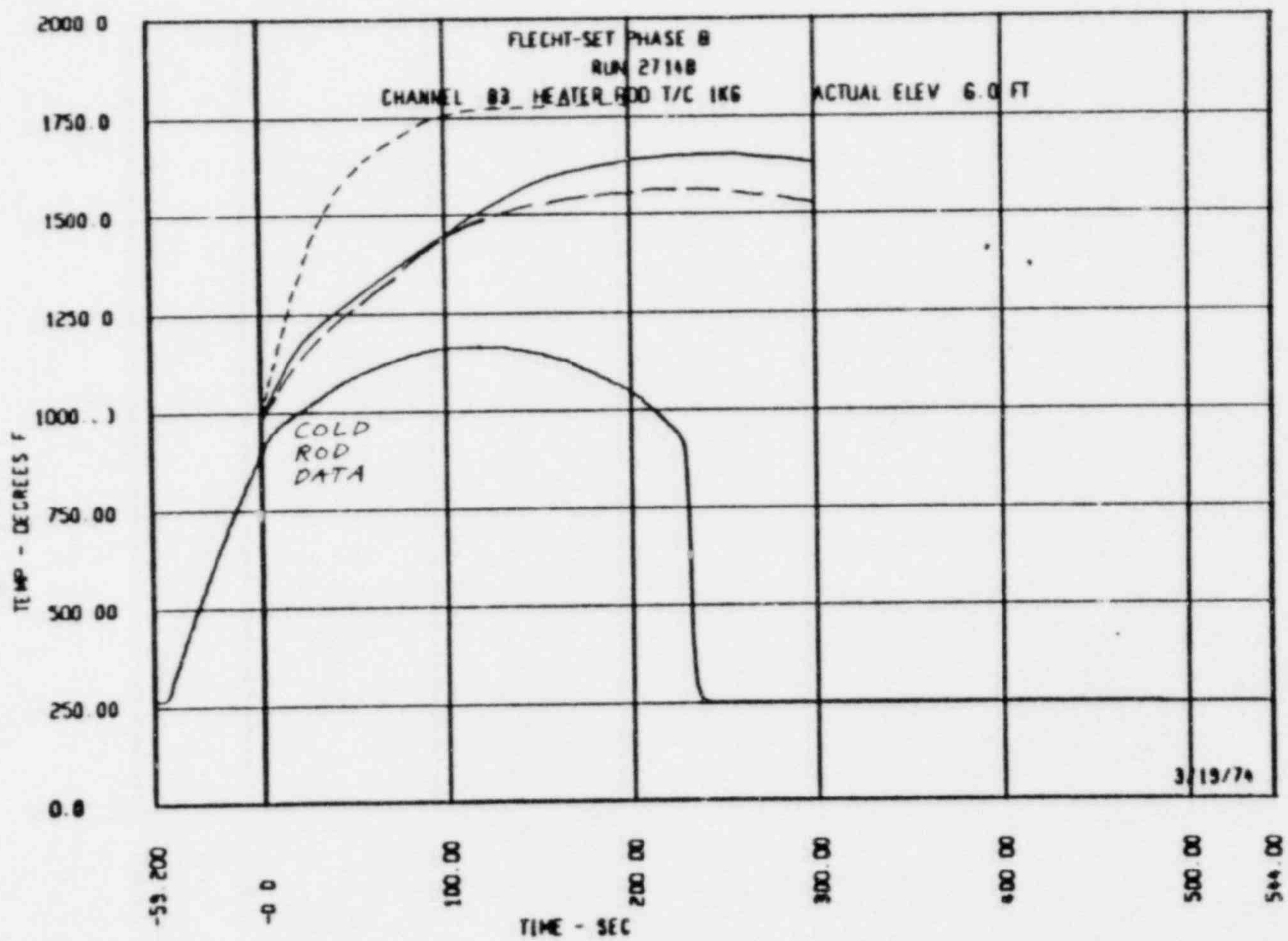


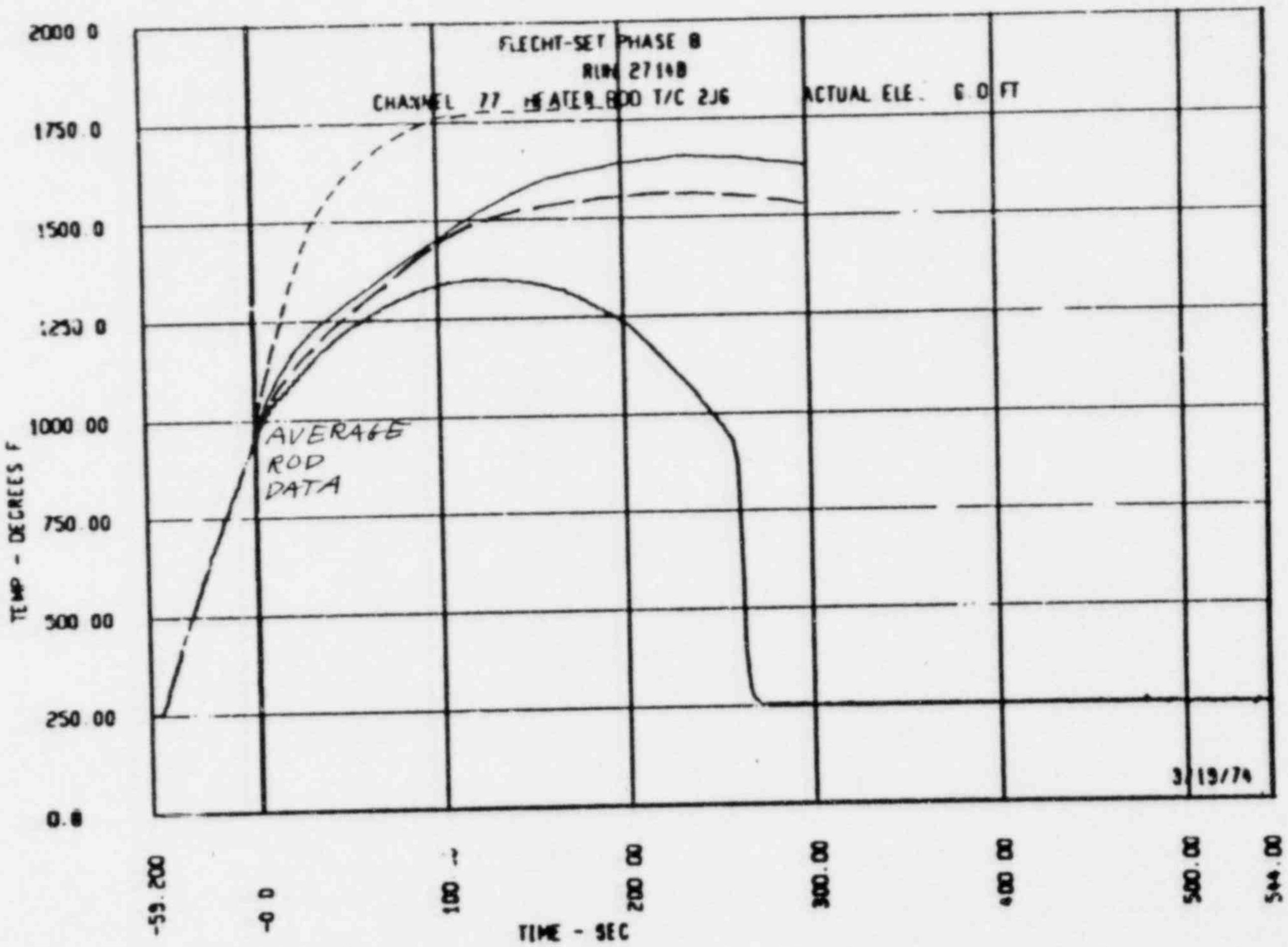
Figure 6-4 Flooding Rate Into Test Section Calculated for Run 27148 Expressed as Inches/Second



BART PREDICTION VS. F/S 2714B DATA

6' ELEVATION

BART:
- - - - - - ORIGINAL PREDICTION
——— AUGMENTED FLOODING RATE (INITIAL PEAK)
— — — FLOODING RATE INCLUDING 2714B "LOST MASS"



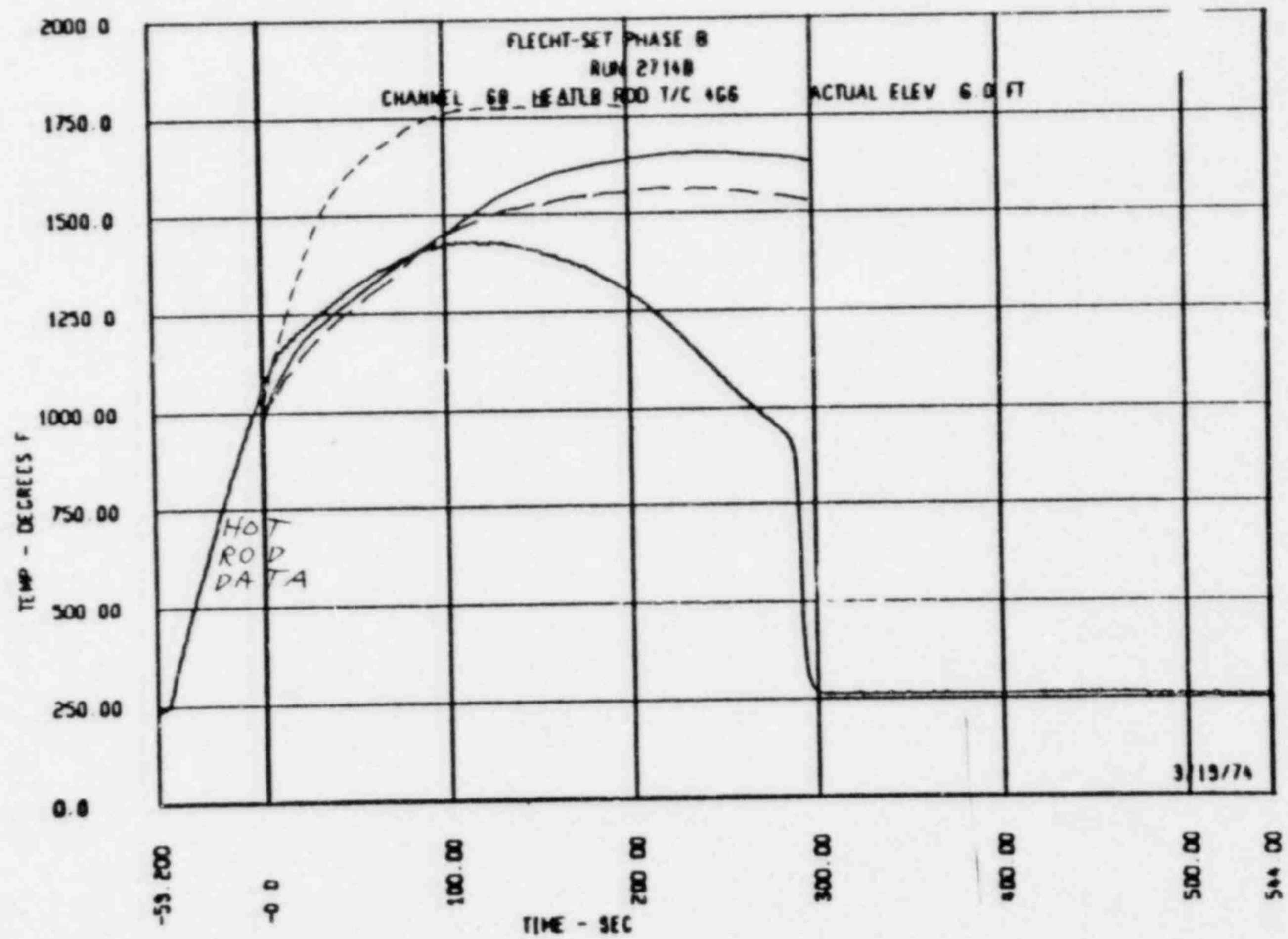
BART PREDICTION VS. F/S 2714B DATA

6' ELEVATION

BART: - - - - - - ORIGINAL PREDICTION

——— AUGMENTED FLOODING RATE (INITIAL PEAK)

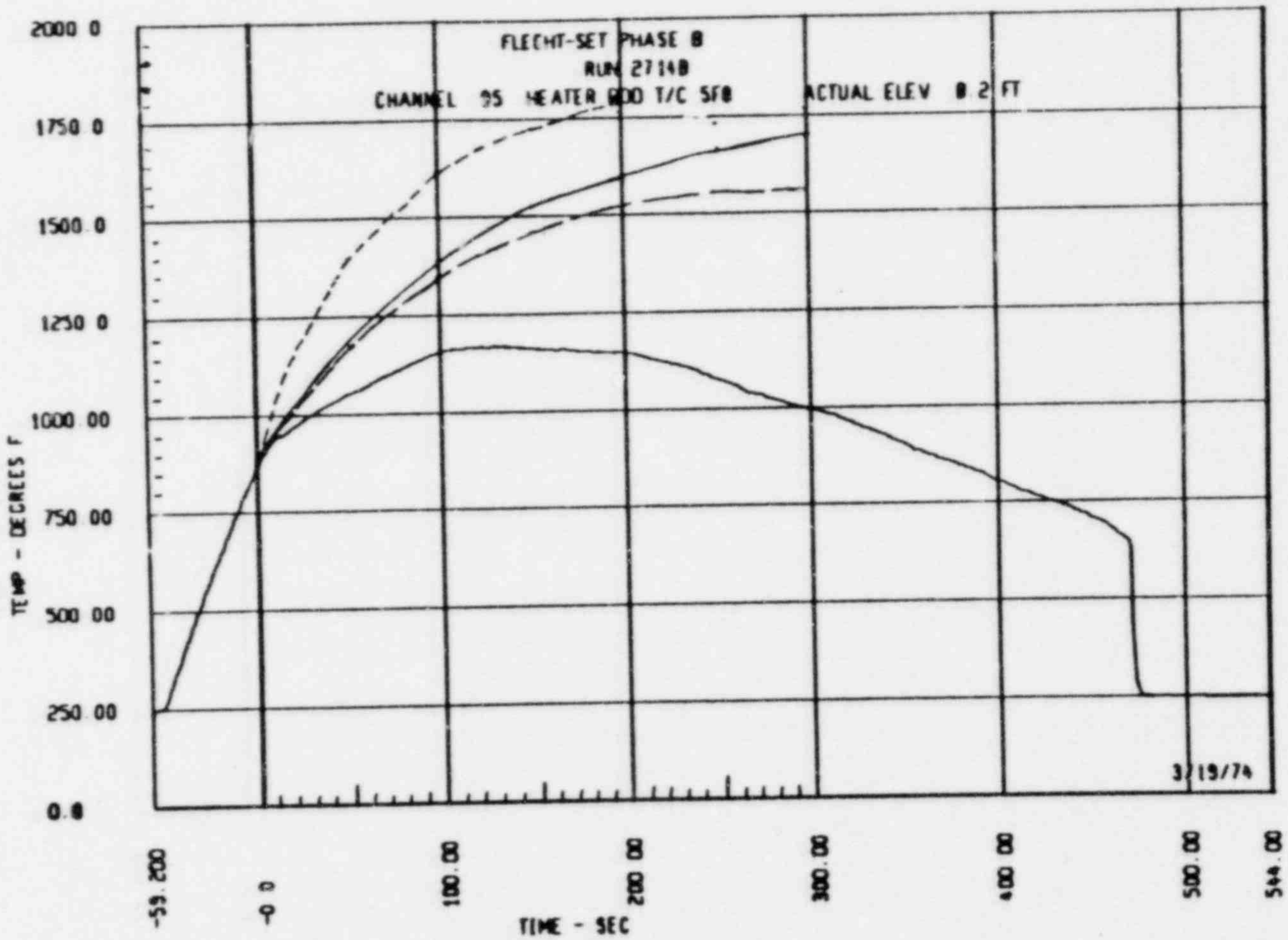
— — — FLOODING RATE INCLUDING 2714B "LOST MASS"



BART PREDICTION VS. F/S 2714B DATA

6' ELEVATION

BART:
- - - - - - ORIGINAL PREDICTION
——— AUGMENTED FLOODING RATE (INITIAL PEAK)
— — — FLOODING RATE INCLUDING 2714B "LOST MASS"



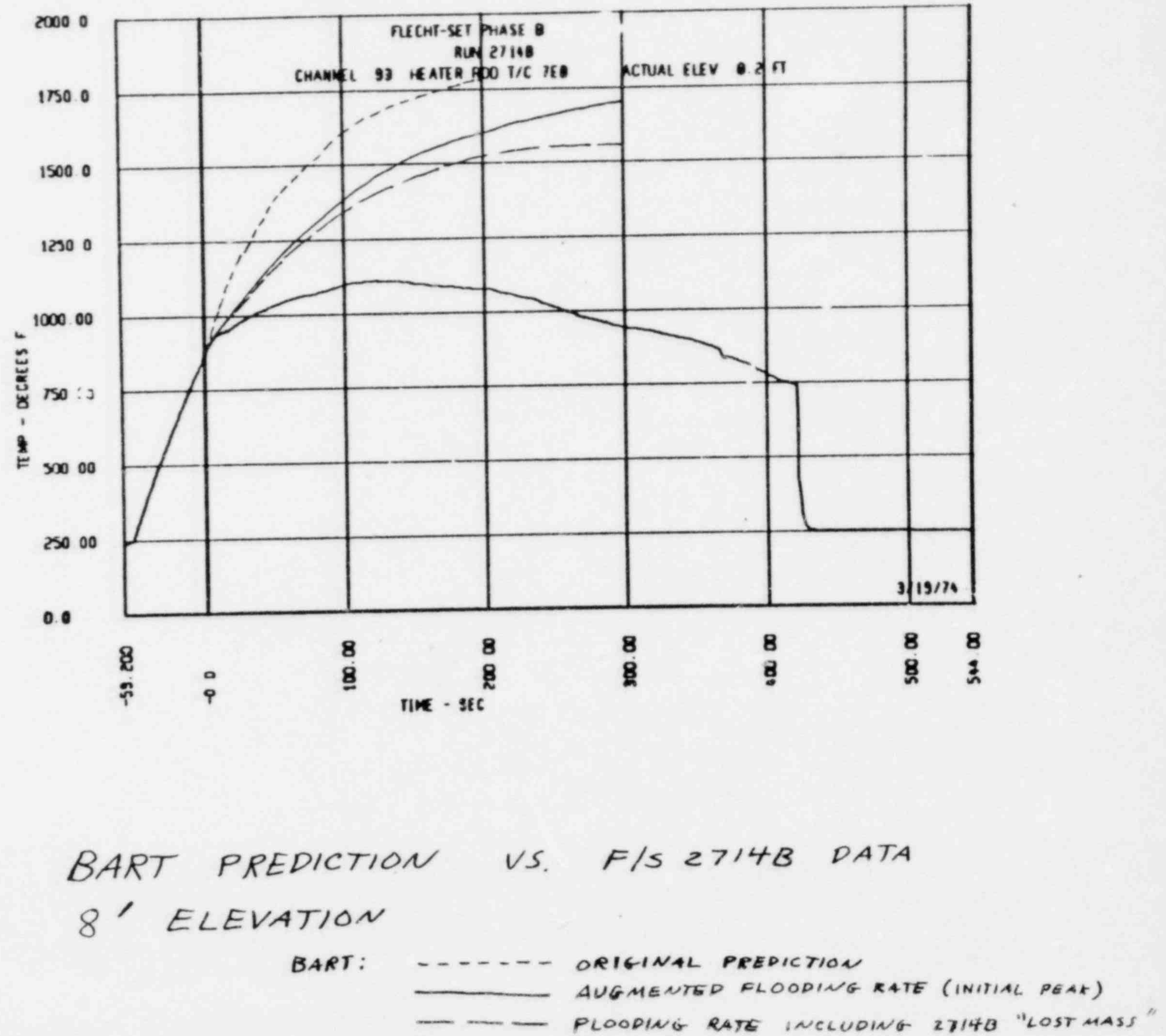
BART PREDICTION VS. F/S 2714B DATA

8' ELEVATION

BART: - - - - - - - ORIGINAL PREDICTION

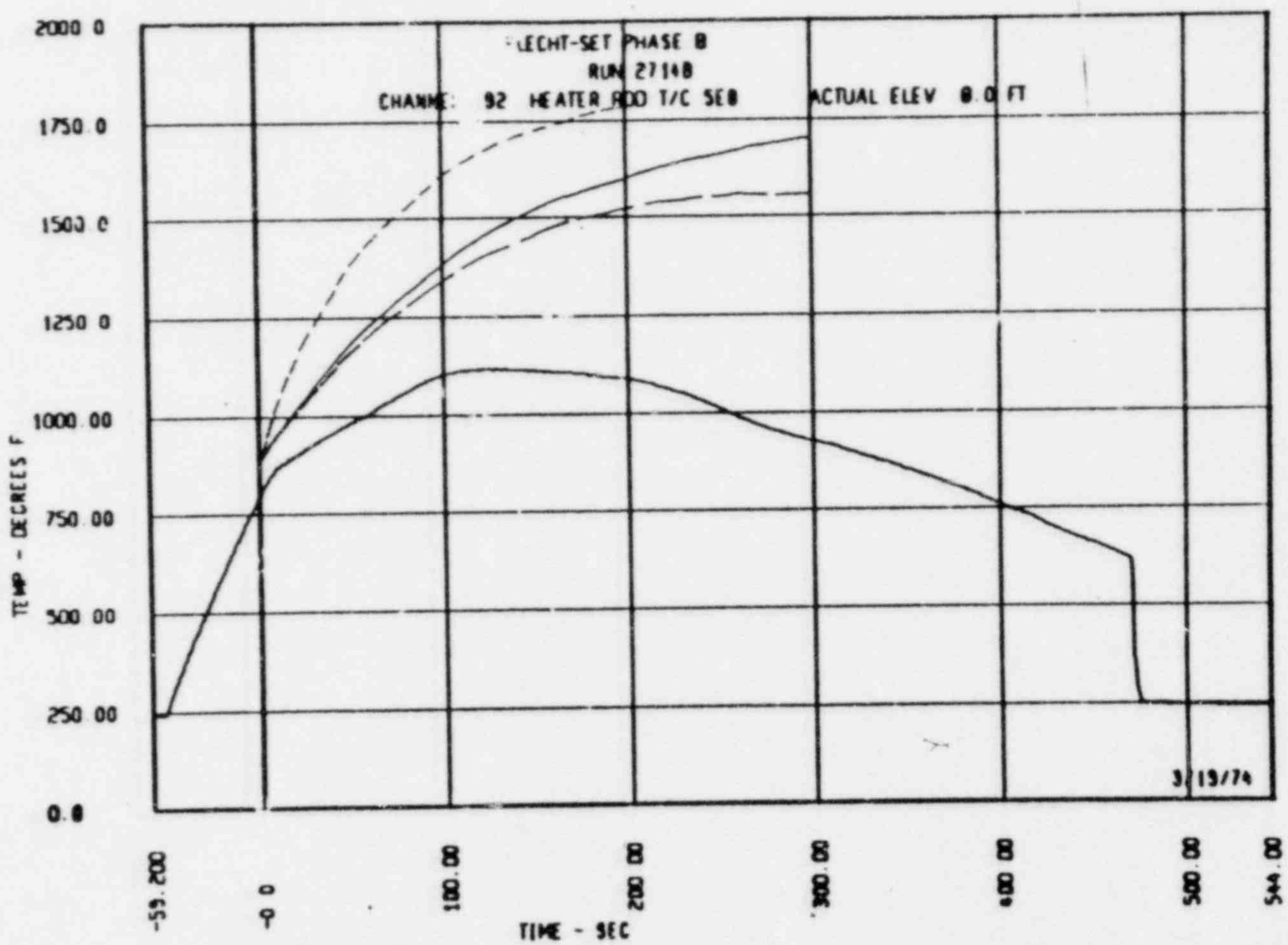
——————— AUGMENTED FLOODING RATE (INITIAL PEAK)

— — — — FLOODING RATE INCLUDING 2714B "LOST MASS"



BART PREDICTION VS. F/S 2714B DATA

8' ELEVATION



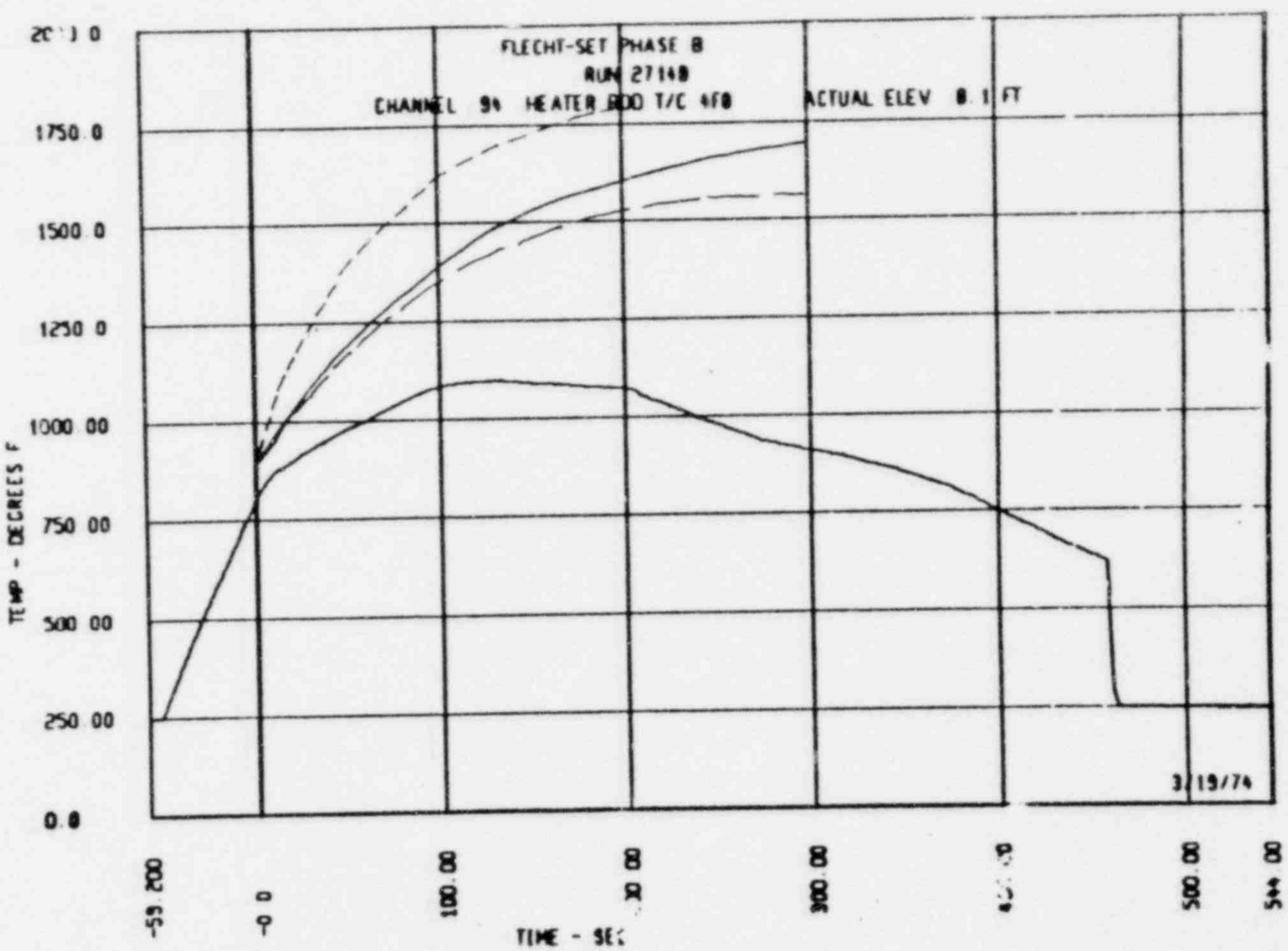
BART PREDICTION VS. F/S 2714B DATA

8' ELEVATION

BART: - - - - - - ORIGINAL PREDICTION

——— AUGMENTED FLOODING RATE (INITIAL PEAK)

— — — FLOODING RATE INCLUDING 2714B "LOST MASS"



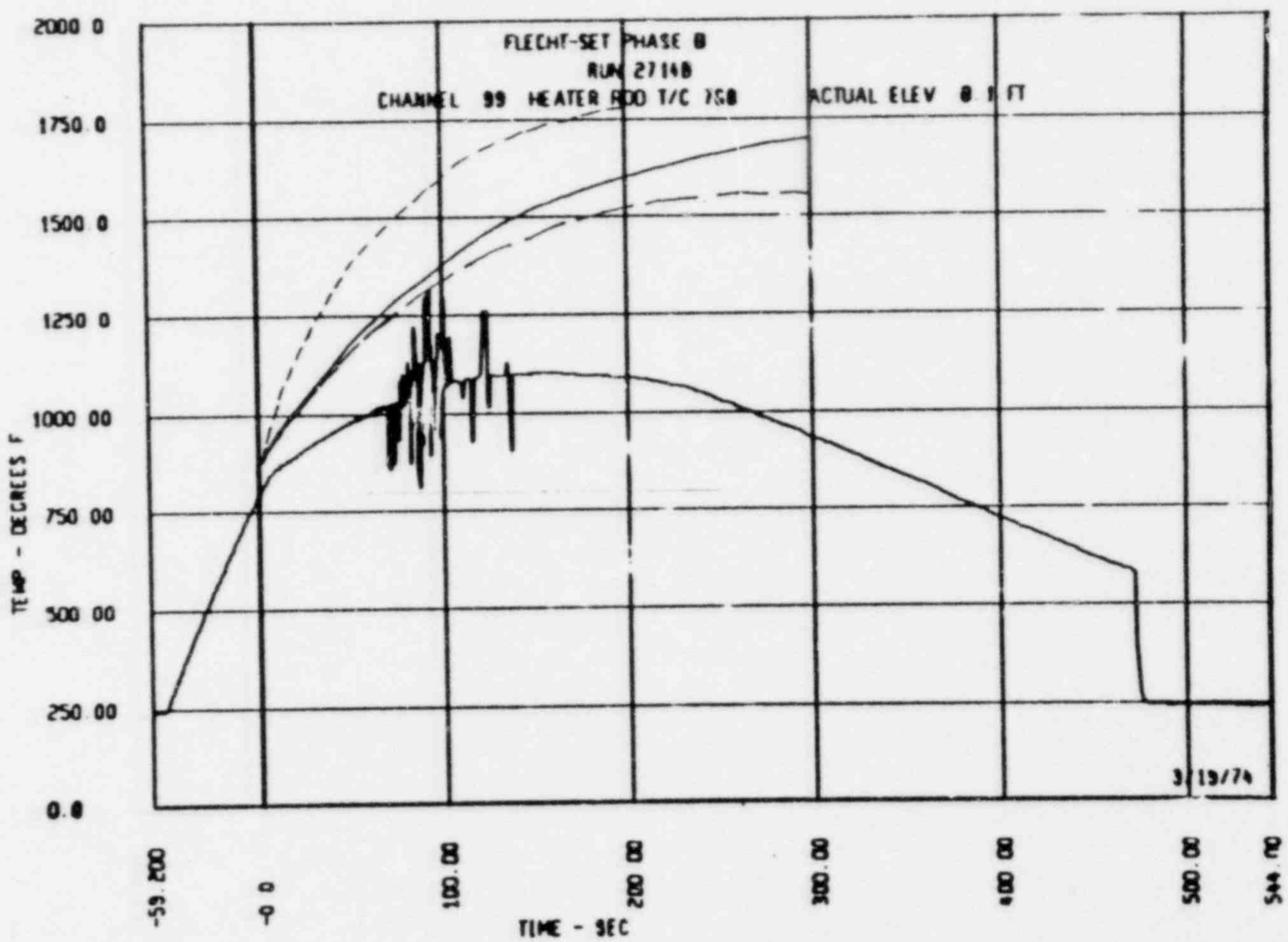
BART PREDICTION VS. F/S 2714B DATA

8' ELEVATION

BART: - - - - - - ORIGINAL PREDICTION

——————— AUGMENTED FLOODING RATE (INITIAL PEAK)

— — — FLOODING RATE INCLUDING 2714B "LOST MASS"



BART PREDICTION VS. F/S 2714B DATA

8' ELEVATION

BART: - - - - - - - ORIGINAL PREDICTION

——————— AUGMENTED FLOODING RATE (INITIAL PEAK)

— — — FLOODING RATE INCLUDING 2714B "LOST MASS".

SECTION 6.0

4.) Provide comparison calculations of the PWR FLECHT SEASET unblocked bundle, forced and gravity reflood tests 32333 and 32234. These comparisons should include but are not restricted to calculations modelling rod 6L in test 32333 and 6K in test 32235; also rods 7J, 8K, 9K and 11E for both tests. Include the input data in the calculations summary.

Table 1 lists the initial and boundary conditions for tests 32333 and 32235. Figure 1 shows the noding scheme, power profile, and initial temperature profile used in the BART calculation. Figures 2 - 5 compare BART predicted clad temperatures to the measured temperature of the rods listed above for test 32333 wherever these measurements are available. A more representative comparison is shown in Figures 6 - 9, where the BART prediction is compared to the mean temperature of all rods more than two rows away from the test housing and dead rods. Similar comparisons are shown in Figures 10 - 13 and 14 - 17 for test 32235. It can be seen that agreement is quite good for these stepped flooding rate tests.

TABLE 1

INITIAL AND BOUNDARY CONDITIONS

TEST	FLOODING RATE (M/S)	PEAK POWER (kw/ft)	PRESSURE (psia)	INLET TEMP (°F)	INITIAL TEMP (°F)
32333	6.36 for 5 s .82 onward	0.7	40	125	1631
32235	6.53 for 5 s .98 for next 200 s .62 onward	0.7	20	88	1630

FIGURE 1 - BART NODING AND INITIAL CONDITIONS

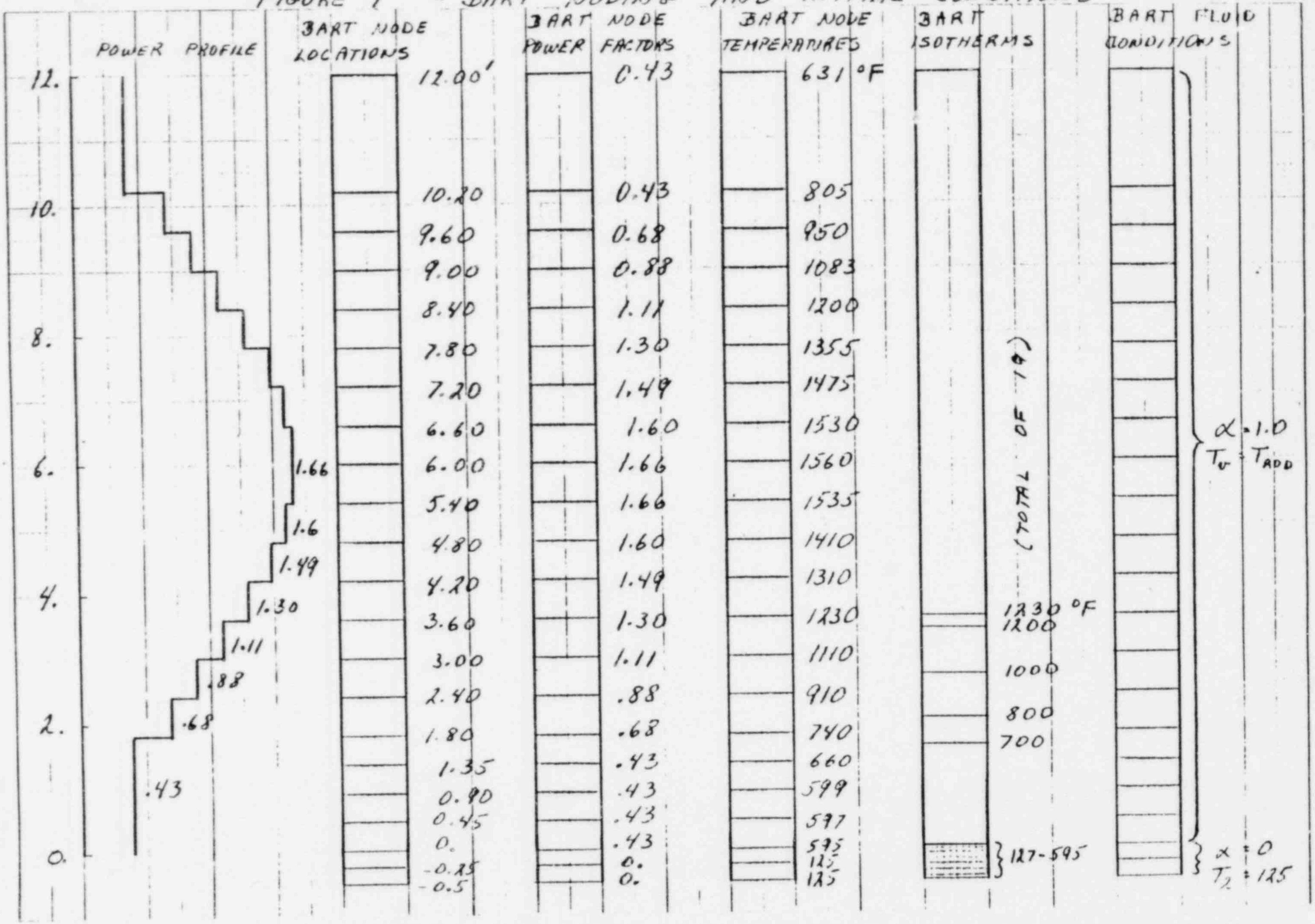


FIGURE 2.

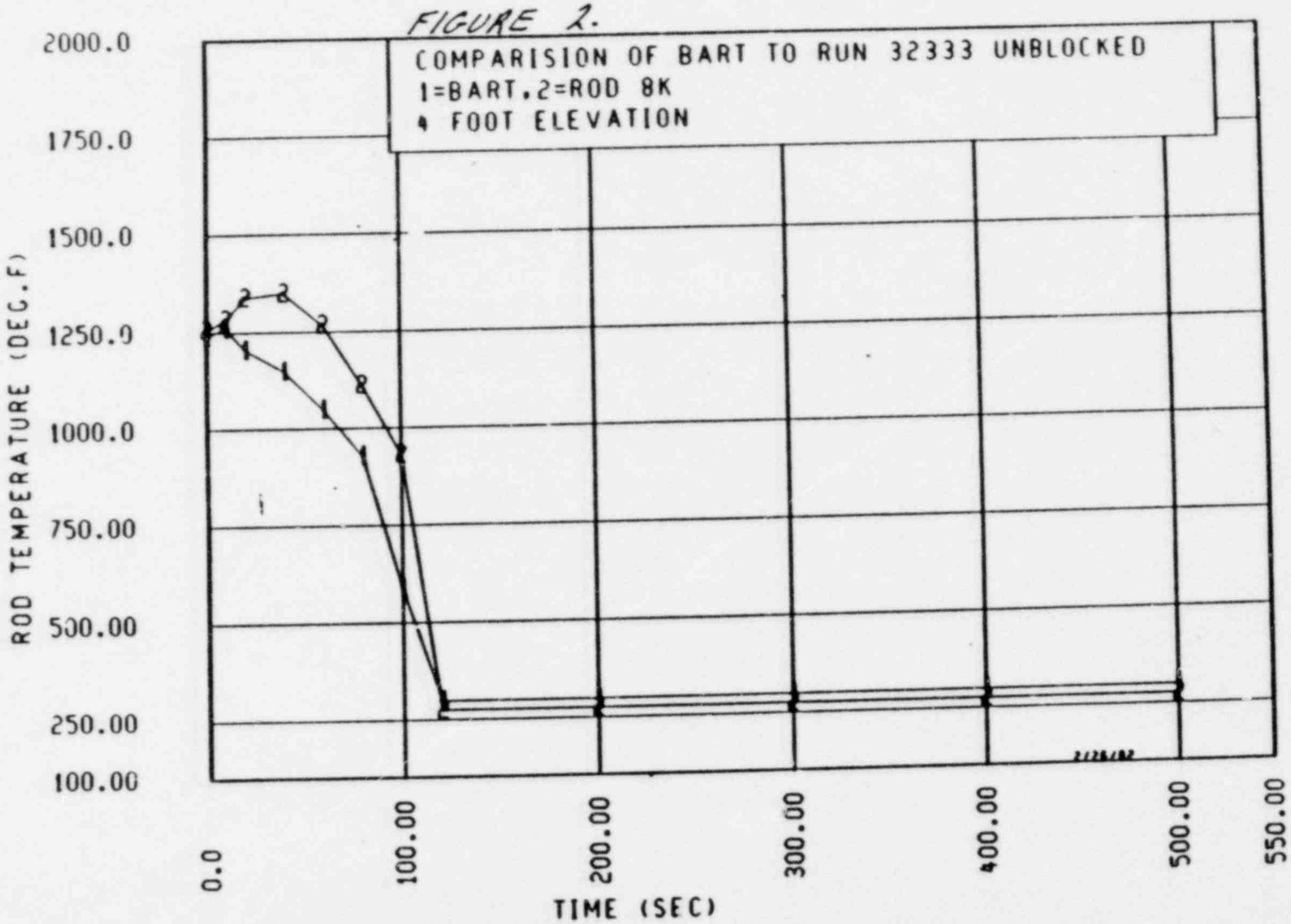
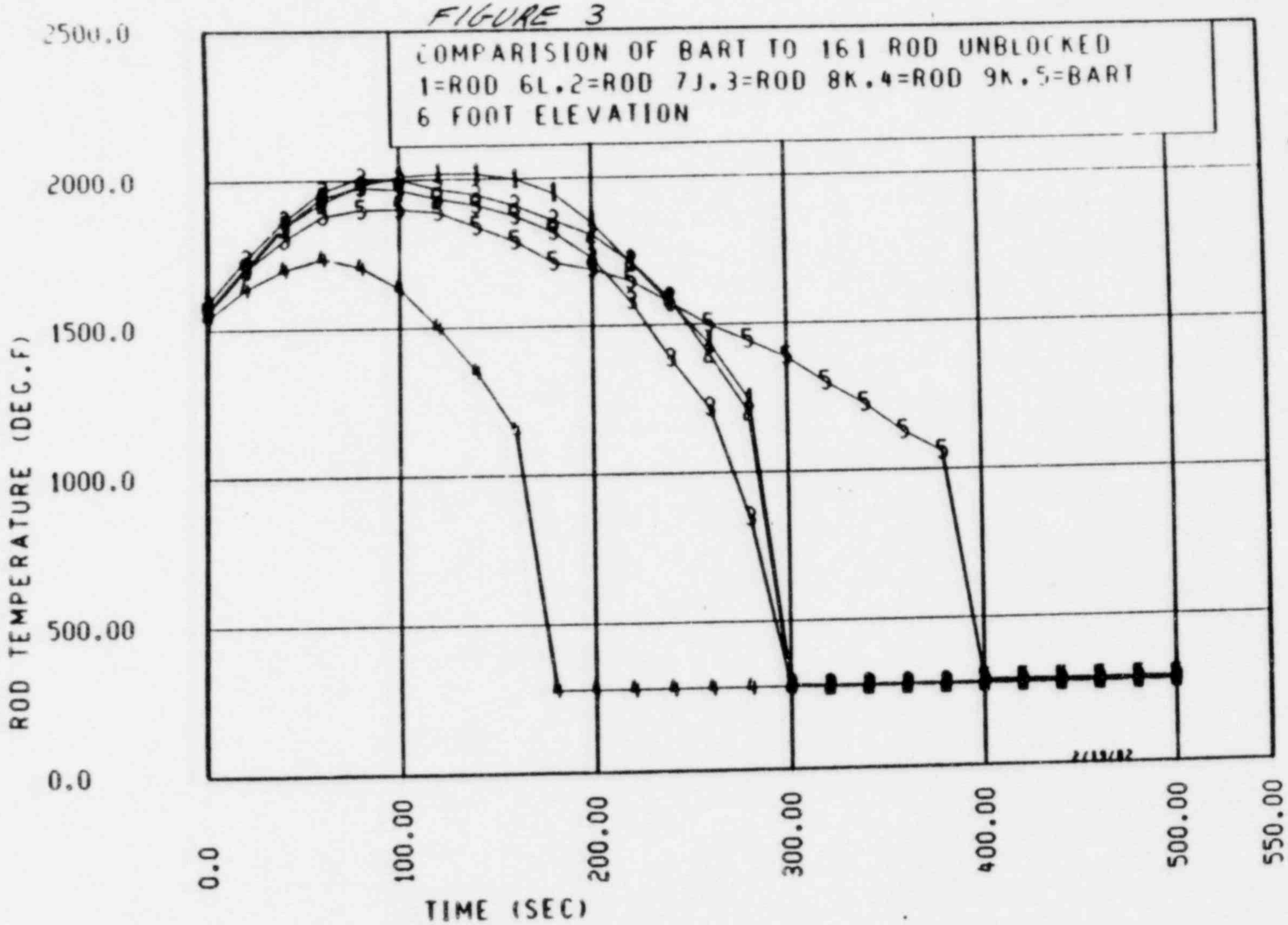
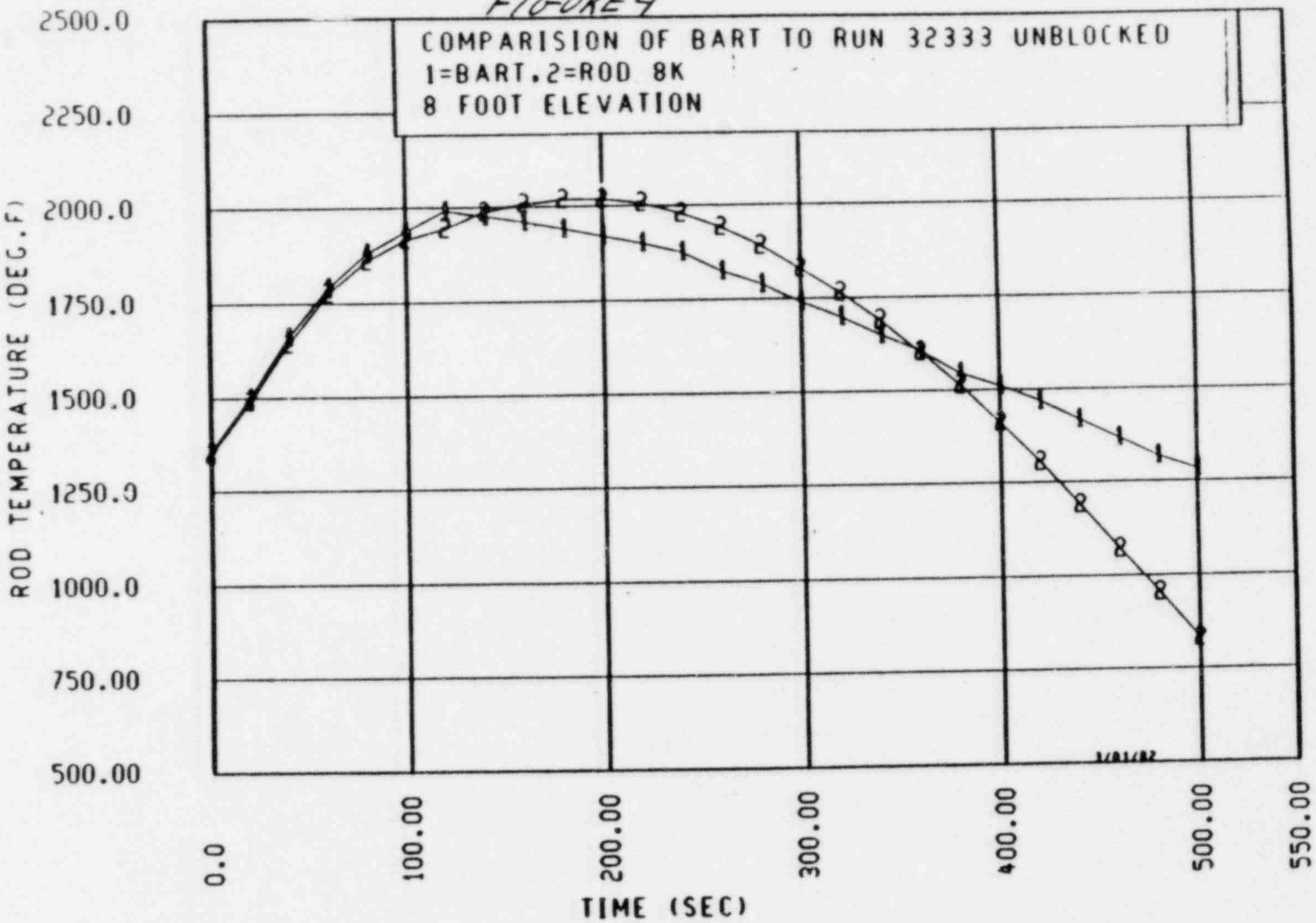

COMPARISION OF BART TO RUN 32333 UNBLOCKED
1=BART,2=ROD 8K
4 FOOT ELEVATION
ROD TEMPERATURE (DEG.F)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
100.00
0.0
100.00
200.00
300.00
400.00
500.00
550.00
TIME (SEC)

FIGURE 3



COMPARISION OF BART TO 161 ROD UNBLOCKED
1=ROD 6L.2=ROD 7J.3=ROD 8K.4=ROD 9K.5=BART
6 FOOT ELEVATION
ROD TEMPERATURE (DEG.F)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
TIME (SEC)
0.0
100.00
200.00
300.00
400.00
500.00
550.00

FIGURE 4



COMPARISION OF BART TO RUN 32333 UNBLOCKED
1=BART, 2=ROD 8K
8 FOOT ELEVATION
2500.0
2250.0
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
ROD TEMPERATURE (DEG.F)
0.0
100.00
200.00
300.00
400.00
500.00
550.00
TIME (SEC)

FIGURE 5

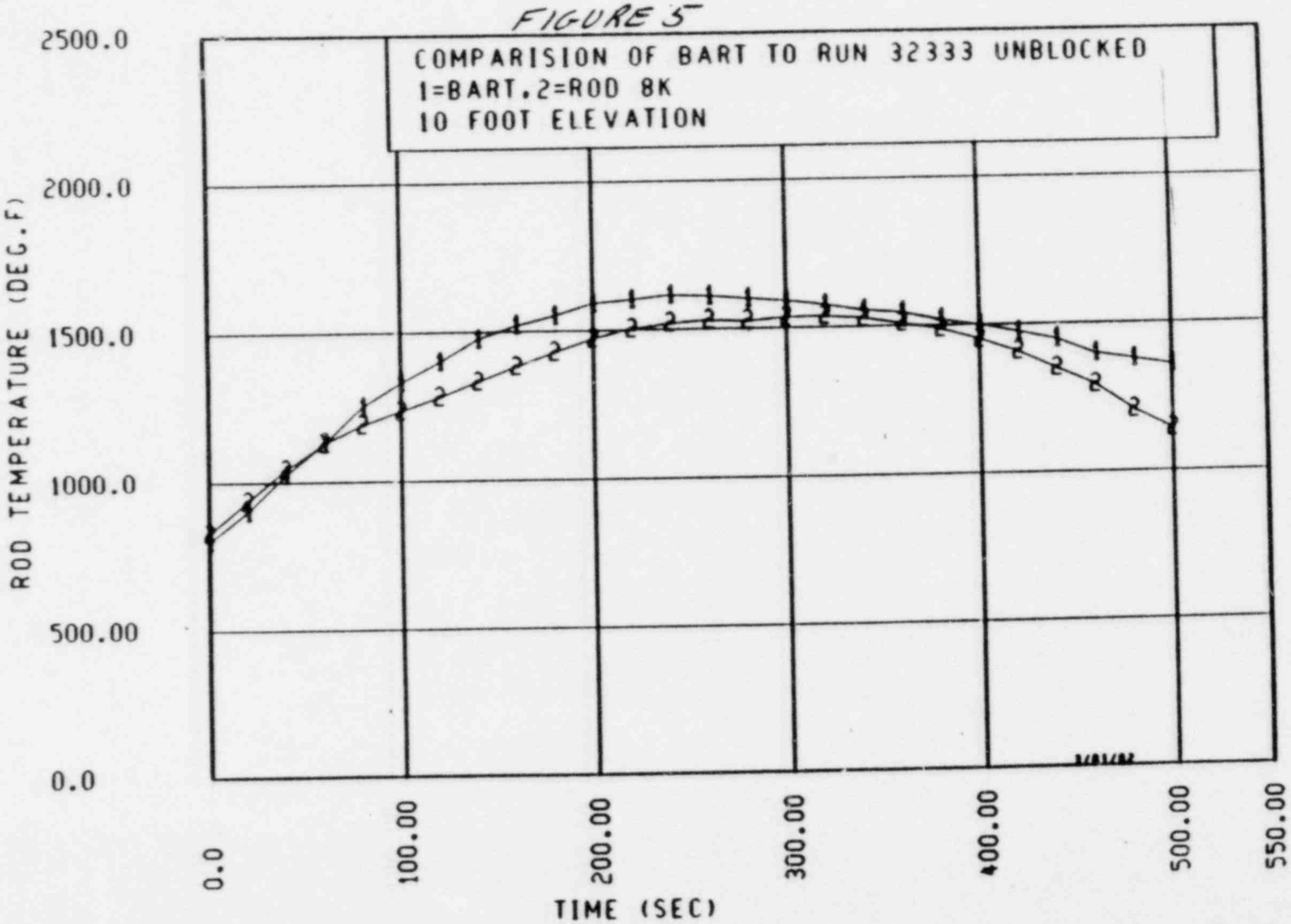

COMPARISION OF BART TO RUN 32333 UNBLOCKED
1=BART, 2=ROD 8K
10 FOOT ELEVATION
ROD TEMPERATURE (DEG. F)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
TIME (SEC)
0.0
100.00
200.00
300.00
400.00
500.00
550.00

FIG 6

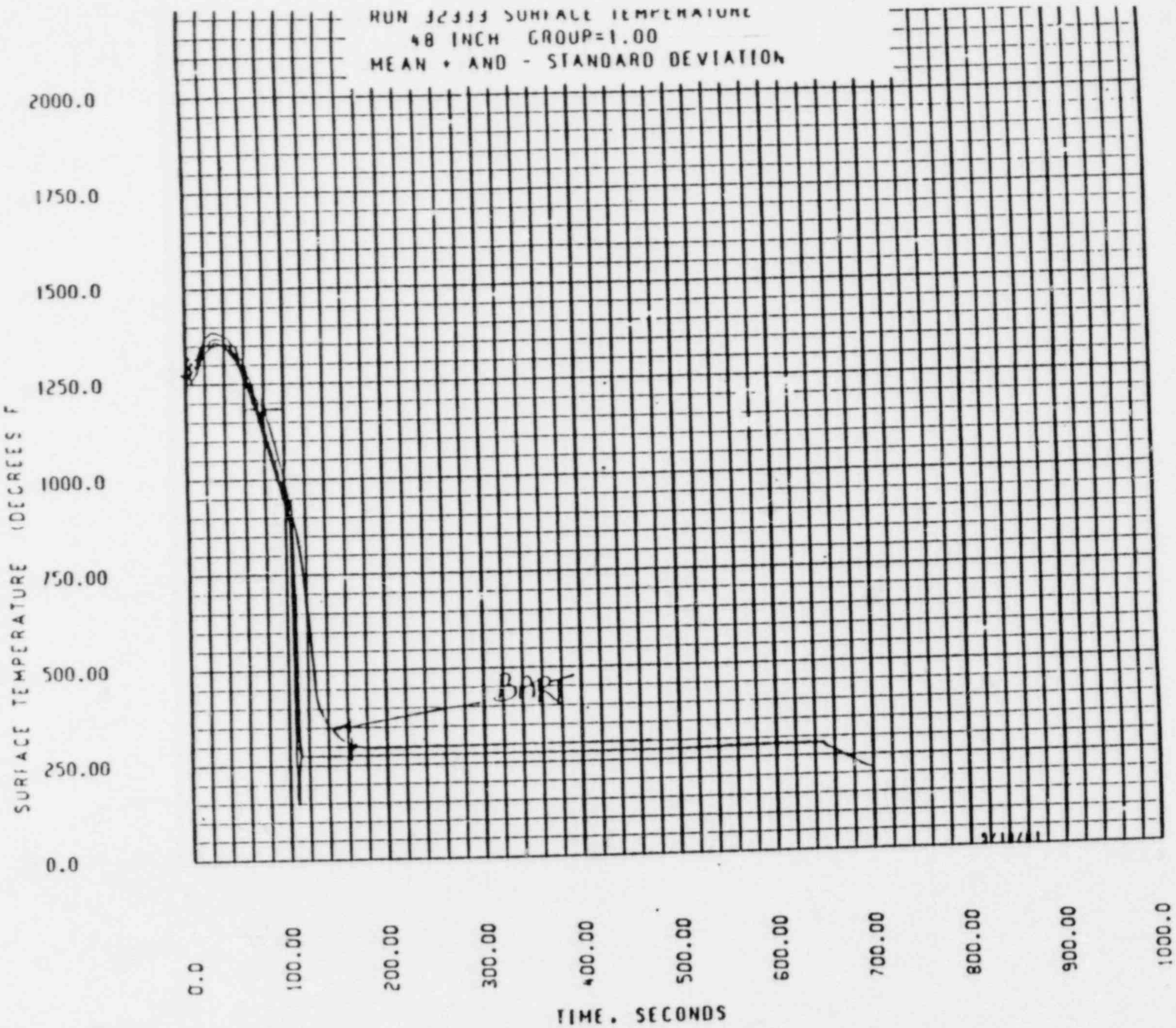
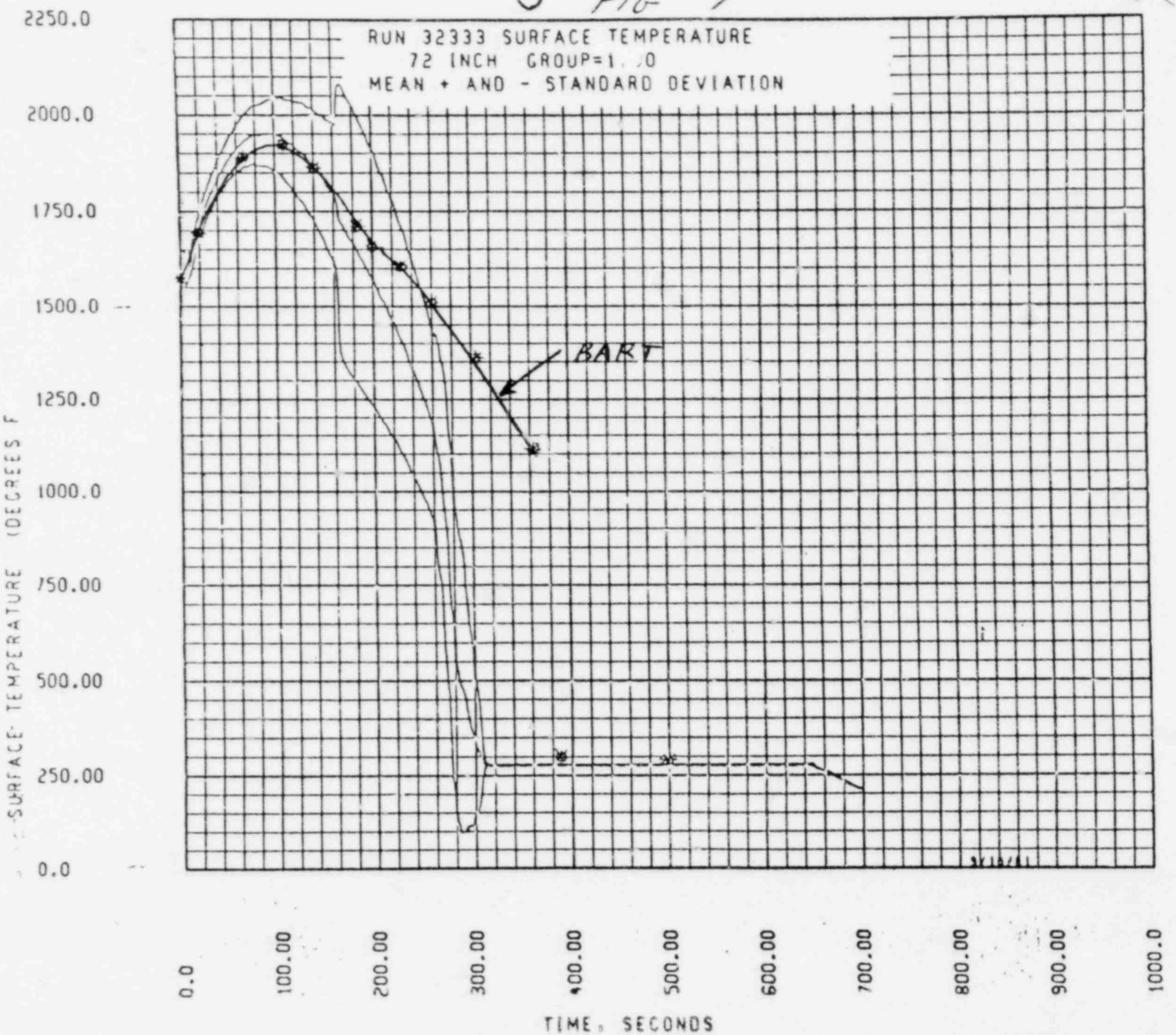

RUN 32333 SURFACE TEMPERATURE
48 INCH GROUP=1.00
MEAN + AND - STANDARD DEVIATION
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
SURFACE TEMPERATURE (DEGREES F
BART
0.0
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
900.00
1000.0
TIME, SECONDS

FIG 7



RUN 32333 SURFACE TEMPERATURE
72 INCH GROUP=1. 0
MEAN + AND - STANDARD DEVIATION
BART
2250.0
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
SURFACE TEMPERATURE (DEGREES F
0.0
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
900.00
1000.0
TIME, SECONDS

FIG 8

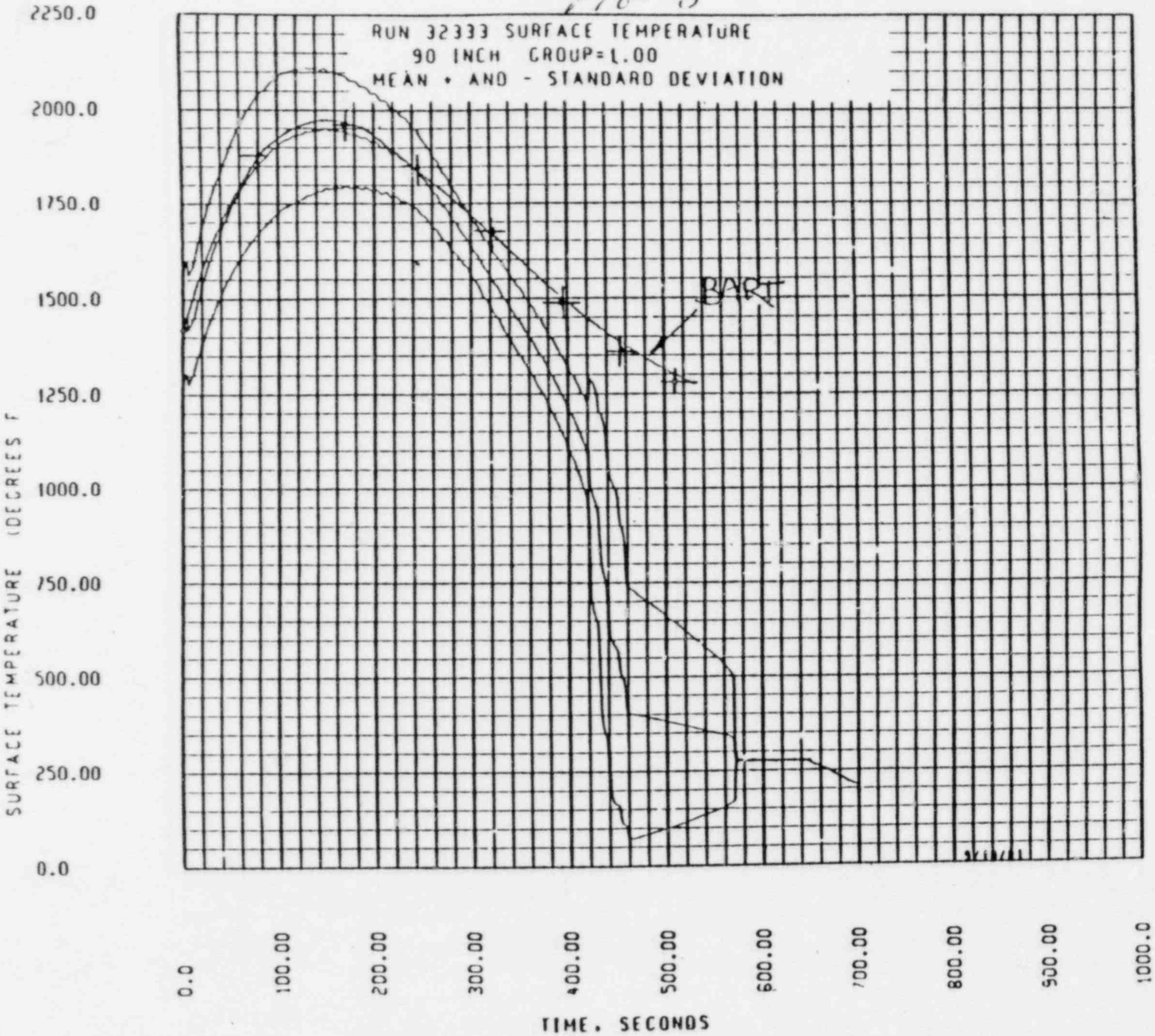
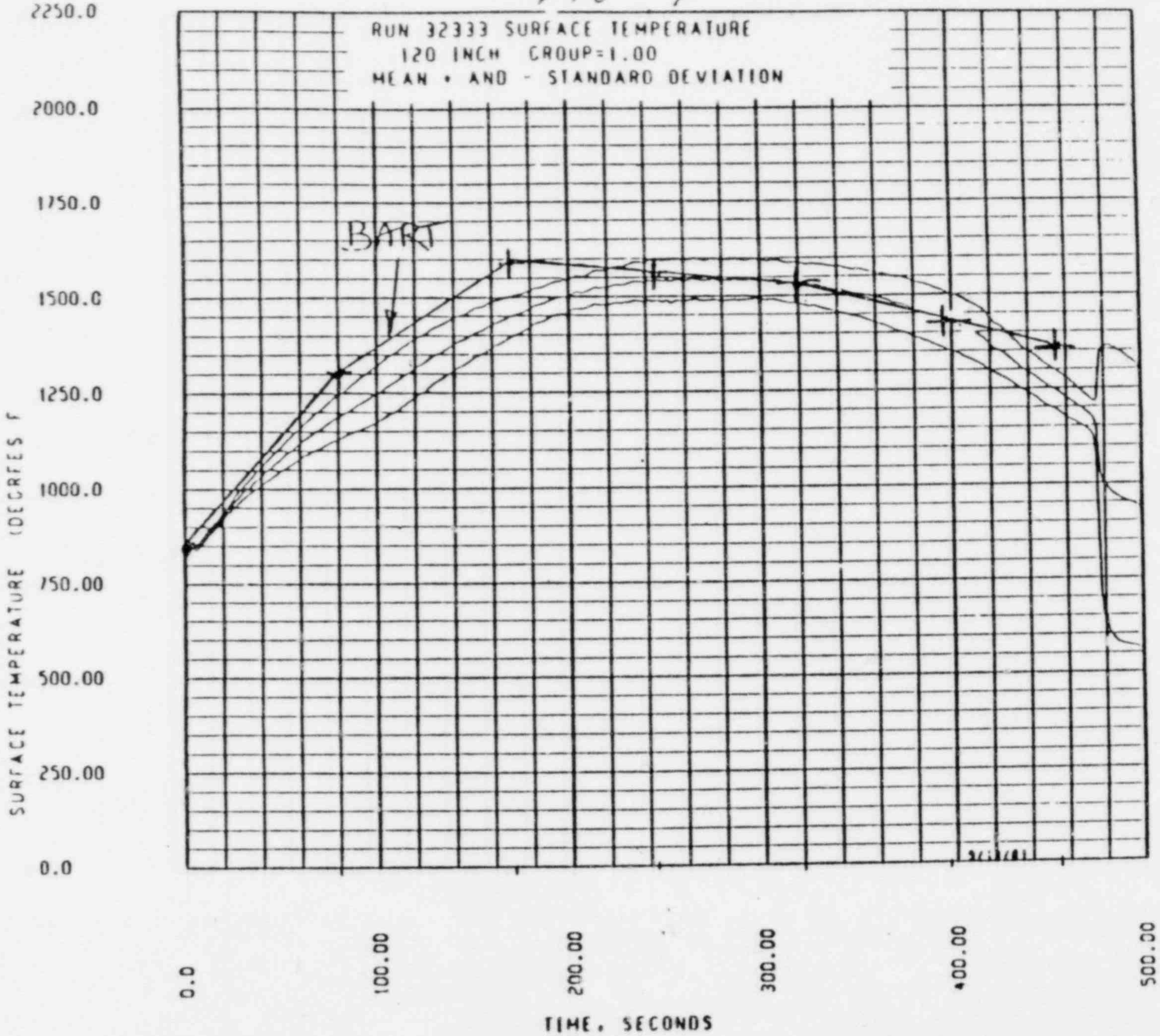
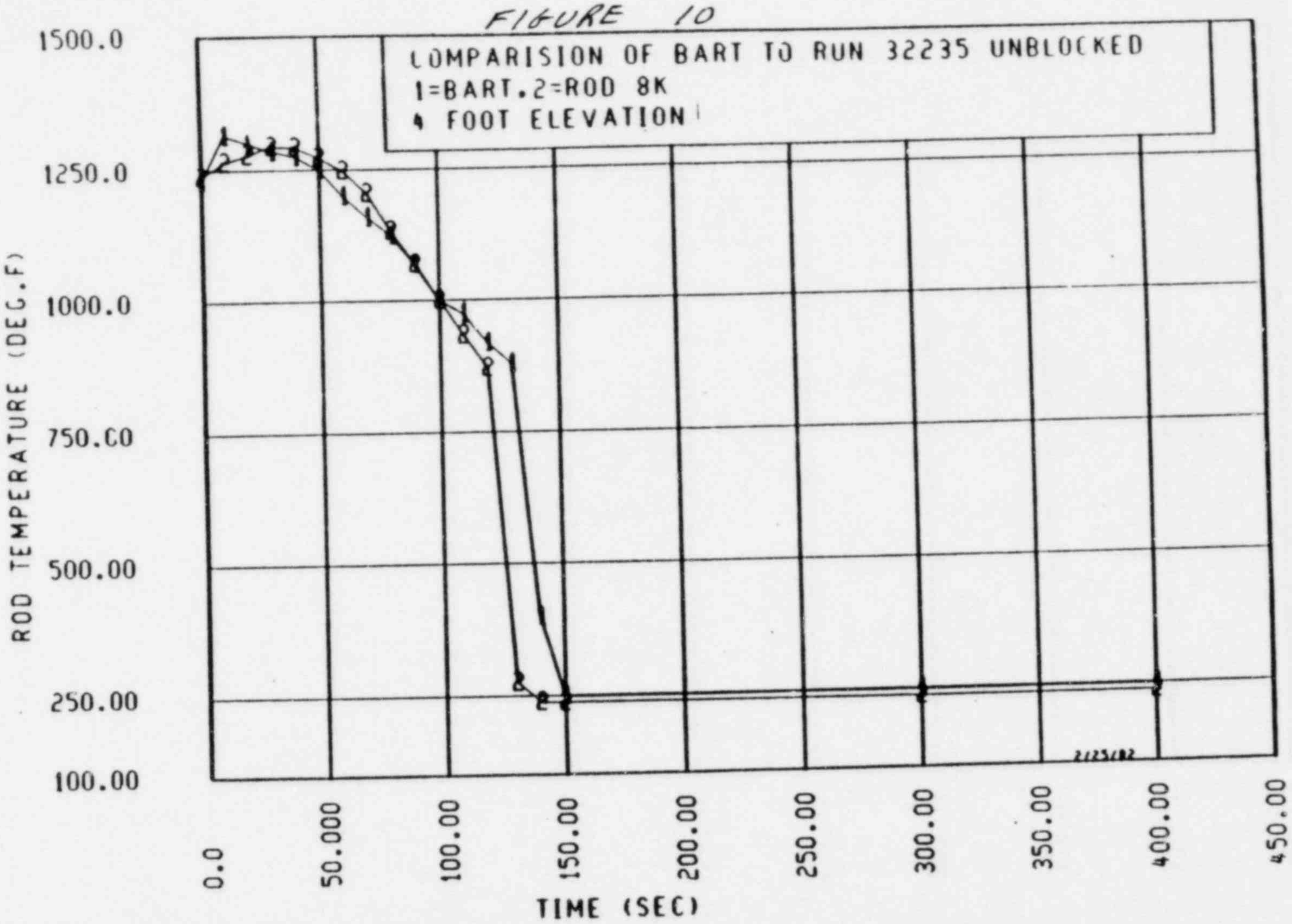

RUN 32333 SURFACE TEMPERATURE
90 INCH GROUP=1.00
MEAN + AND - STANDARD DEVIATION
BART
2250.0
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
SURFACE TEMPERATURE (DEGREES F
0.0
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
900.00
1000.0
TIME, SECONDS

FIG 9



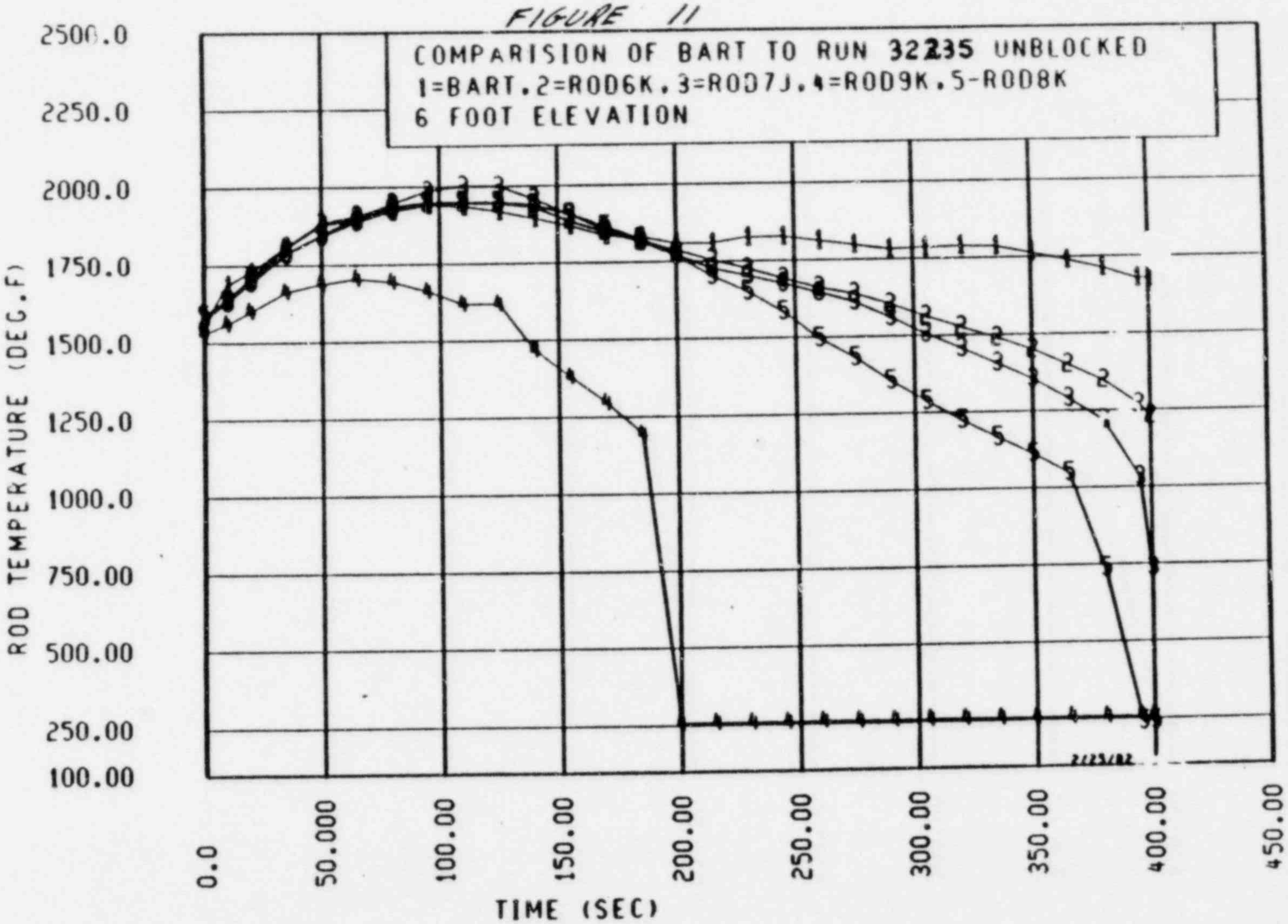
RUN 32333 SURFACE TEMPERATURE
120 INCH GROUP=1.00
MEAN + AND - STANDARD DEVIATION
BART
2250.0
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
SURFACE TEMPERATURE (DEGREES F
0.0
100.00
200.00
300.00
400.00
500.00
TIME, SECONDS

FIGURE 10



COMPARISION OF BART TO RUN 32235 UNBLOCKED
1=BART.2=ROD 8K
4 FOOT ELEVATION
1500.0
1250.0
1000.0
750.C0
500.00
250.00
100.00
ROD TEMPERATURE (DEG.F)
0.0
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
TIME (SEC)

FIGURE 11



COMPARISION OF BART TO RUN 32235 UNBLOCKED
1=BART.2=ROD6K.3=ROD7J.4=ROD9K.5-ROD8K
6 FOOT ELEVATION
ROD TEMPERATURE (DEG.F)
2500.0
2250.0
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
100.00
0.0
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
TIME (SEC)

FIGURE 12

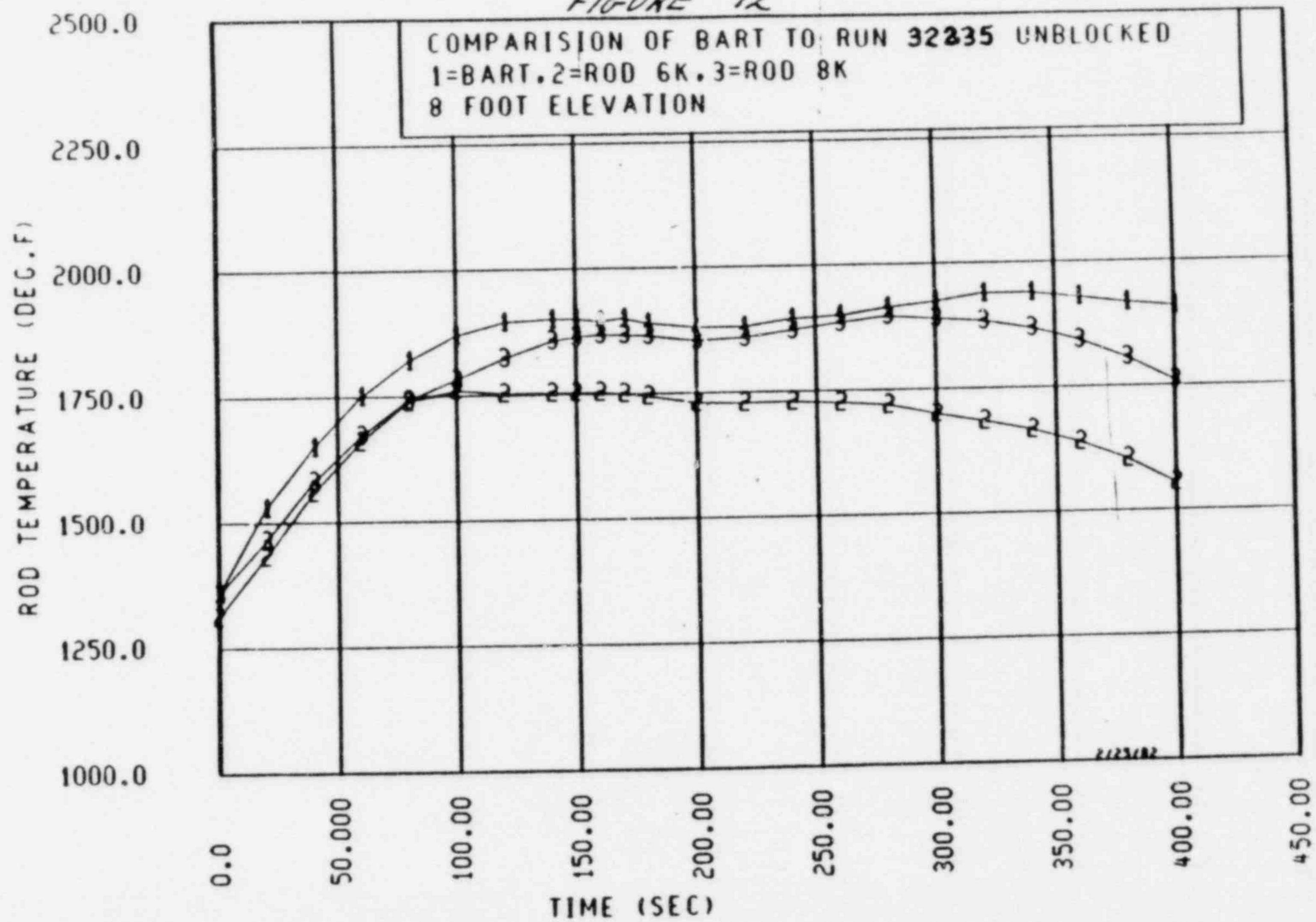
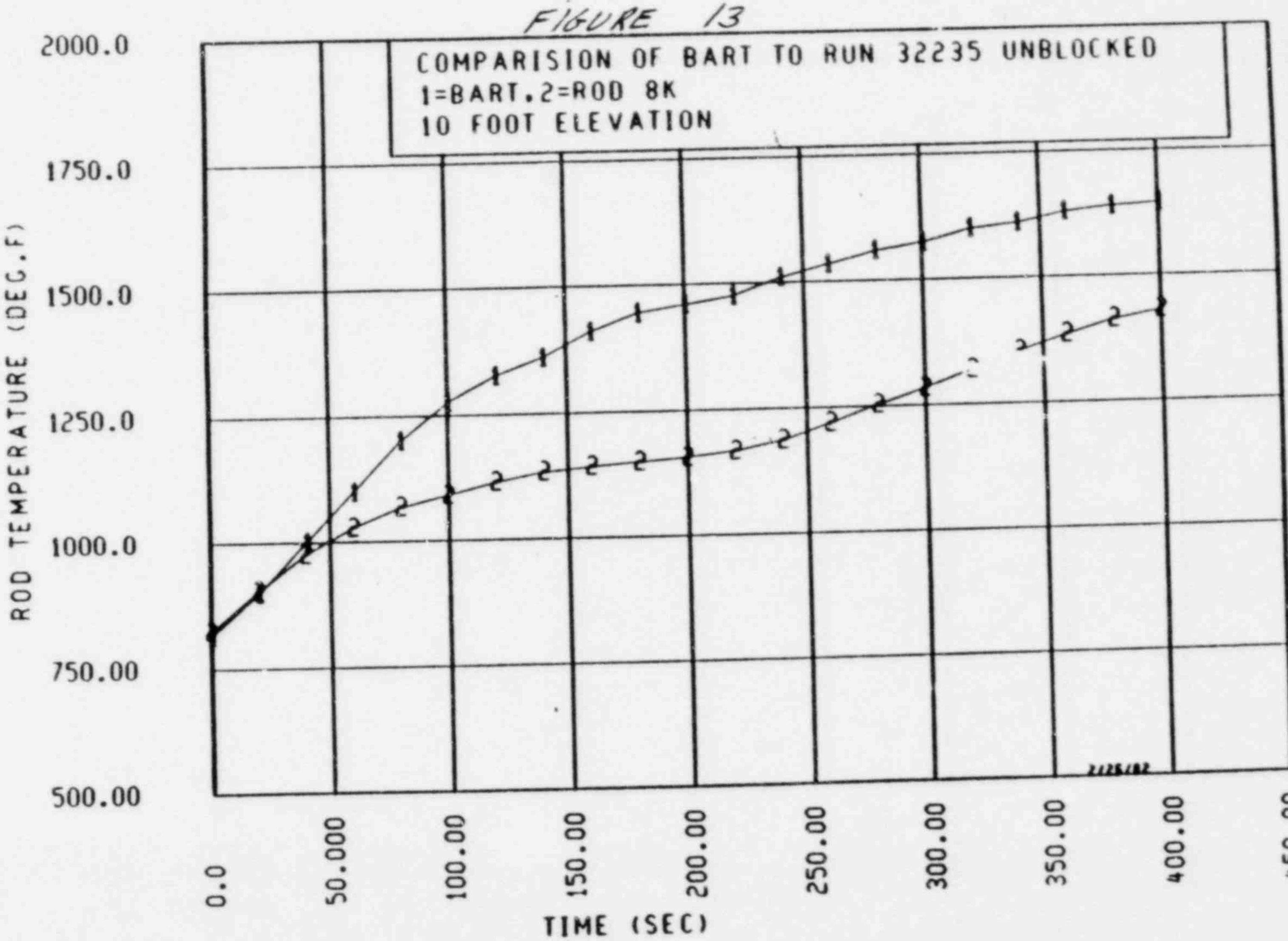
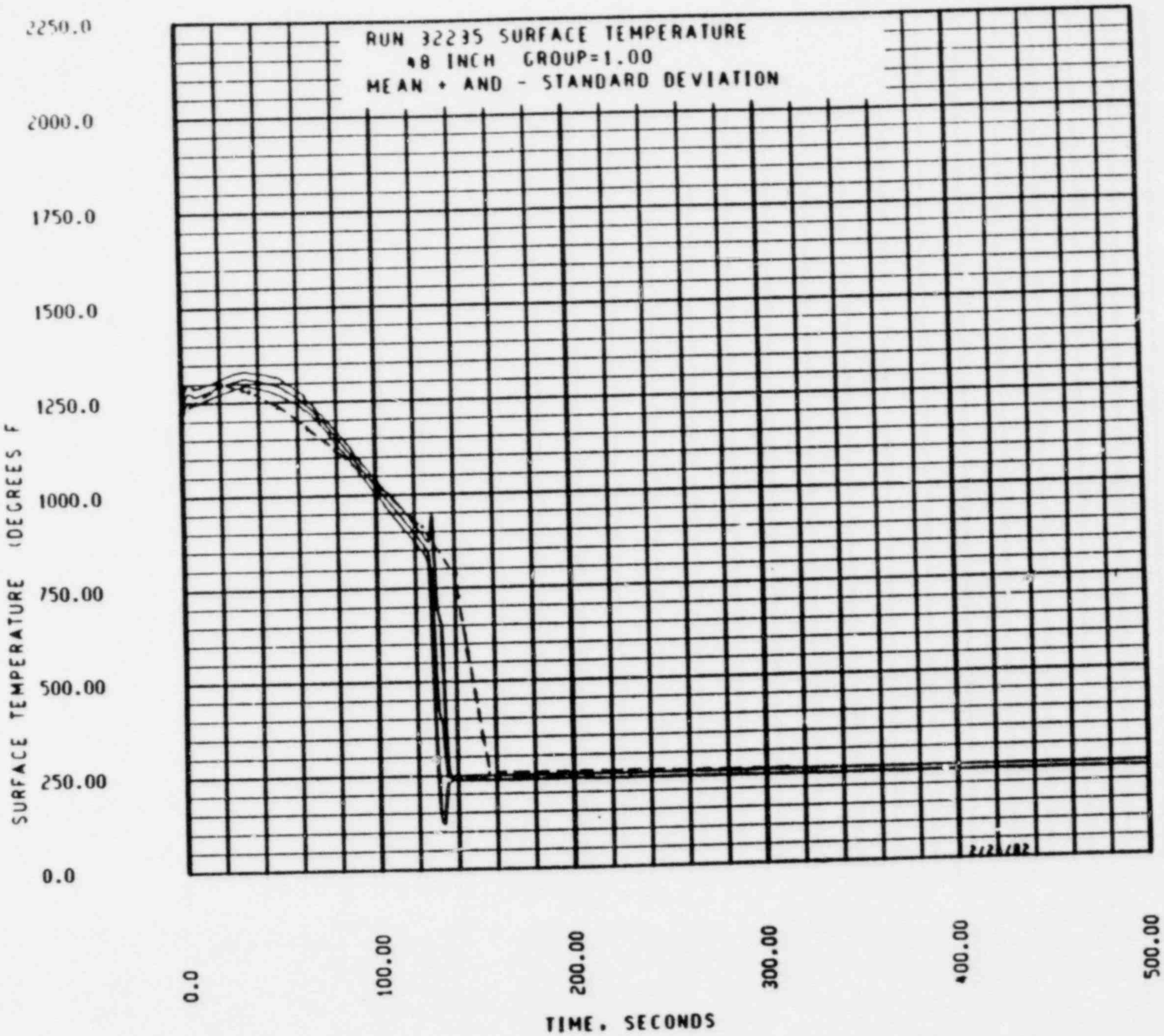
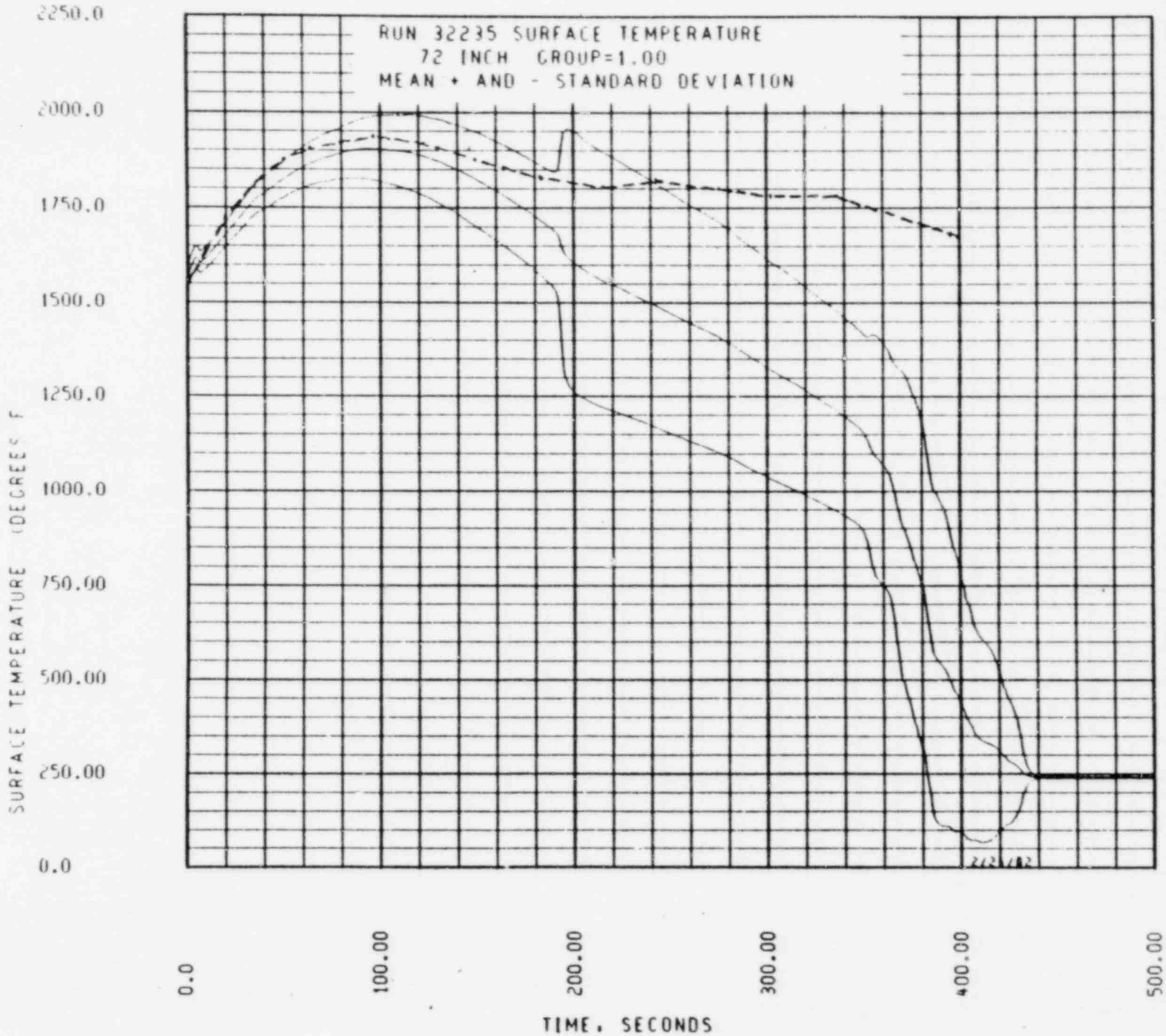
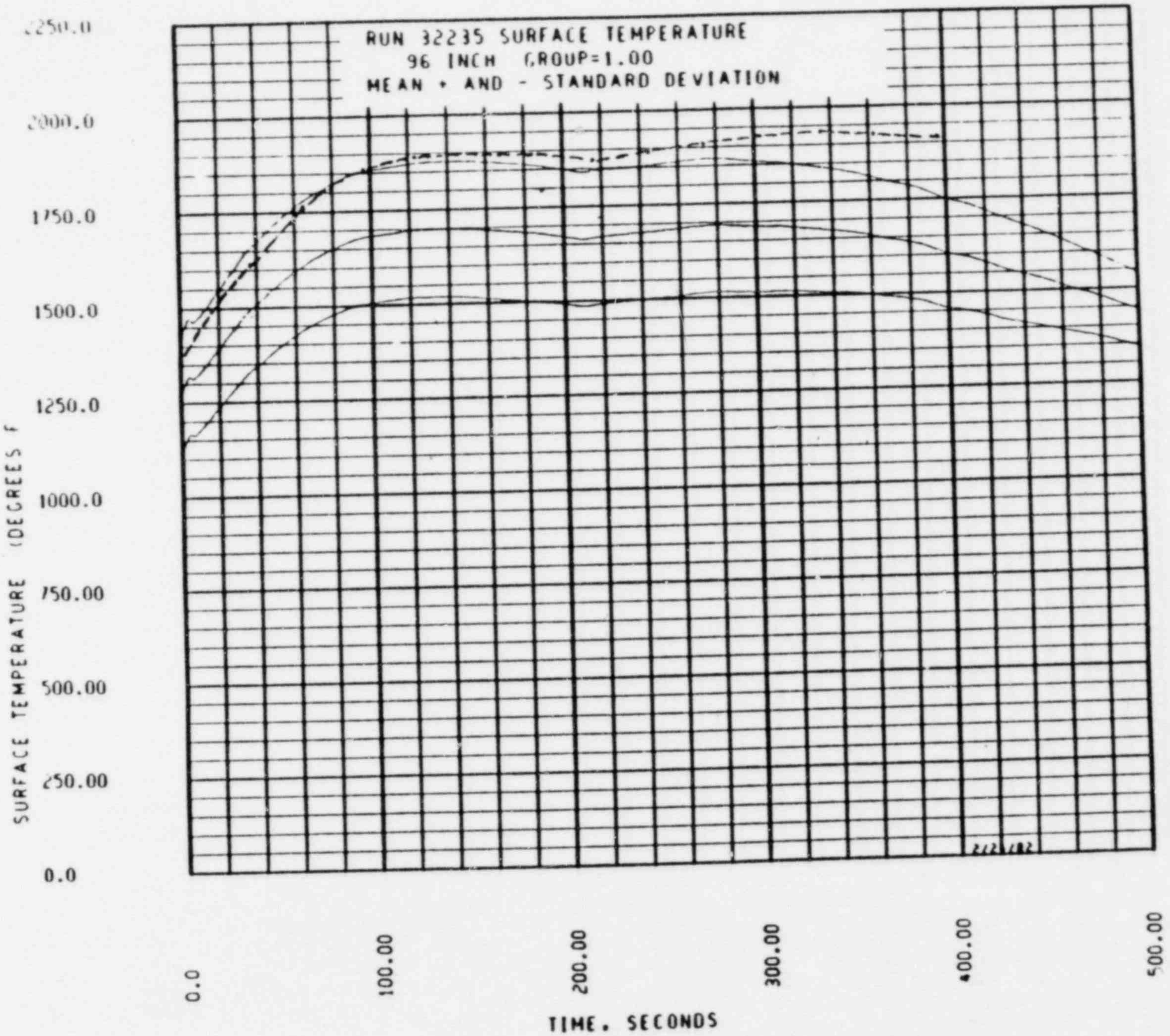

COMPARISION OF BART TO RUN 32235 UNBLOCKED
1=BART, 2=ROD 6K, 3=ROD 8K
8 FOOT ELEVATION
ROD TEMPERATURE (DEG.F)
TIME (SEC)
2500.0
2250.0
2000.0
1750.0
1500.0
1250.0
1000.0
0.0
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00

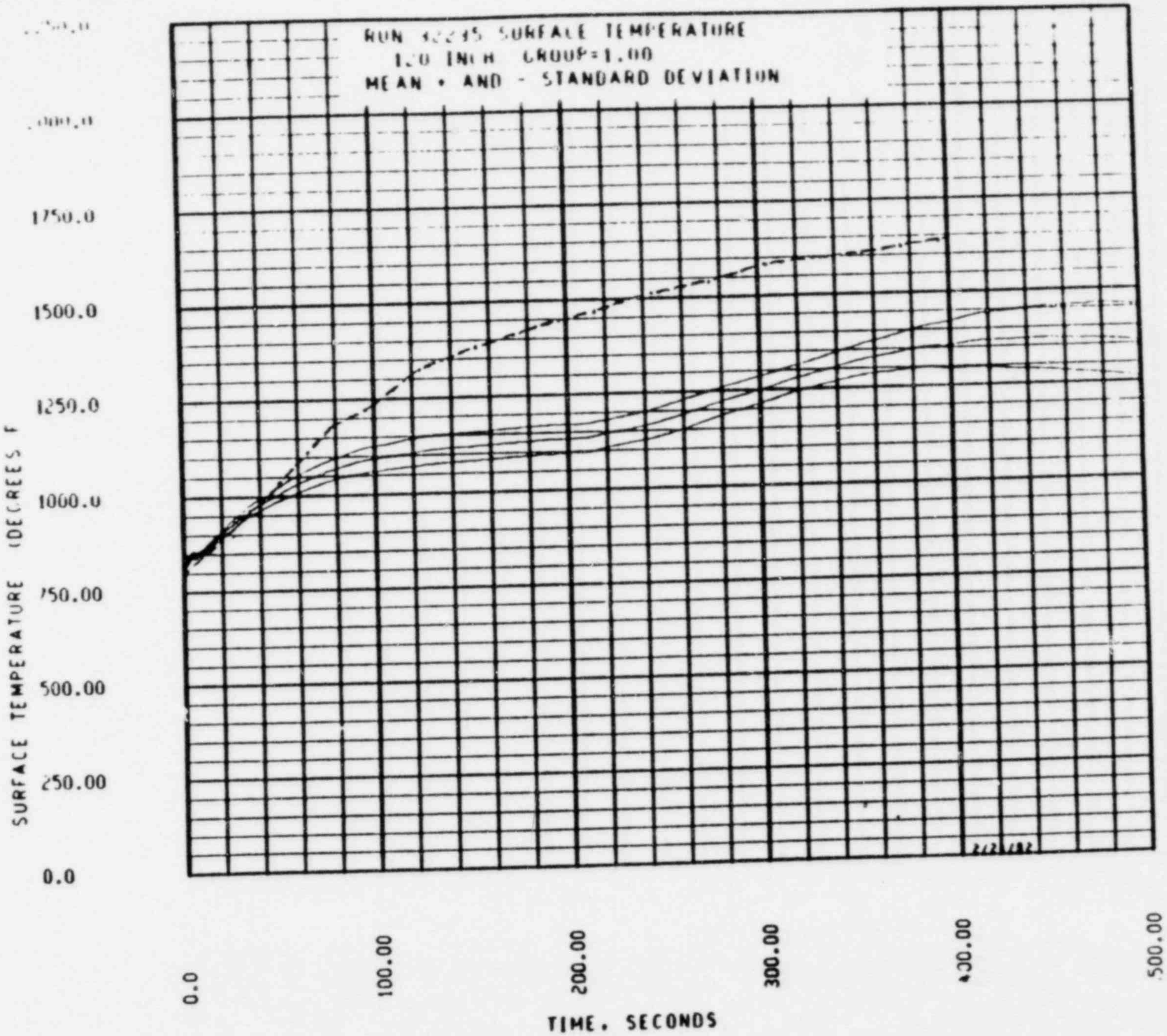
FIGURE 13


COMPARISION OF BART TO RUN 32235 UNBLOCKED
1=BART.2=ROD 8K
10 FOOT ELEVATION
ROD TEMPERATURE (DEG.F)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
0.0
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
TIME (SEC)


RUN 32235 SURFACE TEMPERATURE
48 INCH GROUP=1.00
MEAN + AND - STANDARD DEVIATION
2250.0
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
SURFACE TEMPERATURE (DEGREES F
0.0
100.00
200.00
300.00
400.00
500.00
TIME, SECONDS


RUN 32235 SURFACE TEMPERATURE
72 INCH GROUP=1.00
MEAN + AND - STANDARD DEVIATION
2250.0
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
SURFACE TEMPERATURE (DEGREES F
0.0
100.00
200.00
300.00
400.00
500.00
TIME, SECONDS


RUN 32235 SURFACE TEMPERATURE
96 INCH GROUP=1.00
MEAN + AND - STANDARD DEVIATION
2250.0
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
SURFACE TEMPERATURE (DEGREES F
0.0
100.00
200.00
300.00
400.00
500.00
TIME, SECONDS

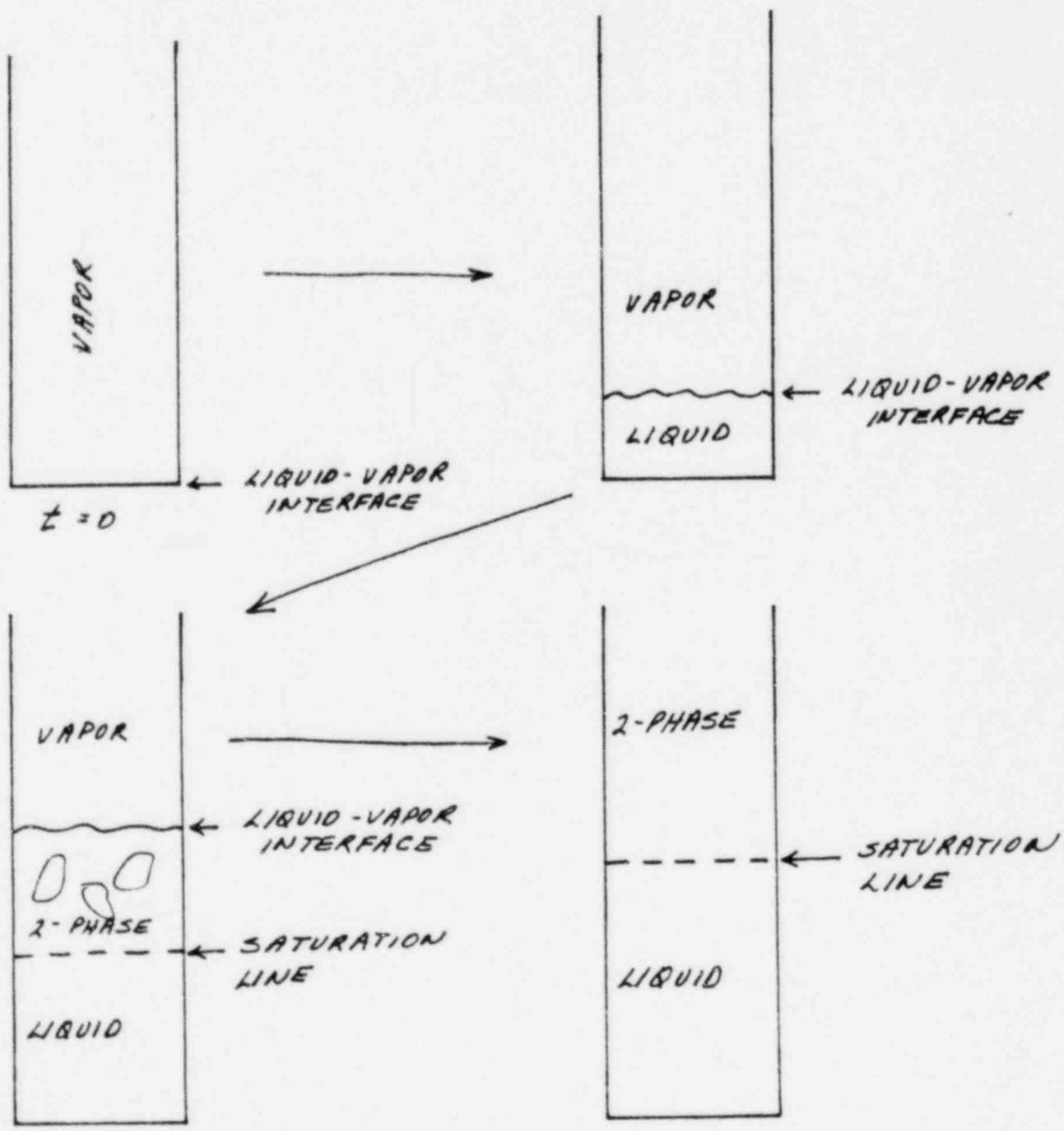


SURFACE TEMPERATURE
GROUP=1.00
MEAN + AND - STANDARD DEVIATION
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
SURFACE TEMPERATURE (DEGREES F
0.0
100.00
200.00
300.00
400.00
500.00
TIME, SECONDS

ATTACHMENT 1

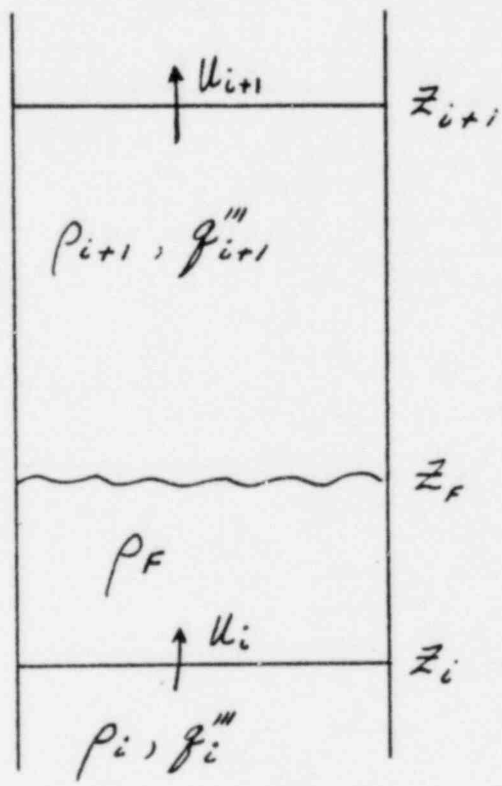
Fluid Interfaces

Fluid interfaces are used in BART to model the initial stages of reflood, and to define the boundary between boiling and subcooled flow. The sequence of events is shown below.



1.) Liquid-Vapor Interfaces

This interface exists at the beginning of the reflood transient and is located initially at the bottom of the core. The numerical scheme is shown below:



Initial conditions

$$z_F = z_i$$

$$\frac{dz_F}{dt} = u_i$$

$$\rho_F = \rho_i$$

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Transient Calculations

a

Similarily, the numerical form of the energy equation is:

2.) Saturation Line.

As the liquid-vapor interface Z_F moves into the core, the enthalpy at the interface H_F increases until it reaches saturation. At this point, the saturation line is formed: The movement of this line is calculated in the following manner:

Initial Conditions

$Z_{sat} = Z_F$ where γ_F/ρ_F first reaches saturation

$$\frac{dZ_{sat}}{dt} = \frac{dZ_F}{dt}$$

to solve equation 2.1-28 for $\frac{dZsat}{dt}$,

the following scheme is used:

ci

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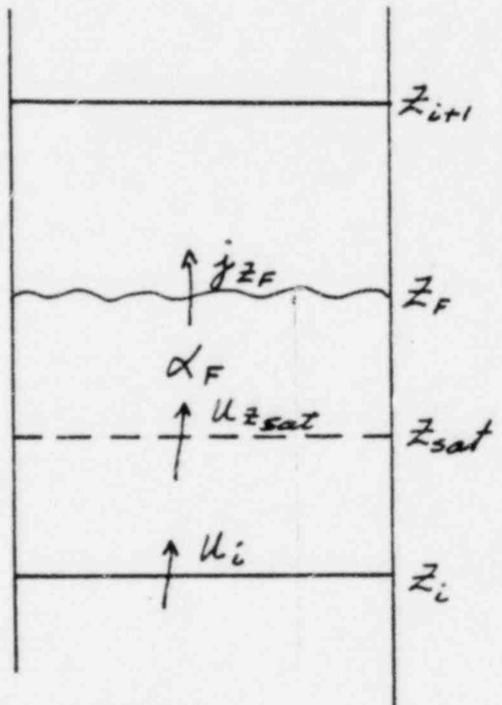
3.) Calcu tions above the saturation line

Above the saturation line, the liquid-vapor interface Z_F continues to exist, except that now the liquid is part of a 2 phase mixture. The situation is shown below:



Initial conditions:

$Z_F = Z_{sat}$

Transient Calculations:

The Z_F interface is defined as the location of the liquid front. In contrast to the subcooled liquid interface, vapor can now flow through the interface. The interface velocity is:

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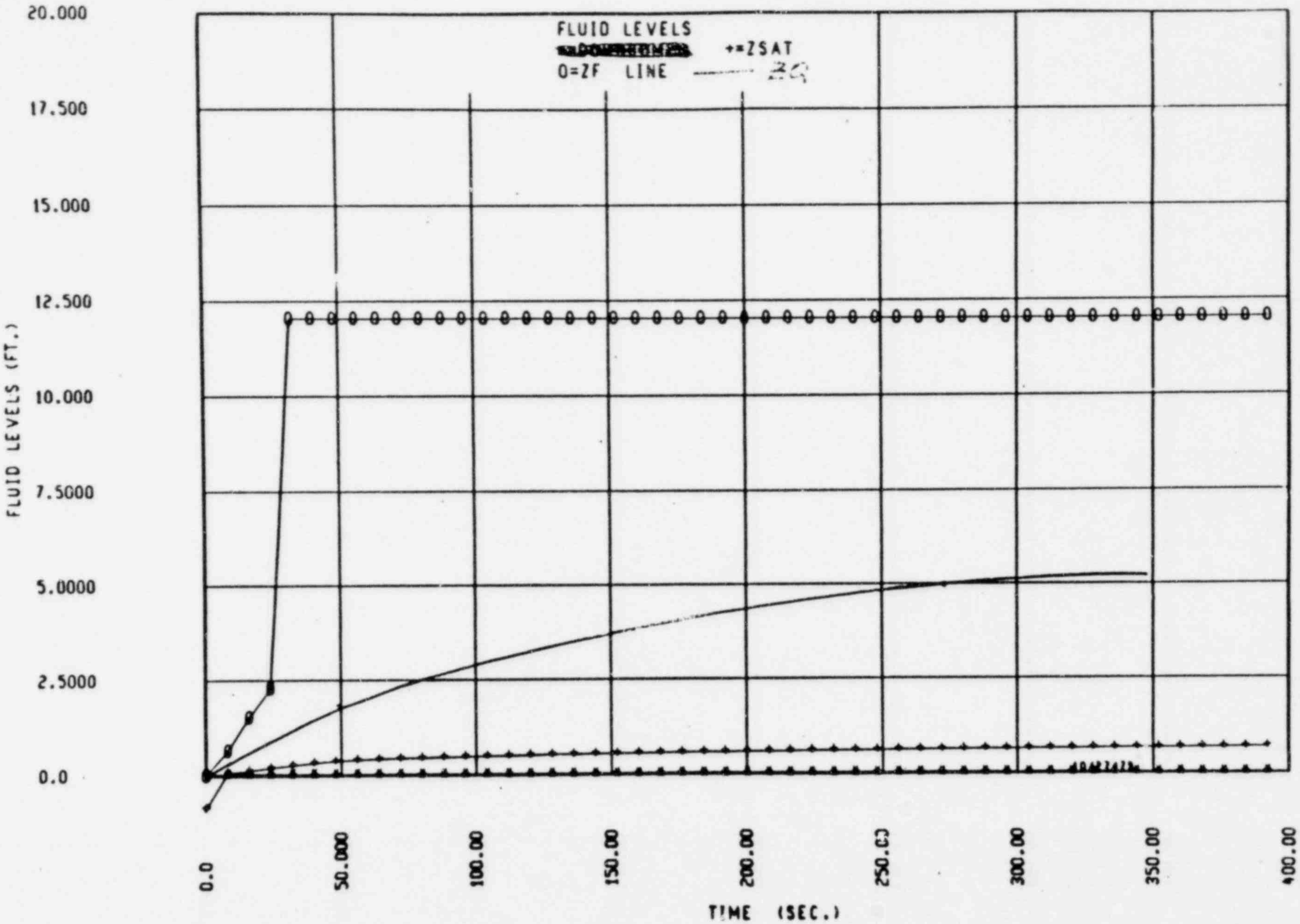
Integrating from Z_{Sat} to Z_f: — a

The above equation can be put in numerical form and re-arranged to give equation 2.1-53 for α_F.

After boiling has begun, Z_F moves rapidly up the channel until liquid begins to exit the core.

The figure below shows the movement of these interfaces for FLECHT test 5342.



FLUID LEVELS
+=ZSAT
0=ZF LINE
FLUID LEVELS (FT.)
20.000
17.500
15.000
12.500
10.000
7.5000
5.0000
2.5000
0.0
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
TIME (SEC.)

ATTACHMENT 2

Heat Transfer Calculations Near The Quench Front

Figure 1 illustrates a typical isotherm mesh and the region within which detailed calculations are made.

The quench region shown is two BART nodes in length below the quench front (defined later) and extends three inches above the front. Below the quench region the fluid temperature and heat transfer coefficient at each isotherm location is determined by interpolating between the values calculated in BART. The conditions at the last isotherm below the region (in this case the 220°F isotherm) serve as the starting point for detailed calculations within the region. Equations 3.3-27 and 3.3-30 are used to calculate the liquid velocity and enthalpy, respectively. If the wall temperature is below the saturation temperature (for example, the 260°F isotherm) the heat transfer regime is subcooled forced convection, and equations 2.2-36 and 2.2-37 are used. If the wall temperature is above saturation, a boiling component is added, using the Rohsenow correlation, so that the total heat flux is:

$$q_i'' = h_{wlc}\left(T_{w_i} - T_{l_i}\right) + h_{wlnb}\left(T_{w_i} - T_{sat}\right) \quad (1)$$

At relatively low heat fluxes the functional form of h_{wlnb} reflects the small number of nucleation sites available. At high heat fluxes h_{wlnb} is much greater than h_{wlc}, thus there is no need for area weighting in the above equation.[1]

1. Chen, J. C., "A Correlation For Boiling Heat Transfer To Saturated Fluids In Convective Flow" ASME 63-HT-34.

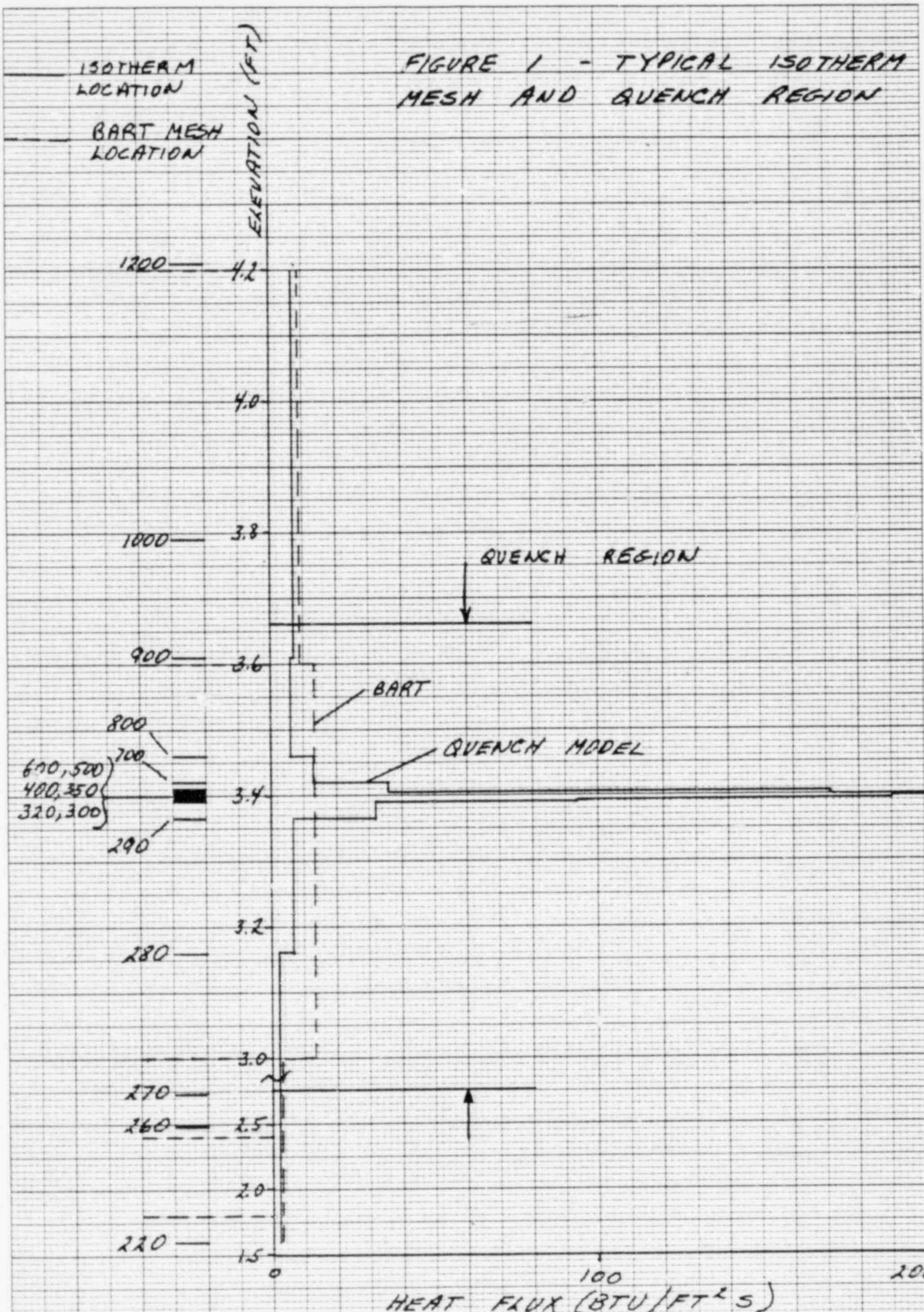


FIGURE 1 - TYPICAL ISOTHERM MESH AND QUENCH REGION
ISOTHERM LOCATION
BART MESH LOCATION
ELEVATION (FT)
HEAT FLUX (BTU/FT² S)
QUENCH REGION
BART
QUENCH MODEL
1200
1000
900
800
700
600,500
400,350
320,300
290
280
270
260
220
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.5
2.0
1.5
0
100
200

The forced convection component of q''_i, is assumed to generate vapor which is released in the form of bubbles and is then recondensed, as is illustrated in figure 2. Although the bubbles released into the fluid shrink as they recondense, new bubbles are continually being formed. It is therefore reasonable to use a mean bubble size (eq. 3.3-34) in calculating the condensation rate.

At a heat flux defined by:

$$q_b'' = \rho_v H_{lv} \alpha_{bb} U_{rbb} \tag{2}$$

where U_{rbb} and α_{bb} are defined by equations 3.3-40 and 3.3-41, the vapor film is assumed to begin forming. This is defined as the boundary between Region I and Region II.

The void fraction and liquid temperature calculated up to this point are used to calculate the right hand side of equation 3.3-11:

$$Q = \rho_v H_{lv} A_F \left[j_{vc}(\alpha) - j_{vcond}(\Delta T_S) \right] \tag{3}$$

As progressively hotter isotherms are encountered the heat flux from the rod increases rapidly. In this region two heat transfer coefficients are used; the Rohsenow correlation and a transition boiling equation: $h = q''_{max}\, e^{(1 - B\Delta T)}\, B$. At some point the heat flux calculated from the Rohsenow correlation exceeds the transition boiling value. This is the boundary betweeen Region II and Region III.

Once the boundary of the quench Region II - Region III has been passed, the heat flux from the rod is calculated using equation 3.3-46.

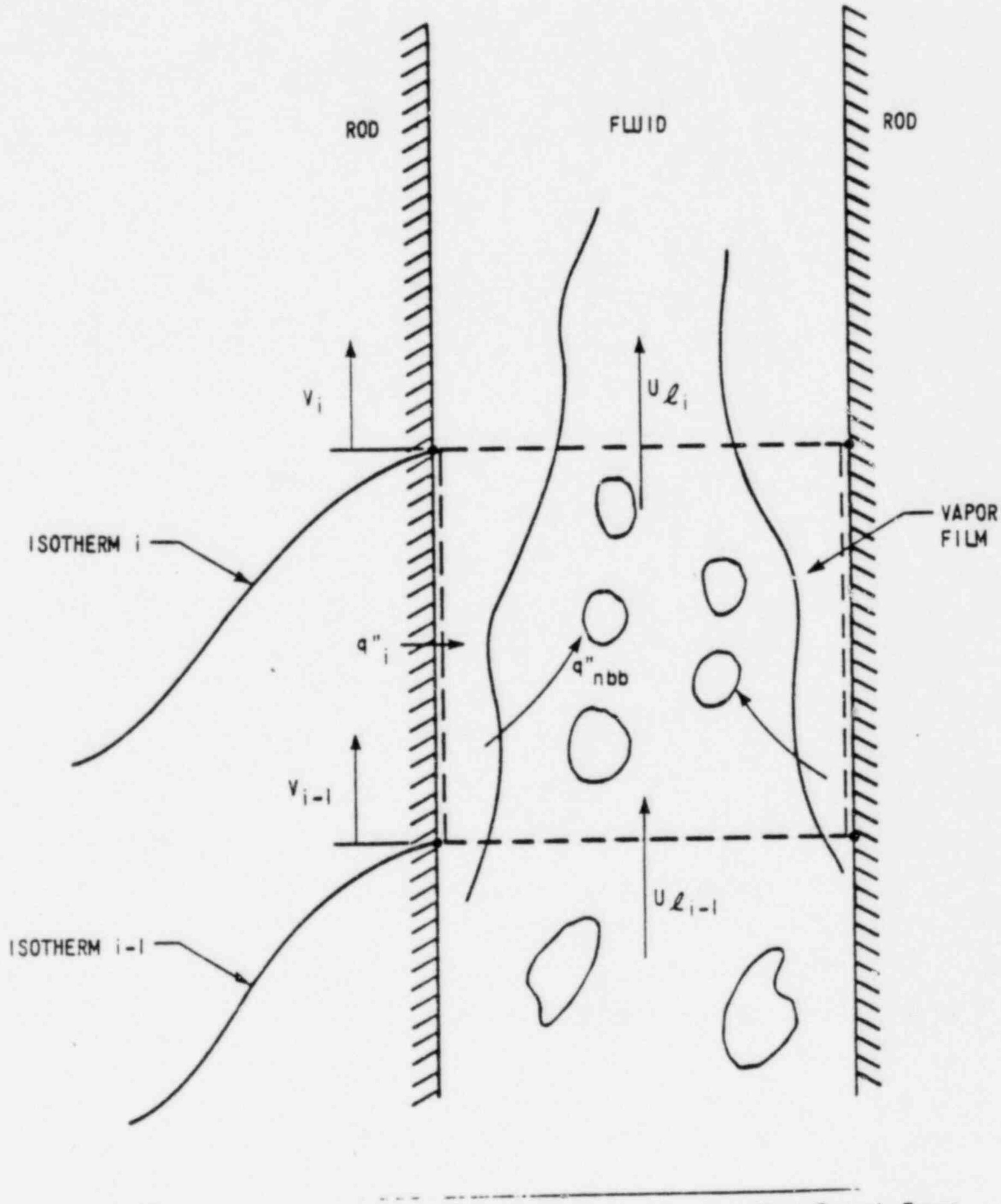


Figure 2 Control Volume Used to Calculate Fluid Conditions Near Quench Front

As calculations proceed from the lower boundary of the quench region (i.e., the Region I - Region II boundary), the heat flux is integrated axially along the rod. At the point where the heat flux calculated by equation 3.3-46 falls below the value calculated from Berenson's correlation, the Region III - Region IV boundary and the upper limit of the quench region are defined.

The total heat flow calculated within the Regions II and III is then compared with the value of Q calculated in equation 3. If the total heat flow is greater than Q, the parameter B is reduced. This has the effect, shown in figure 3, of reducing the integrated heat flow to the value required by equation 3.

Beyond the Region III - Region IV boundary, the heat transfer is calculated using Berenson's equation. The location of the quench front is defined as the isotherm with the minimum heat flux. In figure 1, this would be the 800°F isotherm. As previously mentioned, calculations are continued within the quench region a distance of 3 inches above the quench front. Thus the 900°F isotherm heat transfer would also be calculated. Beyond the quench region, isotherm heat transfer is a value obtained by interpolating between BART nodes.

Beginnning with the first isotherm within the quench region (in figure 1, the 260°F isotherm), and ending at the last isotherm below the quench region (the 900°F isotherm) the total heat release from the rod is summed. This total heat release is then applied in a smoothly varying manner over the two BART nodes within the quench region (see figure 1).

16921-9

FIGURE 3

BOILING CURVE CONSTRUCTION NEAR QUENCH FRONT SHOWING METHOD OF VARYING HEAT RELEASE INTEGRAL