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OFFICE MEMORANDUM

TO : Distribution

DATE: Feb. 24, 1981

FROM : H. N. Fisher

#1

SUBJECT : DEVELOPMENT OF THE PHASE I FENTON HILL HDR RESERVOIR: PART I, FRACTURE DIMENSION

SYMBOL : G-6

MAIL STOP: 981

INTRODUCTION

Sufficient data now exists to allow a description of the general and probable growth of the Fenton Hill HDR reservoir. The reservoir discussed here is that associated with the original EE-1 to GT-2B connection (Phase I, Segments 2 and 3) and the EE-1 to GT-2B connection after the recementing of the EE-1 casing (Phase I, Segments 4 and 5). Many aspects of the reservoir development are discussed in Refs. 1 through 3.

Here the growth and general characteristics of the reservoir are discussed in terms of the general aspects of the pressure transient, tracer, and temperatuure measurements. Much of the existing data has not been analyzed in terms of specific flow models. Any model must satisfy all data sets to be acceptable. Only in this manner will non-unique interpretations of the data be eliminated. In particular some remaining modeling possibilities are the inclusion of the following in specific flow models.

- o Include dispersion routines in flow models and predict tracer distribution.
- o Reproduce pressure transient data for Segments 4 and 5 with a heterogeneous flow model.

- o Reproduce Segments 2 and 3 wellbore temperature logs and drawdown with multi-fracture flow and conduction model.

In some cases crucial data is missing and a continuouss history cannot be deduced. Often the data is not sensitive to the desired parameters, non-unique interpretations are possible, and the interpretation is model-dependent.

The questions to be addressed are:

- o How much heat transfer area exists at any time?
- o What is the mechanism that created the heat exchange area?
- o How is it distributed in space and what is the volume of hot rock accessible?

A number of general conclusions that apply to all phases of development are:

- o The system contains several fractures which constitute partly independent flow paths.
- o The flow is confined to narrow fractures.
- o The heat transfer area grows during pressurizations and energy extraction in nearly equal amounts. At least 30 percent of the area growth is not accounted for.

Here in Part I of this memo the reservoir dimension and its general growth are discussed. In the second part the physical mechanisms that dominate the growth and size of the reservoir and possible fracture configurations will be discussed.

II. INDICATIONS OF MULTIPLE FRACTURES

The evidence for multiple fractures falls into three types. None gives conclusive proof but taken together they imply independent flow paths in separate fractures.

The major production zones have been identified in GT-2B (Refs. 1, 2, and 3) during Segments 2, 3, 4, and 5. Figure II-1 is a plot of temperatures in GT-2B taken just above each major flow entrance. The temperature of all three entrances show a total of four crossings. This would be unlikely if the upper zones were extensions of a single fracture. Complete flow data for individual entrances does not exist, so the actual temperatures of each flow cannot be determined.

For Segment 5 the flow and temperature for each of these same three entrances is available. The independent behavior is described in Appendix.

The most explicit evidence is the multiple flow connection in the production and injection wells (Refs. 1, 2, and 3) production wells (GT-2, 2A, and 2B) have at least five discrete entrances spaced over a lateral distance of 40 m. The temperature logs in EE-1 have shown multiple temperature depressions that are either flow exits from the wellbore or are fracture crossings of the wellbore. Figure II-2 shows these depressions after Segment 2 and before the EE-1 wellbore was made inaccesible above 2926 m by the recementing of the casing. At this time there was a well-developed system of ten connections (three in the main reservoir) extending over 900 vertical and 100 lateral meters. Figure II-3 shows three well-developed connections in the main reservoir and one below 2900 m before the 75 day extraction. After Expt. 176 the distinct peaks were merging.

The third type of evidence is in the tracer data. If the connections to GT-2B are extensions of a single fracture the various measurements of volume (Ref. 3) would show that the higher connections have larger volumes during a given tracer experiment. Two exceptions to this are found during experiment 217 for the modal volume. These cases are discussed in Appendix.

III. GROWTH OF HEAT EXCHANGE AREAS AND TRACER VOLUMES

Previous analyses have compared the measured temperature decrease at the reservoir outlet with the results of calculations with constant heat exchange areas (Refs. 1 and 2). More detailed calculations show that the data is consistent with a rapidly growing heat exchange area for both Segments 2 and 3. This analysis is discussed in Appendix A. It is found that the heat exchange area could have doubled during both the 75 day depletion of Segment 2 and the 28 day depletion of Segment 3. There is some indication of a growing system in the Segment 5 data. However it is unlikely that any quantitative estimates can be made (Appendix B).

The tracer studies have also indicated a system growing in volume during the long-term energy extractions (Refs. 2 and 3). Here the modal ($\mathring{V}$) and mean volume <V> as defined in Ref. 3 are used. These volumes are compared with the free thermal volume (FTV) created by the energy extraction. This volume (FTV) is the contraction that would be produced by the energy removal under stress-free conditions. Only a fraction of this volume will be realized in any system in compression. The percentage of this volume realized is determined by the total stress field in the cooled region.

Figure III-1 is a plot of the modal volume $\mathring{V}$ the mean volume <V> and the increase in the FTV. The actual volume of the flow-through paths is probably between $\mathring{V}$ and <V> and in this case is a small fraction of the FTV.

Figure III-2 is the same data for the high back pressure experiment (186) of Segment 3. The situation here is different than in the first case. The volumes $\mathring{V}$ and <V> are increasing at a faster rate, comparable to the rate of increase of ΔFTV.

Four tracer experiments were conducted during experiment 215. Two of these were done with the pressure conditions close to normal operating conditions. That is, with the pressure in EE-1 near 10 MPa at the surface and GT-2 at 1.4 MPa. The modal and mean volume for these tracer experiments are shown in Fig. III-3 along with the increase in the free thermal volume (ΔFTV). The FTV accumulated up to this time is also plotted (ΣFTV).

The modal volume continues to increase through the middle of experiment 217, at a rate small compared to that of the FTV. There is insufficient data to trace the mean volume.

It is obvious that the flow-through volume increases during energy extraction. However, since <V> and $\mathring{V}$ represent only upper and lower limits to the actual volume, the actual growth rate has not been determined. The growth rate however does not always have the same relation to the available thermal strain.

IV. RESERVOIR DIMENSIONS

Some approximate dimensions for the reservoir fracture system can now be obtained. These dimensions refer to the flow-through system that contributes to the heat transfer areas.

A. Fracture Spacing

The distance between the fracture can be determined directly from the temperature logs. The interaction of the temperature fields also provides some limits on the spacing.

Some examples are shown in Table IV-1. The first three entries concern the three possible fractures in the upper part of the reservoir. The last two are for the whole reservoir.

The first entry is obtained by multiplying the spacing of the three major temperature minima (between 2650 and 2800 m in Fig. II-3) by the sin of the wellbore from the vertical. This assumes the fractures are vertical. However, the considerable overlap of the temperature fields would suggest that the fractures are not more than 10 m apart, the second entry in the table. The lack of apparent interaction of the fractures in the experiment 217 analysis (Appendix B) suggests that they are more than 5 meters apart.

The three branches of GT-2 (GT-2, 2A, and 2B) have intersected a number of discrete flow exits there have been at least five distinct fractures over a lateral distance of 40 m for a spacing of 8 meters. The EE-1 temperature logs after the Segment 2 flow and before recementing (Fig. II-2) show at least 10 flow exits or crossings in 90 lateral meters for a spacing of 9 meters.

B. Vertical Extent

The vertical dimension of the reservoir are determined only partly by the separation of the major flow entrances. Figures II-3 and IV-1 show the intersection of EE-1 with the Segment 2, 3 reservoir to be almost 150 m high. Since the cooled region must extend to the GT-2B outlets the overall height must be ~200 meters. The individual fractures have an average height of ~150 m in the Segment 2, 3 reservoir. The total height of the Segment 4, 5 reservoir is 370 m with 150 m of hot reservoir in the lower portion.

C. Horizontal Widths

The total horizontal width or the width of individual fractures is now determined from the heat exchange areas (section III) and the vertical heighth estimates.

An important width measurement can be obtained from the EE-1 temperature log after experiment 215 of Segment 4. This estimate was later verified in experiment 217. Figure IV-1 shows that the cooled portion of the reservoir due to the 215 flow has a vertical extent of $\sim$100 meters. Computer calculations and simple analytical calculations show that the total width of the fracture(s) involved is 45 to 60 meters. The width estimate from the 217 analysis (Appendix B) is 50 meters.

The Segment 2 dimensions obtained here, in Appendices A and B, and Ref. 1 through 3, are summarized in Table IV-2. Some independent areas for the lower GT-2B fracture connection are included (see Appendix A). The parameters are presented for the beginning and end of the extraction. A system that is growing in area and volume with a relatively constant aperture is indicated. The total width is the sum of the widths of all flow paths.

Table IV-1

Fracture Spacing

Data	N	D(m)
T-min	3	6.7
Temp Overlap	3	<10
Expt 217	3	> 5
GT-2, 2A, 2B Exits	5/40 m	8.0
EE-1 Crossings	10/90 m	9.0

Table IV-2
Summary of Segment 2 Dimensions

			Lower Fracture	Total
Area (m^2)		Begin	1500	7500
		End	2500	15000
Volume (m^3)	Begin	V		11.4
		<V>	--	34.4
	End	V	--	26.5
		<V>		56.2
Aperture (mm)	Begin	V/A	--	1.52
		<V>/A		4.58
	End	V/A	--	1.76
		<V>/A		3.75
Width*		Begin	15	50
		End	25	100

*Based on a 150 m height

The system dimensions for Segment 3 are summarized in Table IV-3. Again a growing system is indicated. Much wider limits on the aperture areapparent.

Table IV-4 is a similar summary for Segment 5. Although definite changes are occuring in the system during the energy extraction, it may not be possible to trace a growth in the heat exchange area because so little drawdown actually occurred. More data is available for the individual flow paths. The table is applicable at the 5/9/80 Br^{82} tracer.

Table IV-3

Summary of Segment 3 Dimensions for Total System

Area (m^2)		Begin	6000
		End	12000
Volume (m^3)	Begin	$\overset{o}{V}$	3.8
		$\langle V \rangle$	33.1
	End	$\overset{c}{V}$	11.4
		$\langle V \rangle$	49.6
Aperture (mm)	Begin	$\overset{c}{V}/A$	0.63
		$\langle V \rangle/A$	5.5
	End	$\overset{c}{V}/A$	.095
		$\langle V \rangle/A$	4.13
Width*		Begin	40
		End	80

*Based on a 150 m height.

Table IV-4

Summary of Segment 5 Dimensions

Reservoir	Upper			Lower	Total
Fracture	Upper	Main	Lower		
Area (m^2)	7500	15000	7500	7500	37500 to 45000
Modal Volume (m^3)	56	77	45	← included	178
Minimum Aperture (mm)	6.0	4.1	4.8		3.9 to 4.7
Average Widths (m)	50	100	50	60	100 to 120

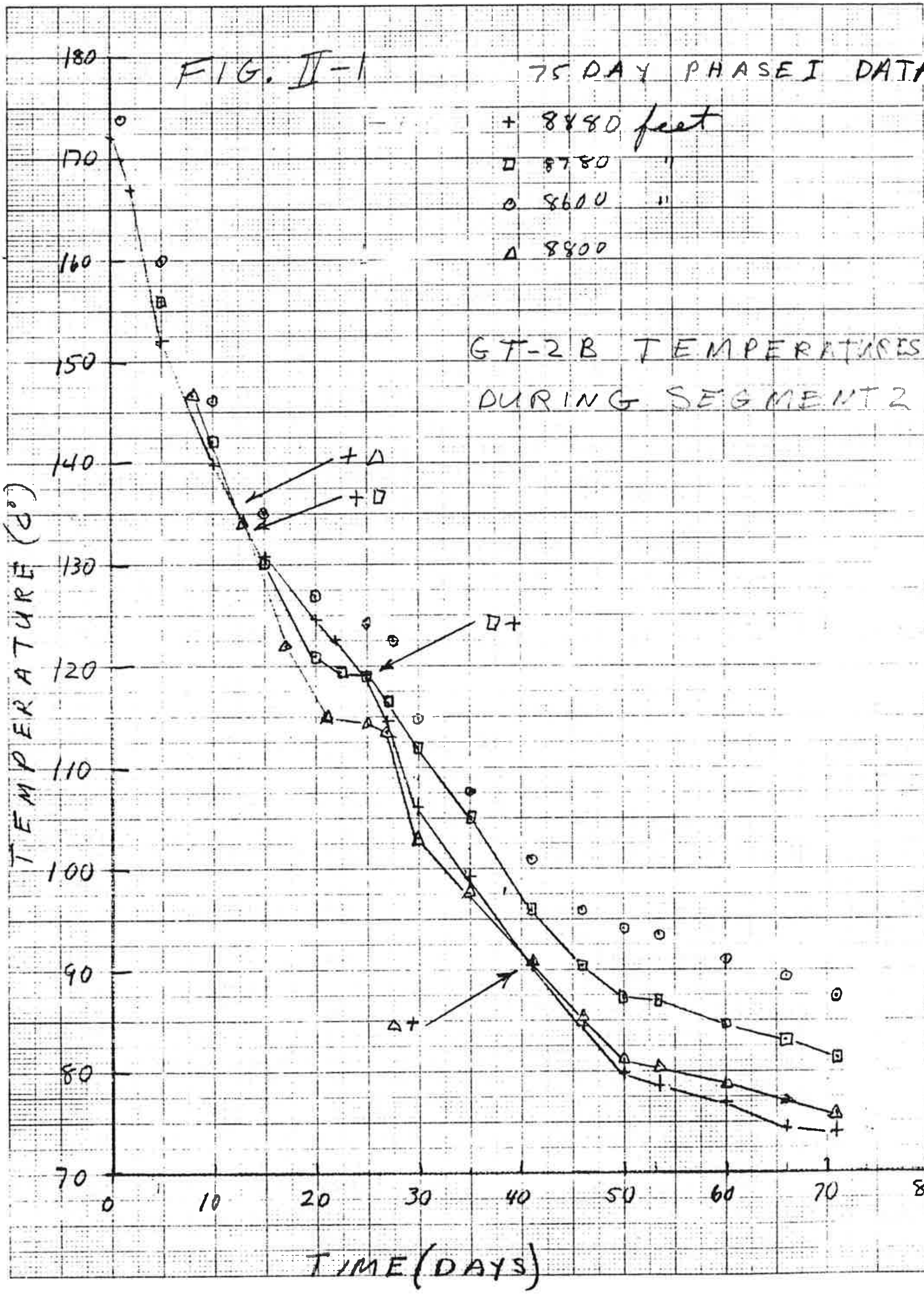


FIG. II-1
75 DAY PHASE I DATA
+ 8880 feet
□ 8780 "
⊙ 8600 "
Δ 8800
GT-2B TEMPERATURES
DURING SEGMENT 2
+ Δ
+ □
□ +
Δ +
TEMPERATURE (C°)
TIME (DAYS)
180
170
160
150
140
130
120
110
100
90
80
70
0
10
20
30
40
50
60
70
80

FIG. II-2

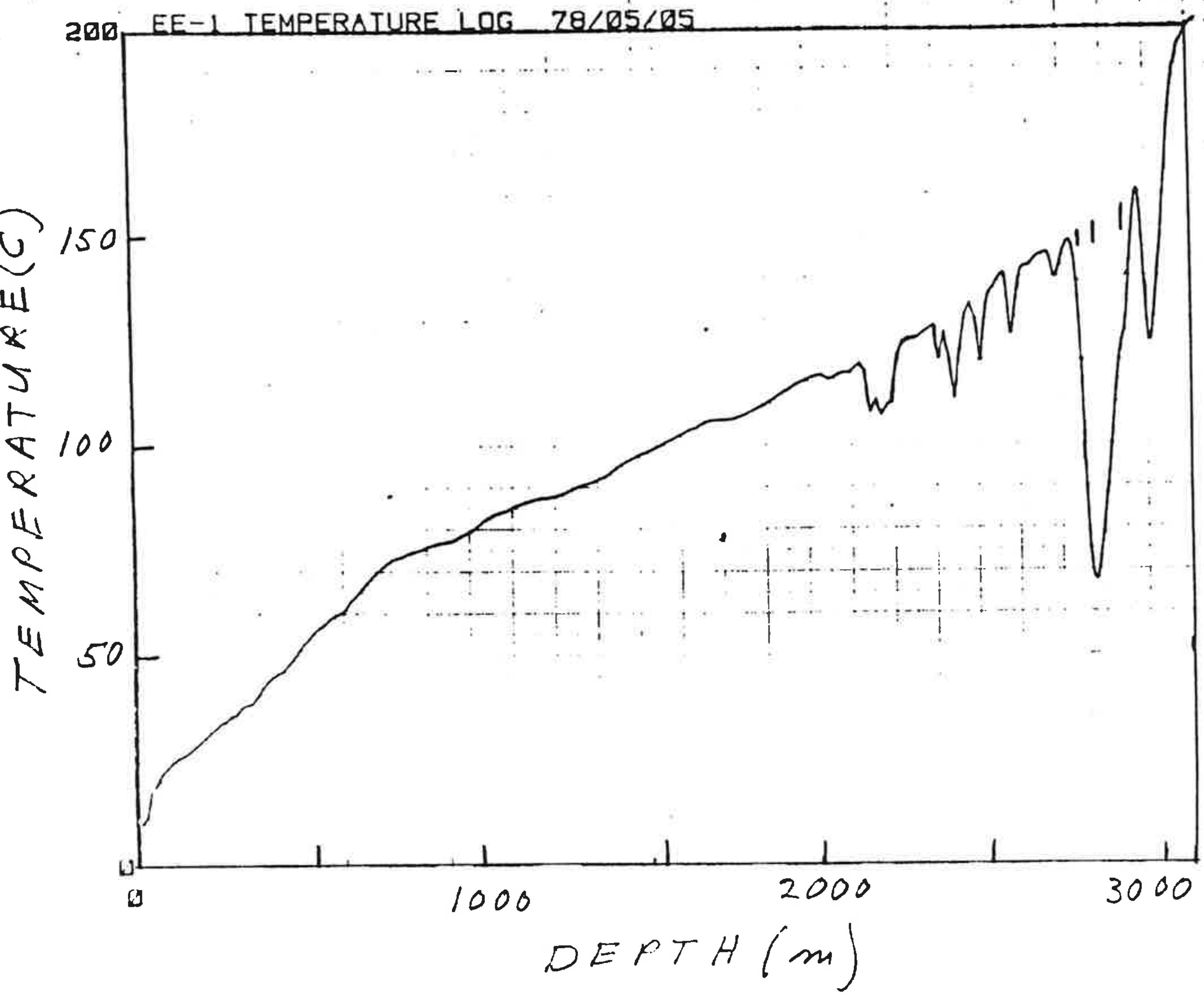
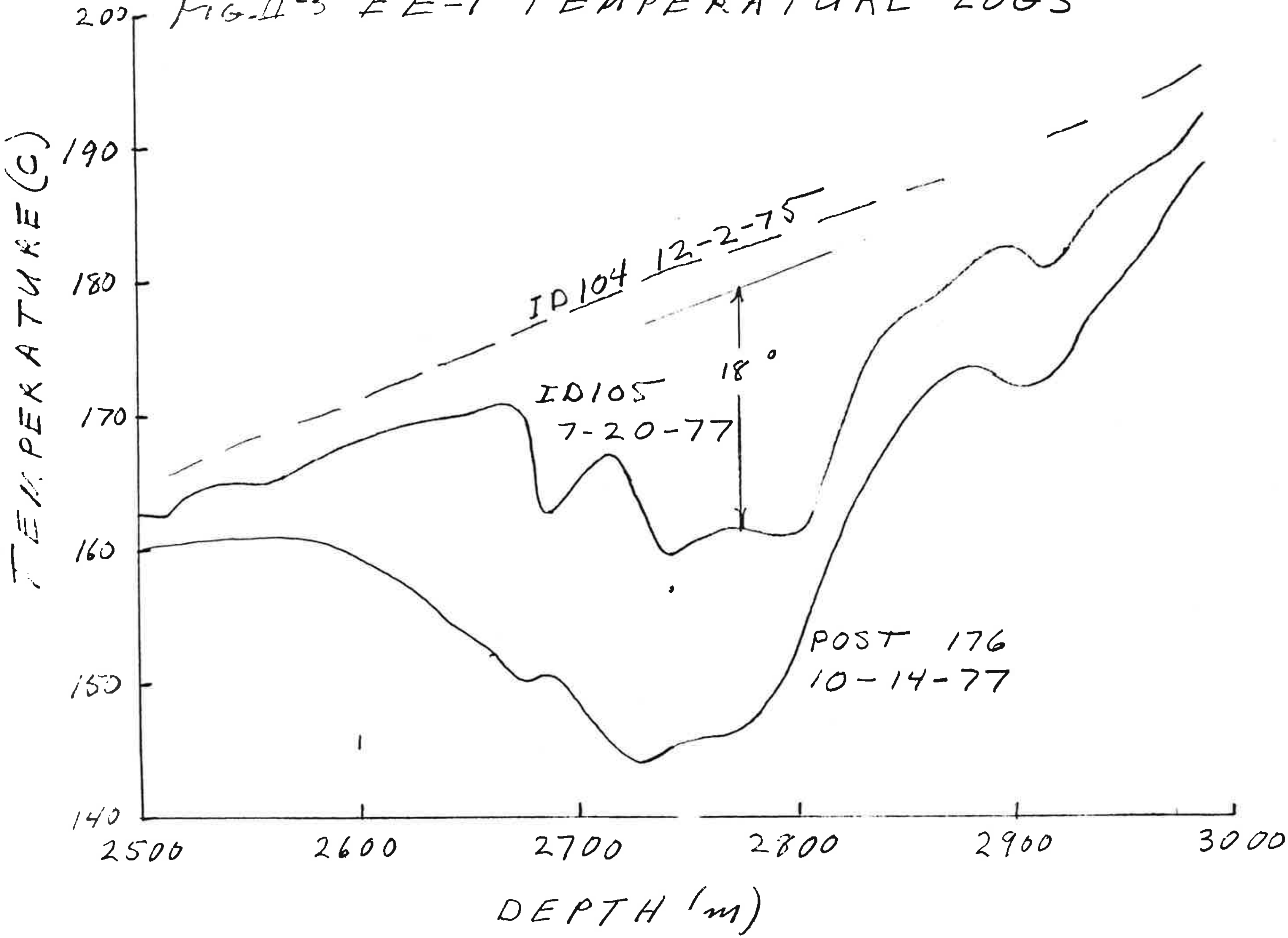

EE-1 TEMPERATURE LOG 78/05/05
200
150
100
50
0
1000
2000
3000
TEMPERATURE (C)
DEPTH (m)

FIG. II-3 EE-1 TEMPERATURE LOGS



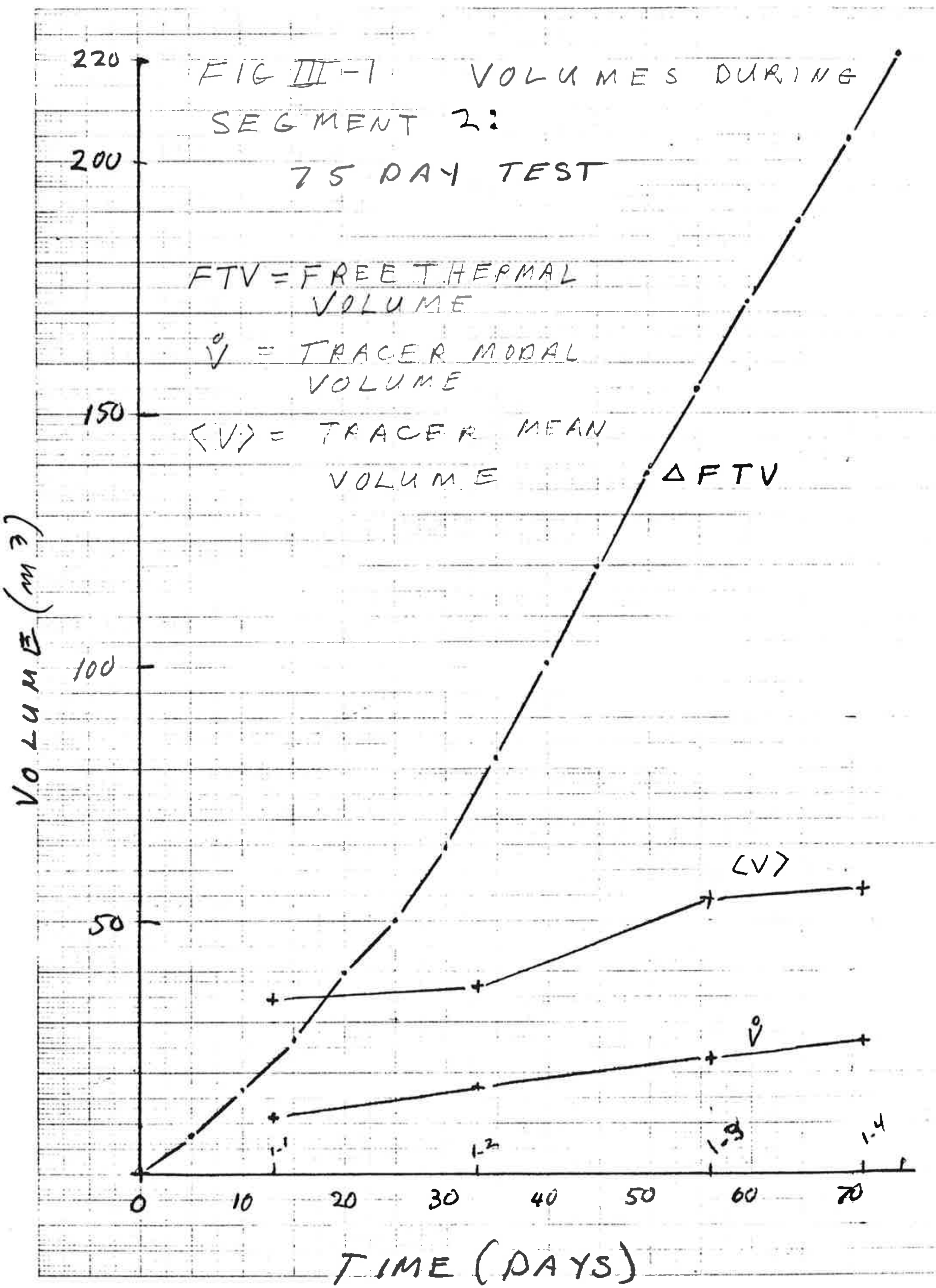


FIG III-1 VOLUMES DURING SEGMENT 2: 75 DAY TEST
FTV = FREE THERMAL VOLUME
V̊ = TRACER MODAL VOLUME
⟨V⟩ = TRACER MEAN VOLUME
ΔFTV
⟨V⟩
V̊
VOLUME (m³)
220
200
150
100
50
0
10
20
30
40
50
60
70
1-1
1-2
1-3
1-4
TIME (DAYS)

FIG. III-2 VOLUMES DURING SEGMENT 3

EXPT 186 HBP

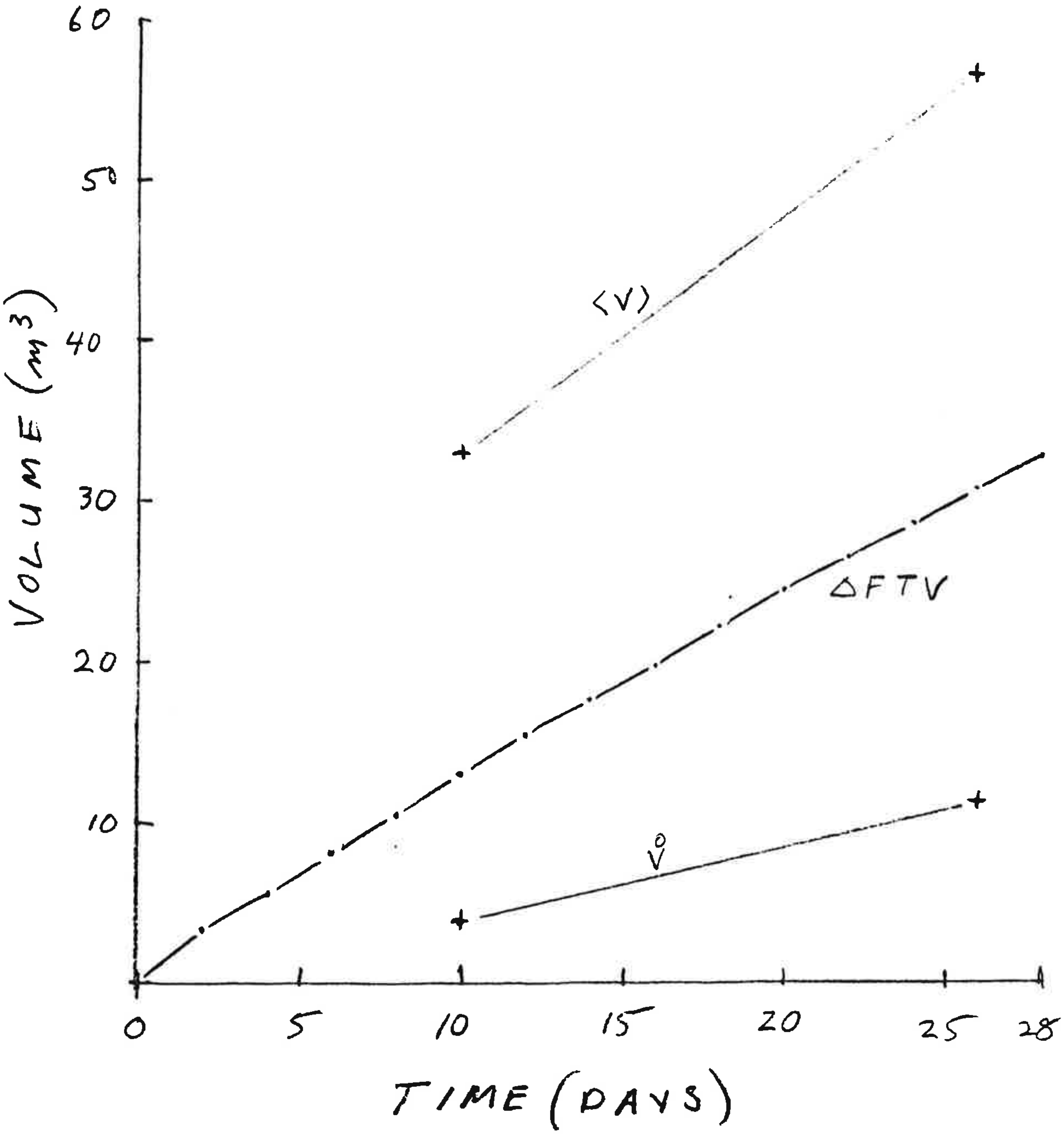


FIG III-3 VOLUMES DURING SEGMENT 4: EXPT 215

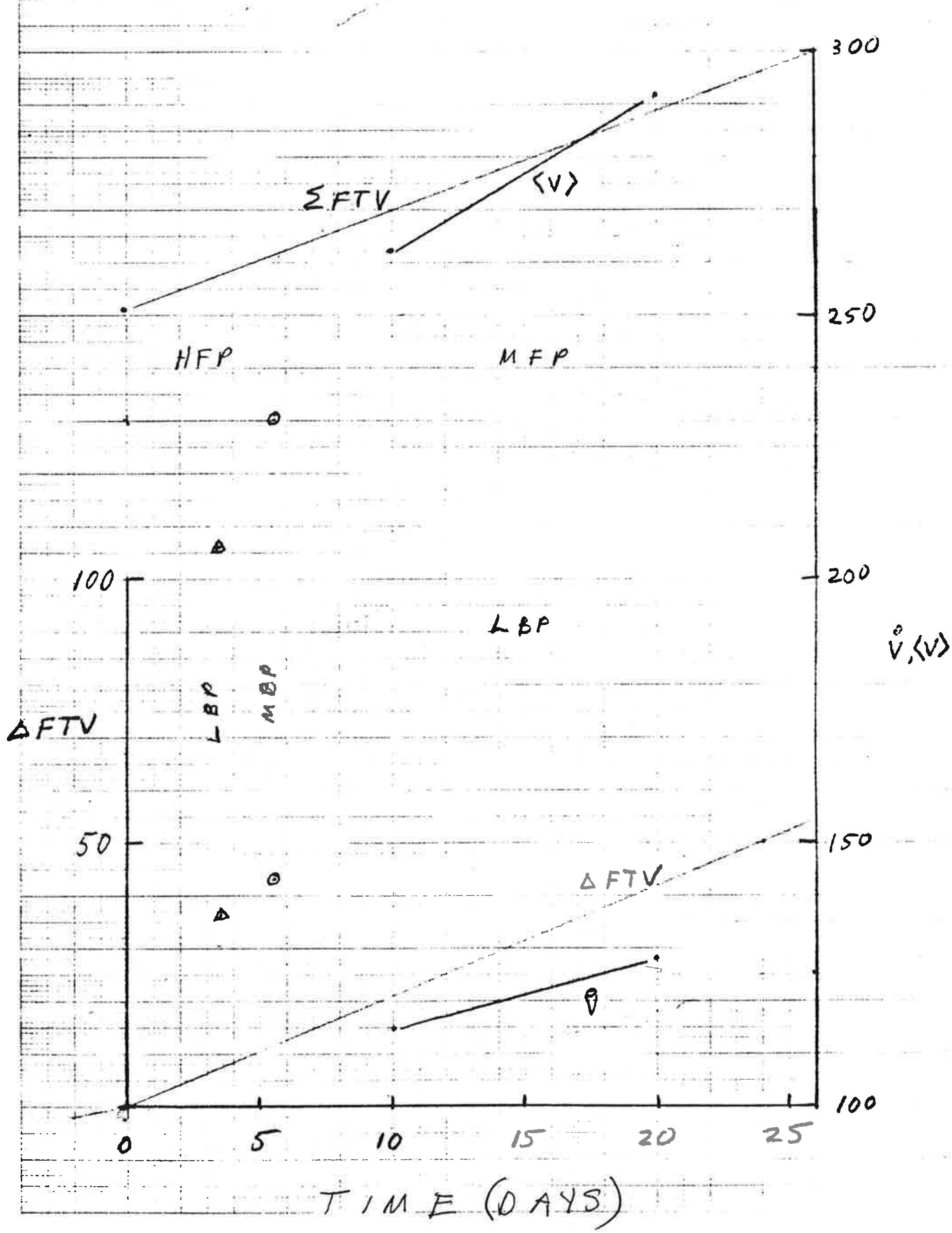
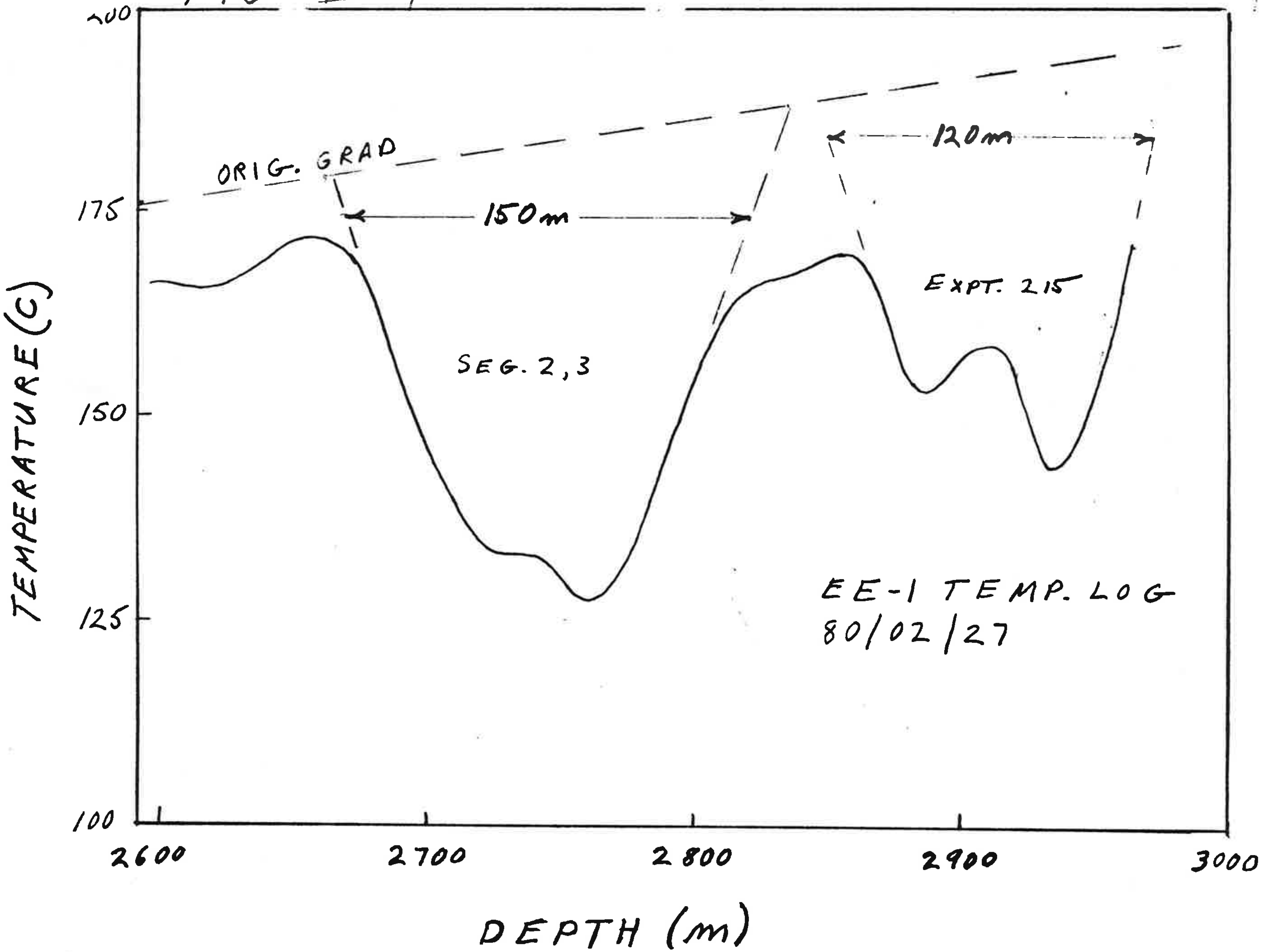


FIG IV-1



200
175
150
125
100
TEMPERATURE (C)
ORIG. GRAD
150m
120m
SEG. 2,3
EXPT. 215
EE-1 TEMP. LOG
80/02/27
2600
2700
2800
2900
3000
DEPTH (m)

REFERENCES

1. J. W. Tester and J. N. Albright (eds.), "Hot Dry Rock Energy Extraction Field Test: 75 Days of Operation of a Prototype Reservoir at Fenton Hill," Los Alamos National Laboratory report LA-7771-MS (April 1979).

2. D. W. Brown, "Results of Expt. 186, The High Back-Pressure Flow Experiment," (in preparation).

3. HDR Staff, "Preliminary Evaluation of the Second Hot Dry Rock Geothermal Energy Reservoir: Results of Phase I, Run Segment 4," Los Alamos National Laboratory report LA-8354-MS (May 1980).

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<u>APPENDICES</u>

A Heat Transfer Characteristics of the Phase I Reservoir: Segments 2 and 3.

B Heat Transfer Characteristics of the Phase I Reservoir: Experiment 217.

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OFFICE MEMORANDUM

TO : Distribution

DATE: Nov. 21, 1980

#2

FROM : H. N. Fisher

SUBJECT : HEAT TRANSFER CHARACTERISTICS OF THE PHASE I RESERVOIR PART I: CHANGES OF HEAT TRANSFER AREA DURING DRAWDOWN

SYMBOL : G-6

MAIL STOP: 981

I. INTRODUCTION

To establish unique heat transfer areas one must have complete flow and temperature data for each flow path in question. This is available for experiment 217. For the 75 Day Test and Experiment 186 the total flow and mixed temperatures are available. For the 75 Day Test the mixed temperatures at each flow entrance is available but not the complete flow history.

Here a simple model with one-dimensional fracture flow and two-dimensional heat conduction is used to test for growth of the heat transfer area during thermal drawdown. If the outlet temperature is to be reproduced accurately, the downhole EE-1 temperature and the GT-2B flow rate must be programmed in accurately. The AYER heat conduction code (Ref. 1) was used for the numerical simulations.

II. TOTAL HEAT TRANSFER AREA FOR 75 DAY TEST

The system output temperature as measured at 2620 m (8600 ft) in GT-2B is plotted in Fig. II-1 during the 75 Day Test. The GT-2B flow rate, Fig. II-2, is shown with the smooth approximation used in these calculations. The following procedure is used to fit the data using the AYER simulator with all parameters lumped in a single fracture.

- o The GT-2B flow rate as given by the fit in Fig. II-2, is programmed in.
- o The EE-1 downhole temperature as calculated by WELBOR is programmed in.
- o The initial fracture area is adjusted to obtain the best fit at early time before the first flow change.

o A programmed fracture area is established that allows a fit to the remaining data.

The resulting step increases in the area necessary to fit the data are shown in Fig. II-1. Each step is labeled with the area. The area increases during the same time that the flow increases. This inferred area increase is compared with the mean system volume obtained from dye tracer experiments (Ref. 2) in Fig. II-3.

III. HEAT TRANSFER AREA FOR THE LOWEST GT-2B CONNECTION

The outlet temperature for this connection is plotted in Fig. III-1. However, only the initial (19.2 gpm) and final (61.0 gpm) flow rates are known; so a slightly different procedure has followed. After the initial area was determined by fitting the data with 19.2 gpm during the first 24 days, the specific flow rate was programmed to obtain a fit to the remaining data. The specific flow rate (flow rate divided by area) can then be interpreted as changes of flow or area subject to the constraint that the final flow rate be 61.0 gpm. This requires that the area increase from 1500 m^2 to 2500 m^2 between day 25 and day 50.

IV. THE HEAT TRANSFER AREA FOR EXPERIMENT 186

For the high back pressure experiment 186 measured downhole inlet temperatures are available. In Fig. IV-1 the measured GT-2B flow rates are plotted along with the fit used in the calculations. The same procedure is followed as before. Figure IV-2 shows the measured GT-2B downhole temperature (8600 ft) and the results of the calculations with and without a programmed increase in area. The inferred area increases are compared with the mean system volumes (Ref. 3) in Fig. IV-3.

V. DISCUSSION

Previous analyses (Refs. 2 and 3) have not detected any increase in the effective heat transfer area during drawdown. The present analysis indicates that the heat transfer area could have increased by a factor of two during both long drawdowns. Also, considerable recovery of volume and area toward lower values occurred between the two experiments. The smaller initial area and volume may also be due to the different flow split induced by the high GT-2B back pressure.

This analysis assumes that the temperature of any new area is close to that of the existing reservoir. This gives areas that correlate fairly well with the increasing volumes. If the new area is being produced by thermal effects, it most likely occurs in the coldest portions of the reservoir and its temperature would be below the average reservoir temperature. In this case the area increases would be larger than estimated in this analysis.

VI. REFERENCES

1. R. G. Lawton, "The AYER Heat Conduction Computer Program, "Los Alamos Scientific Laboratory report LA-5613-MS (May 1974).

2. J. W. Tester and J. N. Albright (eds.), "Hot Dry Rock Energy Extraction Field Test: 75 Days of Operation of a Prototype Reservoir at Fenton Hill," Los Alamos Scientific Laboratory report LA-7771-MS (April 1979).

3. D. W. Brown, "Results of Expt. 186, The High Back-Pressure Flow Experiment," (in preparation).

FIG. II-1

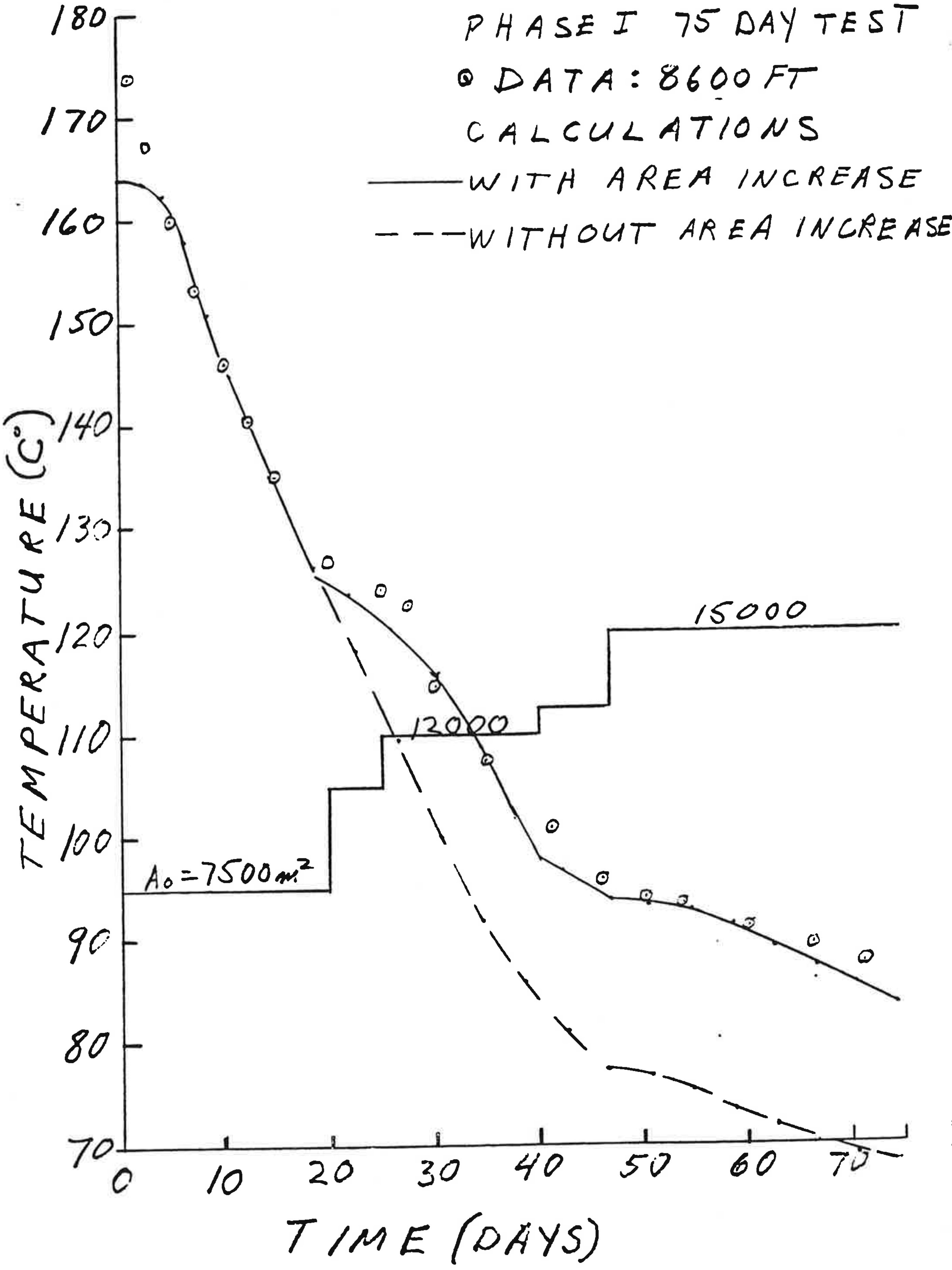
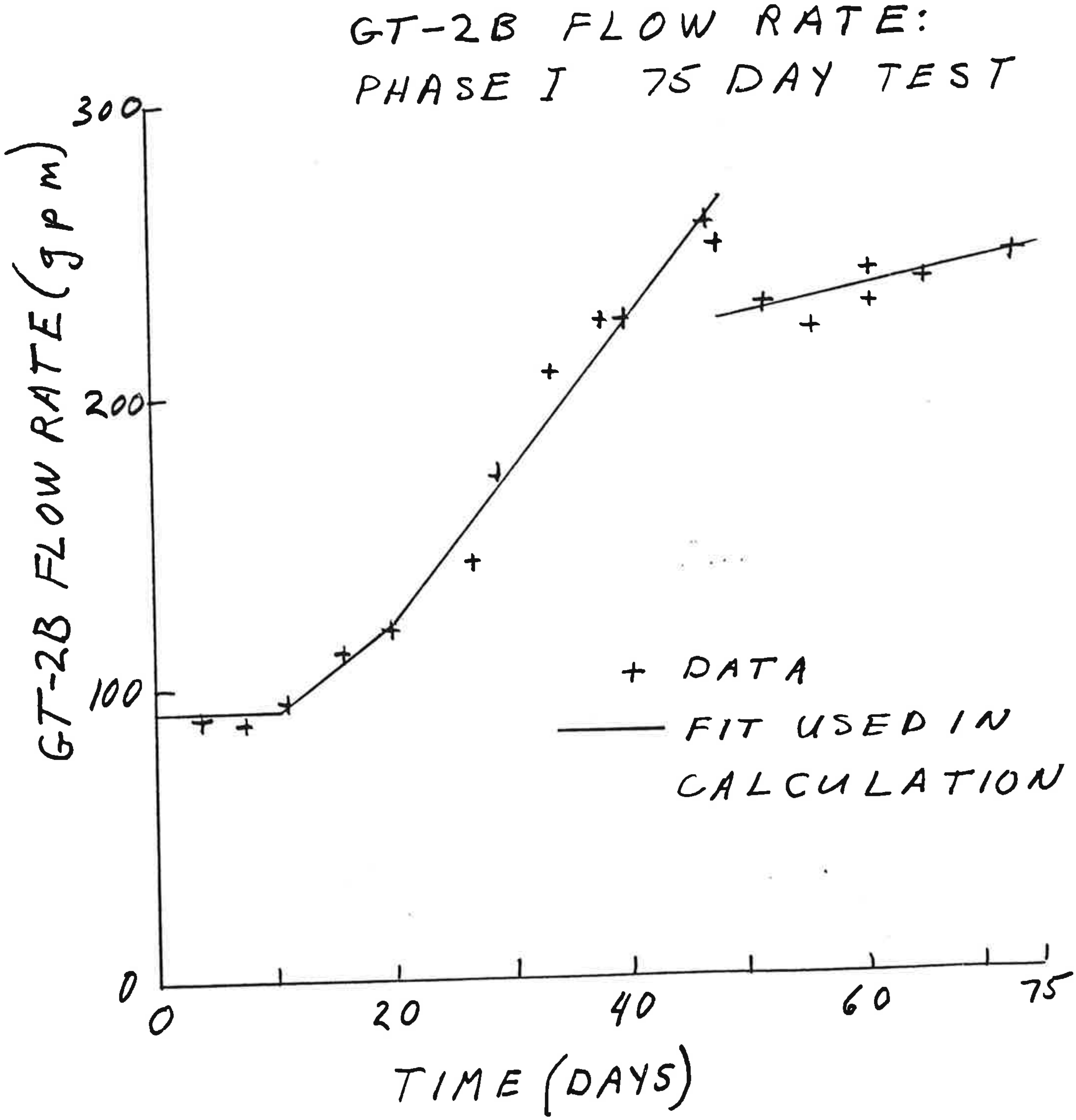

PHASE I 75 DAY TEST
⊙ DATA: 8600 FT
CALCULATIONS
WITH AREA INCREASE
WITHOUT AREA INCREASE
15000
12000
A₀ = 7500 m²
TEMPERATURE (C°)
TIME (DAYS)
180
170
160
150
140
130
120
110
100
90
80
70
0
10
20
30
40
50
60
70

FIG. II-2


GT-2B FLOW RATE:
PHASE I 75 DAY TEST
300
200
100
0
GT-2B FLOW RATE (gpm)
0
20
40
60
75
TIME (DAYS)
+ DATA
FIT USED IN CALCULATION

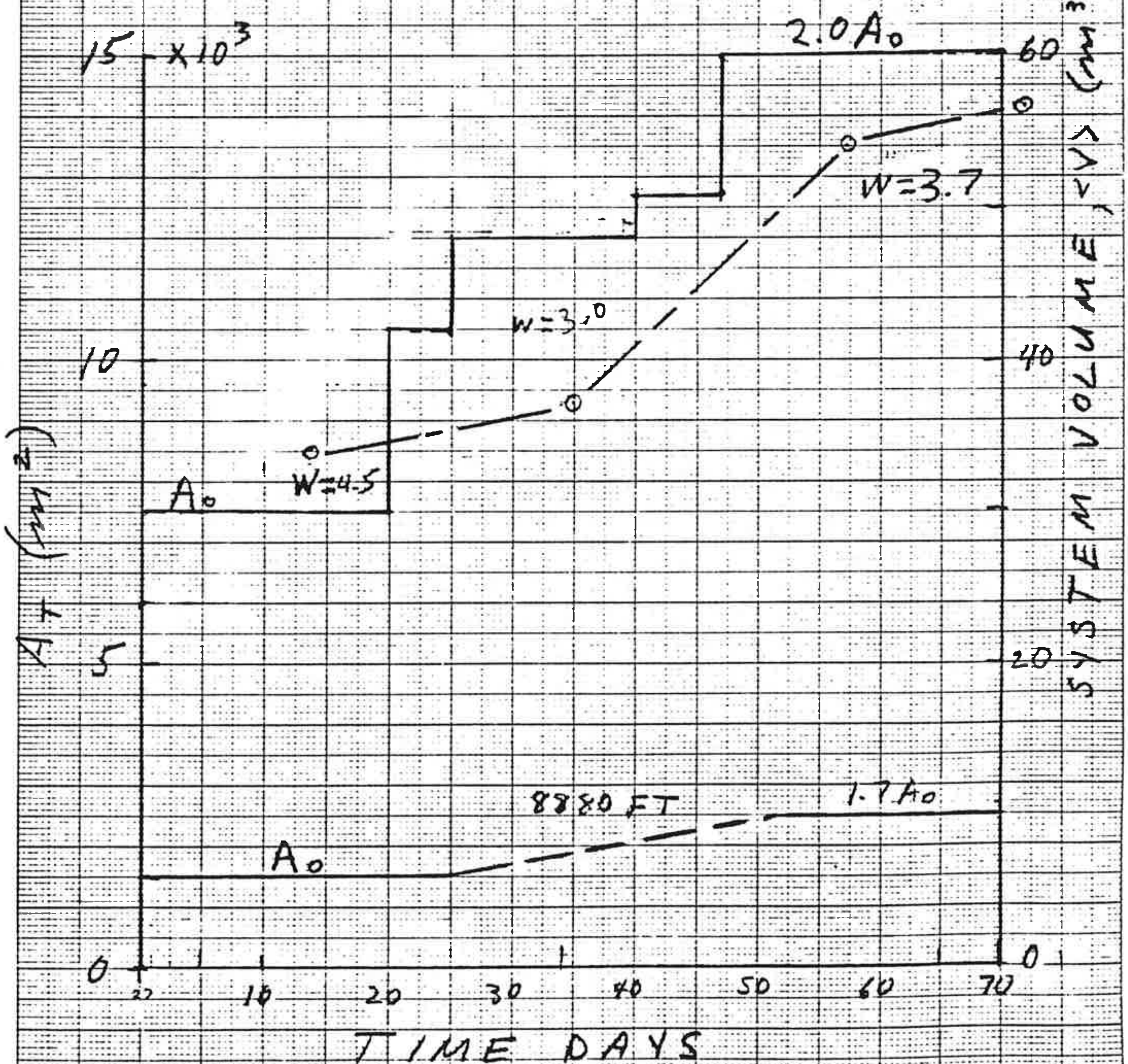


FIG. II-3 HEAT TRANSFER AREA AND MEAN VOLUME FOR 75 DAY EXPT

FIG. III-1

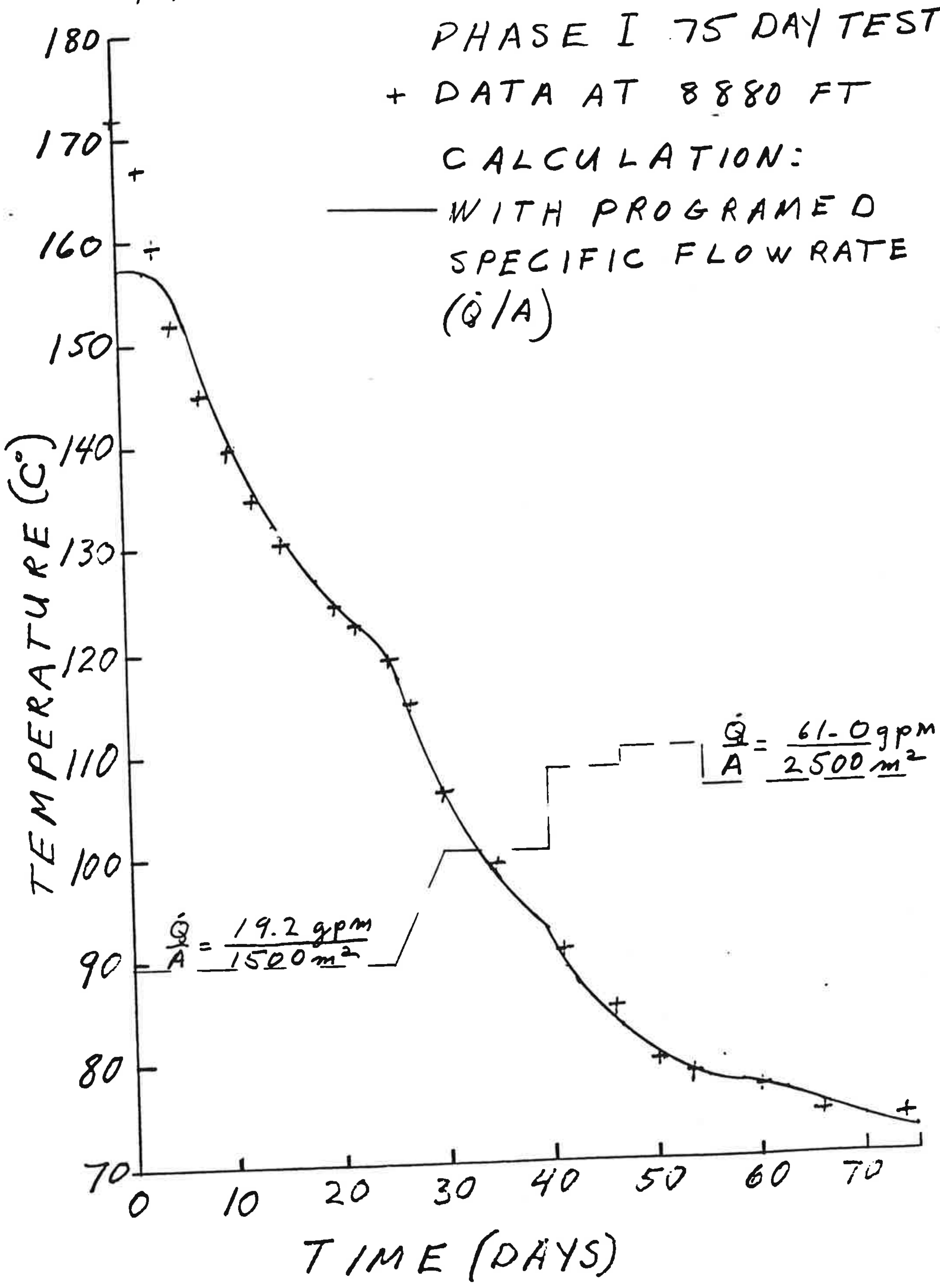

PHASE I 75 DAY TEST
+ DATA AT 8880 FT
CALCULATION:
WITH PROGRAMED SPECIFIC FLOW RATE ($\dot{Q}/A$)
$\dot{Q}/A$ = 61.0 gpm / 2500 m²
$\dot{Q}/A$ = 19.2 gpm / 1500 m²
TEMPERATURE (C°)
180
170
160
150
140
130
120
110
100
90
80
70
0
10
20
30
40
50
60
70
TIME (DAYS)

FIG. IV-1

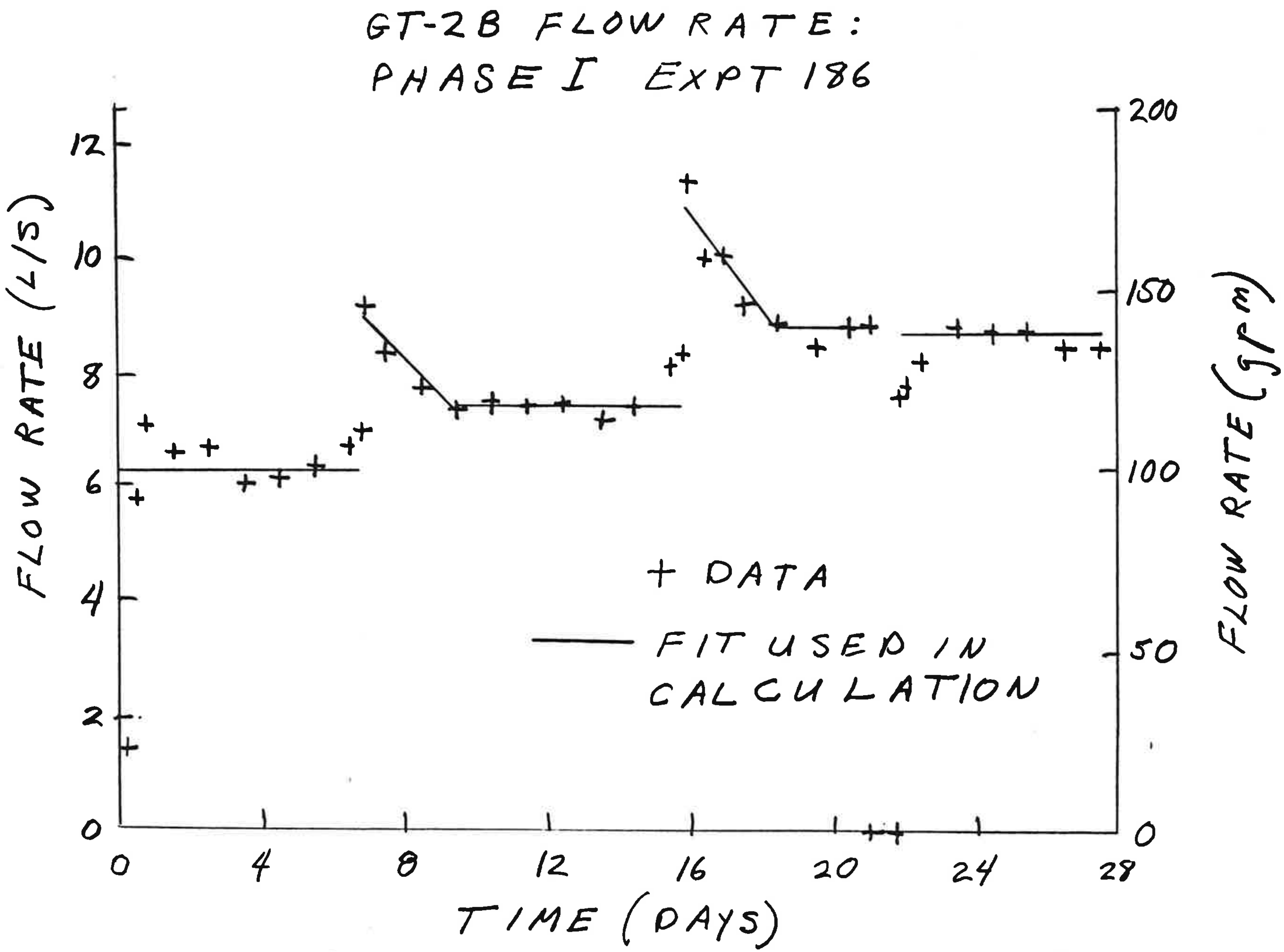

GT-2B FLOW RATE:
PHASE I EXPT 186
FLOW RATE (L/S)
FLOW RATE (gpm)
+ DATA
FIT USED IN CALCULATION
TIME (DAYS)
0
4
8
12
16
20
24
28
2
6
10
50
100
150
200

FIG. IV-2

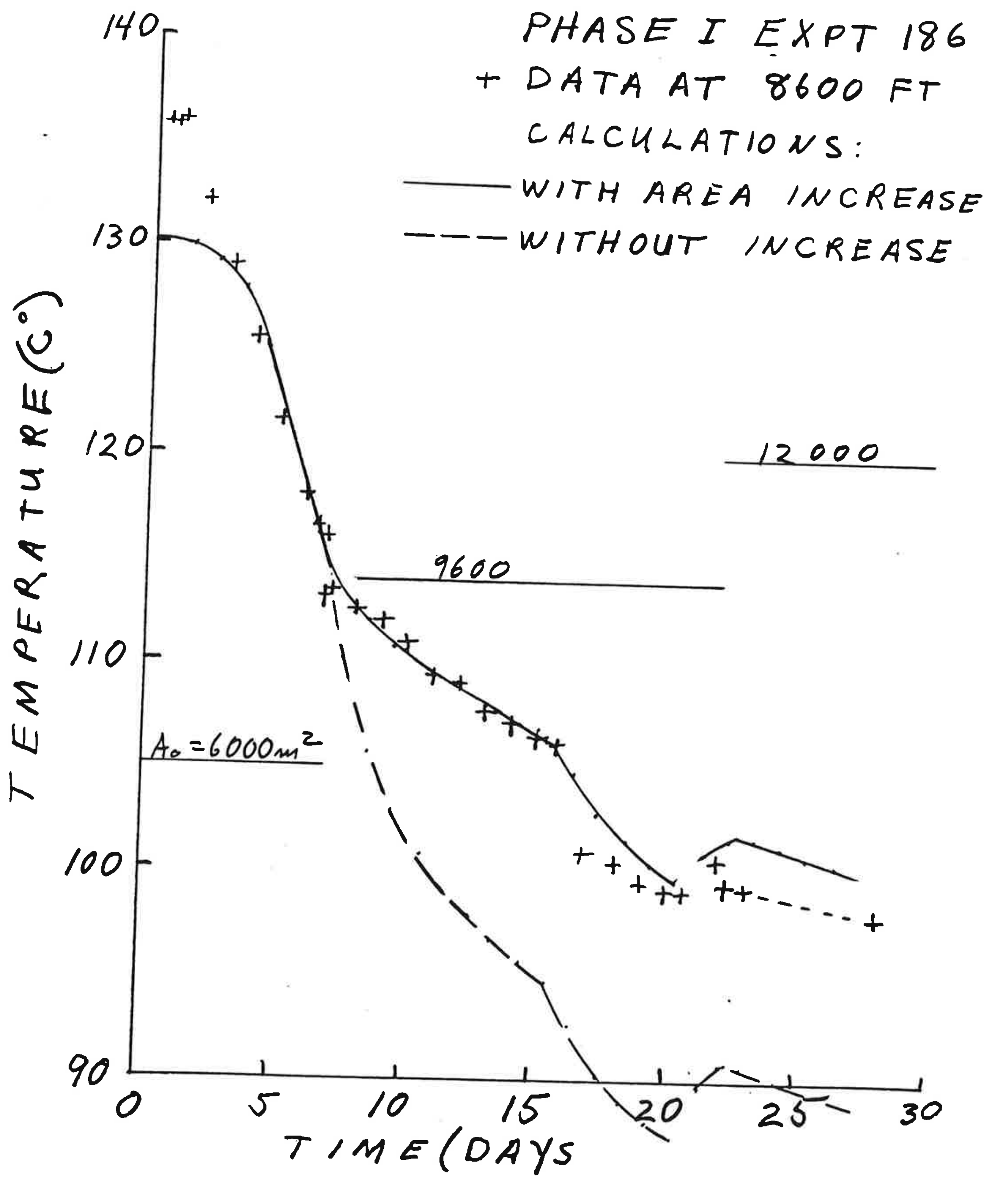
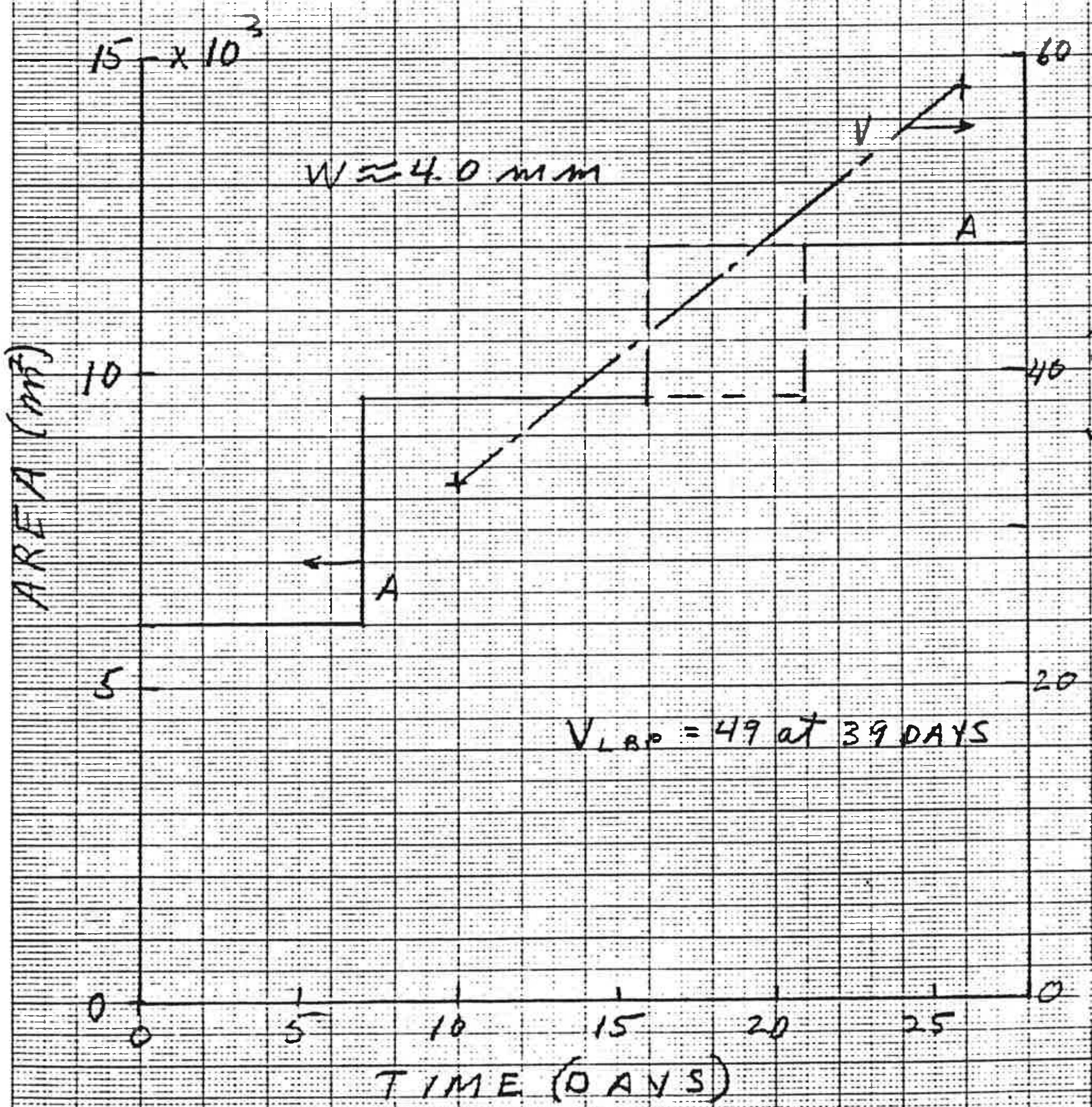

PHASE I EXPT 186
+ DATA AT 8600 FT
CALCULATIONS:
WITH AREA INCREASE
WITHOUT INCREASE
12000
9600
A₀ = 6000 m²
TEMPERATURE (C°)
TIME (DAYS)
140
130
120
110
100
90
0
5
10
15
20
25
30

FIG. IV-3
HEAT TRANSFER AREA
AND MEAN VOLUME
DURING EXPT. 186



Distribution Feb. 20, 1981

H. N. Fisher

HEAT TRANSFER IN THE PHASE I RESERVOIR: EXPERIMENT 217

G-6 #3

981

I. INTRODUCTION

The spinner and temperature surveys in GT-2B during Expt. 217 have provided a complete flow and temperature history of the three main flow exits. Temperature surveys in EE-1 have also provided occasional measurements of the inlet temperature to the reservoir. This complete flow and temperature history and the nature of the data suggest that the temperature drawdown can be interpreted in terms of a multi-fracture model with partly independent flow paths. The discussion is divided into three sections.

Section II is a review of the temperature flow data as reduced by R. Potter. Approximate analytical fits to that portion of the data that provide input to the calculations are obtained.

In Section III the reasons for choosing a particular model and its limitations are discussed. The calculational fits to the drawdown data and the resulting heat exchange areas are discussed.

II. TEMPERATURE AND FLOW DATA OF EXPERIMENT 217

The periodic temperature and spinner flow logs taken in GT-2B duriing expt. 217 have been reduced to the outlet temperatures and flows in three major zones exiting into the GT-2B wellbore (ref. 1). The reduced temperatures and flows are plotted in Figs. 1, 2, and 3 along with the total flow in the casing and the mixed temperature in the casing. The reservoir inlet temperature obtained from three logs in EE-1 are also shown in Fig. 1. A number of significant observations can be made immediately.

The outlet temperatures show little curvature in Fig. 1 when plotted on a scale with the inlet temperature near the zero on the scale. The small temperature change with respect to the possible change makes fits to the data insensitive to the details of the model.

When plotted on a larger scale the temperatures show regular trends (Fig. 3) that allow the determination of approximate reservoir parameters.

Early transients in the temperature data can be due to vertical gradients resulting from previous flow experiments. Any vertical gradients due to cooling previous to experiment 215 are not included in the mmodel.

Little reccovery is observed. Only the lower fracture zone shows a significant long-term rise in temperature. This indicates that only a small fraction of the heat exchange area is hotter than the mean reservoir.

The mixed outlet temperature remains near that expected in the recovered temperature field of the previous flow experiments. This infers that most of the heat exchange area is in the depleted volume of the reservoir.

After the start of the EE-1 annulus flow the inlet temperature increased seven degrees. This preheat of the inlet water indicates a new floow path; and, in some way an enlargement of the system. The increase in inlet temperature is the same size as the overall decrease in the average outlet temperature and retards the drawdown significantly.

The variations in the flow in the upper fracture zone are out of phase with those in the lower fracture zone. In the absence of a mechanism for such an effect it is reasonable to assume that these variations are due to inaccuracies in the flow measurements.

III. THE MULTIPLE FRACTURE MODEL

The temperature drawdown data will be interpreted in terms of a multiple fracture model containing several partly independent flow paths rather than as a single large fracture with several flow exits. The evidence for multiple independent flow path in both the early Phase I reservoir (segments 1, 2, and 3) and the recemented (segments 4and 5) reservoir exists in much of the data. Only some of this evidence in three main categories will be discussed here.

1) Multiple temperature depressions exist in all wellbores after all flow experiments. Spinner and temperature logs in the three production wells (GT-2, 2A, and 2B) have shown at least five major flow exits distributed over a horizontal distance of almost 40 meters and a vertical distance of 80 meters. Temperature logs in the injection well (EE-1) have shown at least eight major or minor flow exits or crossings in 900 vertical and 100 horizontal meters. Figure 4 is a temperature log in EE-1 just prior to experiment 217. After over a year of recovery the two peaks of the segment 2 and 3 depletions are still distinguishable. The depression has the characteristic shape of two superimposed Gausians that match the recovered temperature field of flat vertical fractures.

2) The temperature drawdown shows characteristics of independent flow paths. In Fig. 3 the lower fracture is seen to draw down at a slower rate than the upper and main fractures. The temperatures of the lower and

main fractures cross at 140 days. This behavior would be unlikely if the upper and main fractures were extensions of the lower fracture.

3) The tracer studies indicate that the model volume of the main fracture was larger than the modal volume of the upper fracture during experiment 217. Figure 4 shows the modal volume $\overset{c}{V}$ of each of the major flow paths for two of the bromine tracer experiments during experiment 217. The occurrence of the maximum model volume in the main fracture would be unlikely if the upper fracture were an extension of the main fracture.

The gross heterogeneous nature of the reservoir must also be considered. The upper half of the reservoir was repeatedly cooled and pressurized prior to the recementing of EE-1. The lower part which is acessed by connections below the casing has had a different flow history.

The vertical extent and temperatures in the reservoir are best characterized by the temperature log in Fig. 4 which is the intersection of the nearly vertical (within 7°) EE-1 wellbore with the reservoir. The temperatures along the wellbore are depressed an extra $10^{\circ}C$ by unrecovered wellbore cooling. The minimum temperature (plus $10^{\circ}C$) in the upper reservoir probably represents the flow entrances and is lower than the average fracture temperatures. Earlier temperature logs show three main fracture crossings of EE-1 in the upper reservoir. The temperature depression in the lower part of the reservoir was created mainly by the large flow in experiment 215. The extent of this temperature depression indicates that this part of the reservoir consists of one major flow path that is $\approx$60 m wide and crosses the wellbore twice or of two narrower flow paths.

The foregoing considerations suggest a simple two-dimensional heat transfer model with lumped parameters (Fig. 6). The grid, shown at (a) in Fig. 6 consists of a multiple fracture system embedded in a two-dimensional rock matrix. Three-dimensional heat conduction effects are ignored. A specific flow rate ($\dot{Q}/A$) is programmed into each branch of the fracture. Since the flow rate ($\dot{Q}$) is known this is a specification of the area (A) of each branch. At the midpoint of the reservoir a small transverse region connects the upper and lower systems. The lower system has one or two fractures; the upper system has three. Each problem in the parameter study runs from the beginning of experiment 215 through the end of 217. This was done since the changes for each run should be applicable to both experiments. The initial temperature field was determined by the depletion of the reservoir in Segments 2 and 3. Since the vertical gradients in each fracture of the upper reservoir are unknown no attempt was made to include them. The transverse temperature profile was a Gausian with a width determined by the recovery time since Segment 2 and a maximum determined by the total energy removed in Segments 2 and 3. Since the temperatures in the lower part of the reservoir are determined by experiment 215, they were initially set to the measured original earth temperatures. A typical transverse profile is shown at (b) in Fig. 6. A typical vertical profile is shown at (c).

The adjustable parameters are considered to be:

a) the area of each branch of the fracture system, and

b) the average starting temperature of each fracture in the upper system which is determined by the exact position in the grid.

Since the actual starting temperature of each fracture is determined by its entire flow history and proximity to other fractures, it would be difficult to obtain an accurate value to insert in the model.

The time-dependent flow programmed into the calculations was approximated by the dashed lines in Fig. 2. The total flow is maintained in the upper and lower reservoir. In the upper part the flow is divided between the three major flow paths as indicated. One reservoir model has the flow divided between two fractures in the lower half. The flow split is adjusted in the calculations as an additional parameter. The second model has only one fracture in the lower half.

Figures 7 and 8 are the best fits to the temperature data obtained thus far. Table 1 summarizes the areas used in each model. Model A has two fractures in the lower reservoir, whereas model B has only one. The best estimate of the total heat exchange area at the end of experiment 217 is 45,000 m^2 with 30,000 m^2 residing in the portion of the reservoir cooled by the Segment 2 and 3 flows.

Table 1. Summary of Heat Exchange Areas for Expt. 217

Reservoir	Fracture	Areas (m^2) Model A	Areas (m^2) Model B
Upper	Upper	7500	7500
	Main	15,000	15,000
	Lower	7500	7500
Lower	(1)	7500	--
	(2)	7500	7500
Total Areas		45,000	37,500

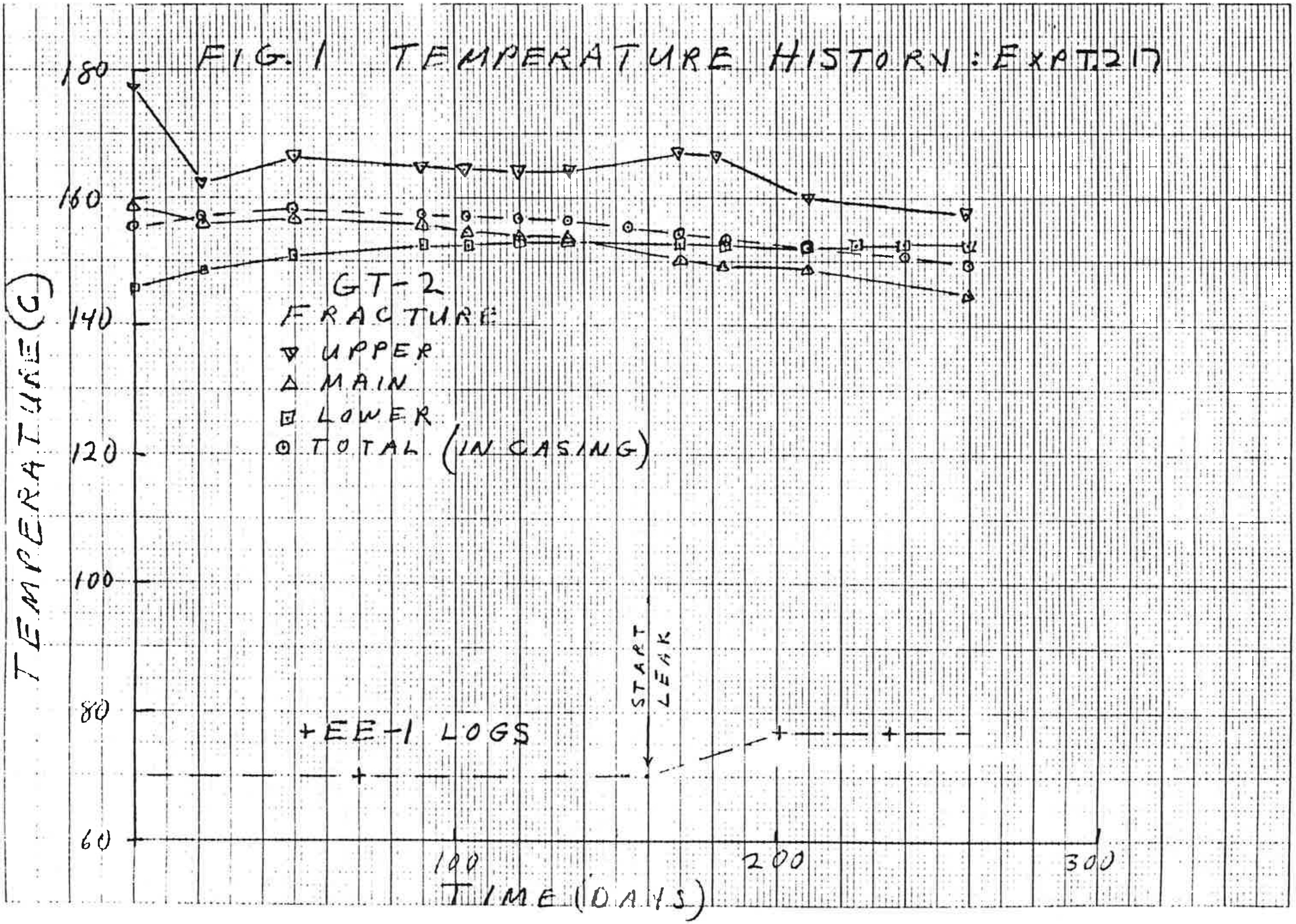
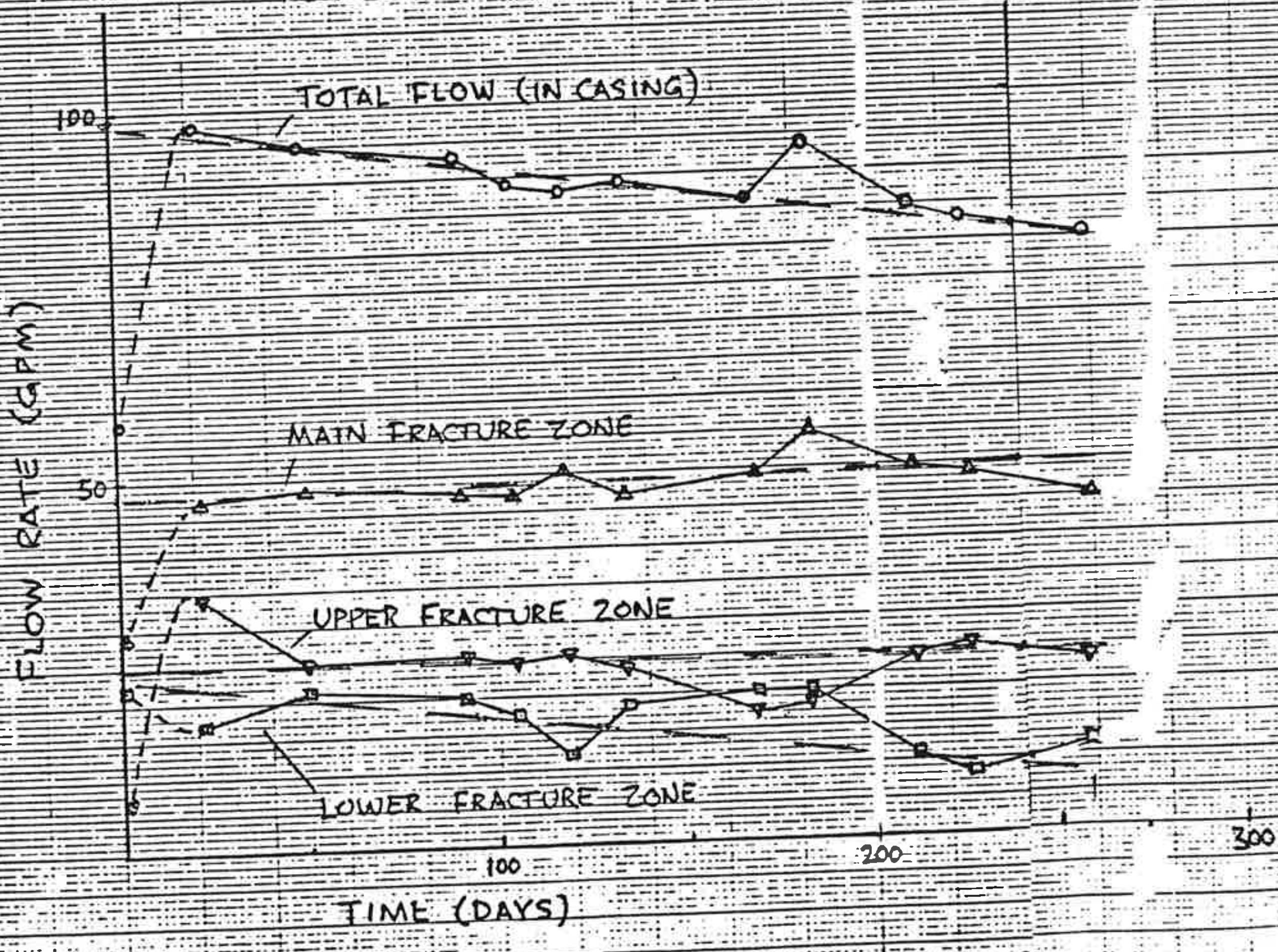


FIG. 1 TEMPERATURE HISTORY: EXPT.217
GT-2
FRACTURE
UPPER
MAIN
LOWER
TOTAL (IN CASING)
+EE-1 LOGS
START LEAK
180
160
140
120
100
80
60
TEMPERATURE (C)
100
200
300
TIME (DAYS)

FIG. 2 GT-2B FLOW RATE HISTORY
RUN SEGMENT 5



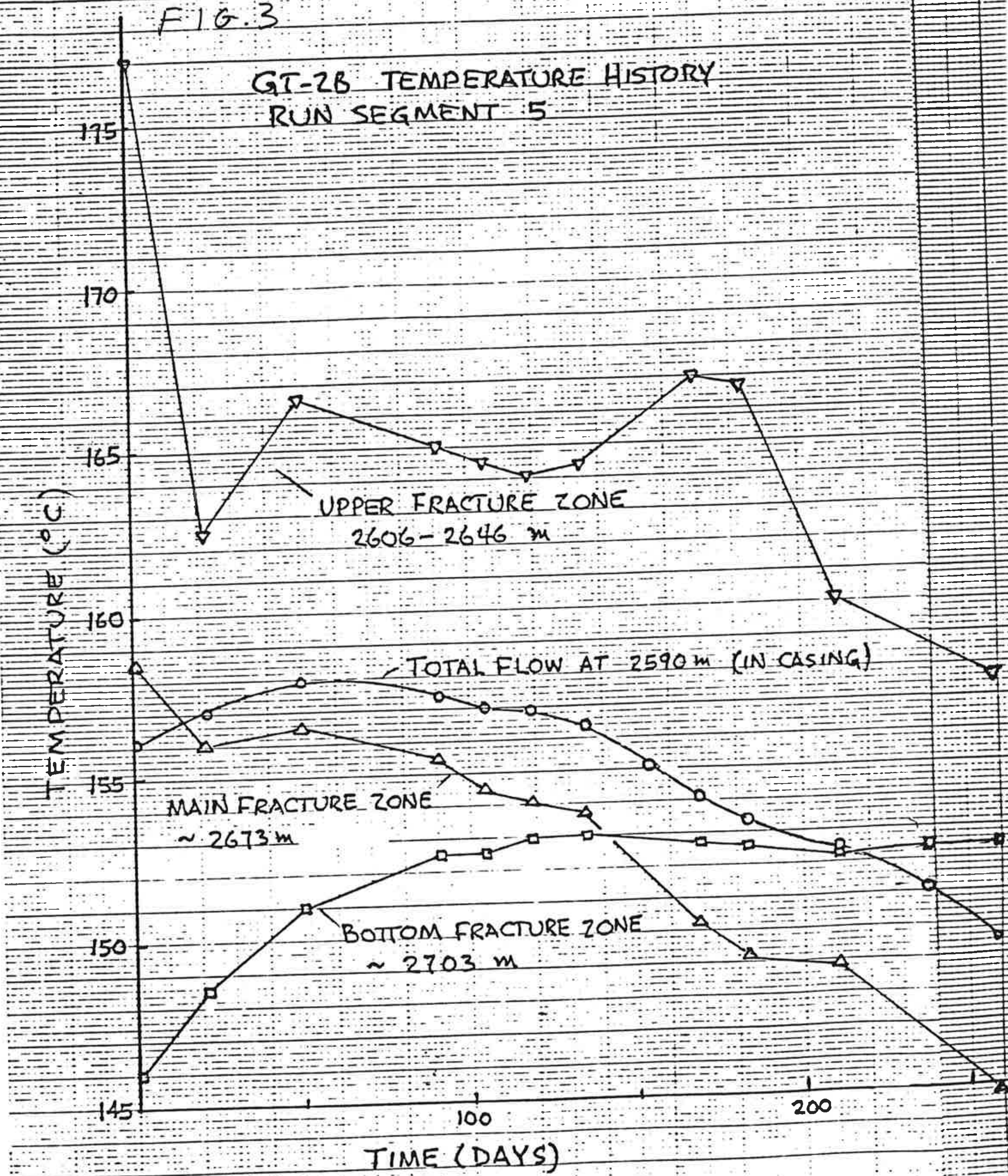


FIG. 3
GT-2B TEMPERATURE HISTORY
RUN SEGMENT 5
UPPER FRACTURE ZONE
2606-2646 m
TOTAL FLOW AT 2590 m (IN CASING)
MAIN FRACTURE ZONE
~2673 m
BOTTOM FRACTURE ZONE
~2703 m
TEMPERATURE (°C)
175
170
165
160
155
150
145
100
200
TIME (DAYS)

FIG.4

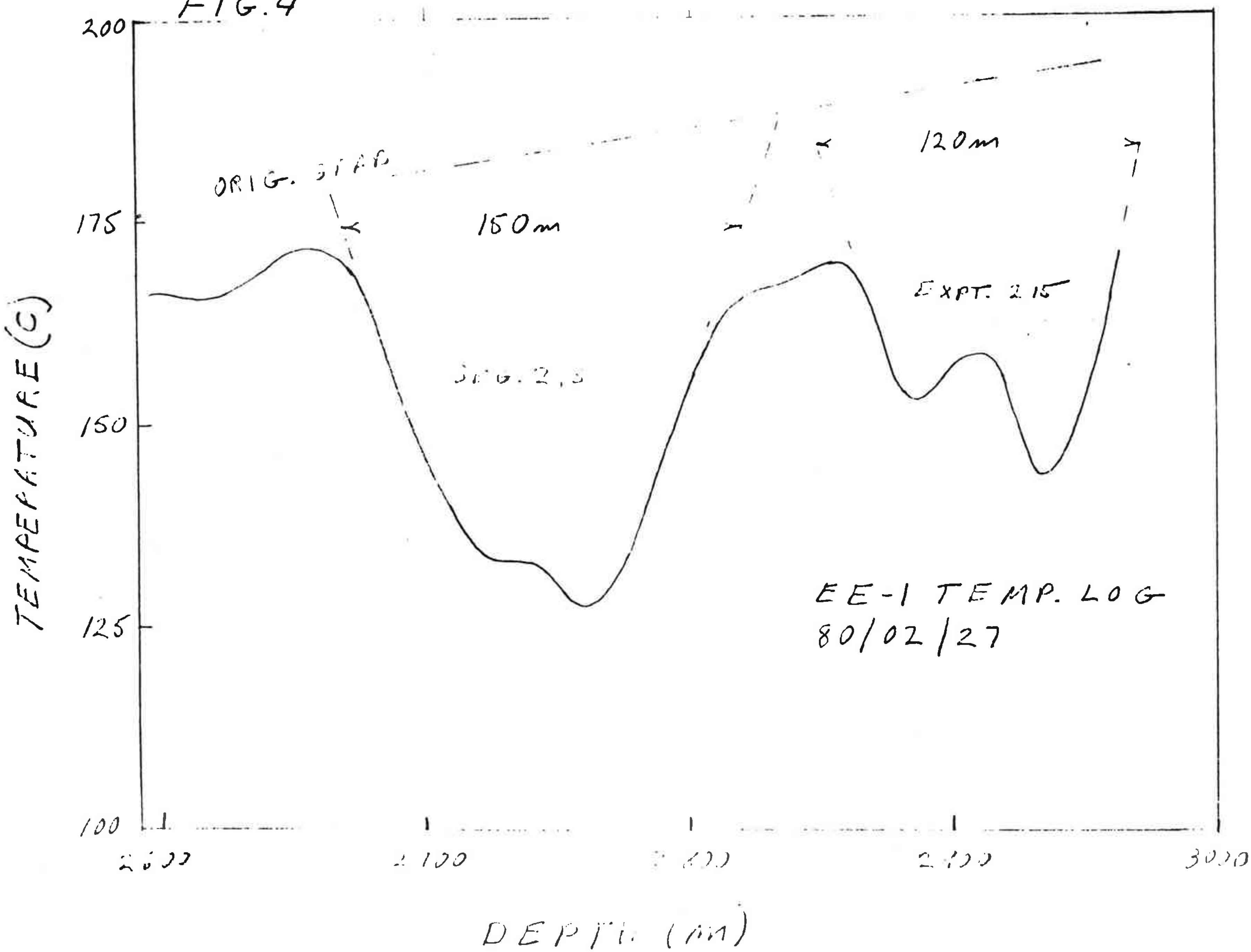

200
175
150
125
100
TEMPERATURE (C)
ORIG.
150m
120m
EXPT. 215
EE-1 TEMP. LOG
80/02/27
3000
DEPTH (M)

FIG.5. TRACER VOLUMES (Br^{82})
EXPT 217

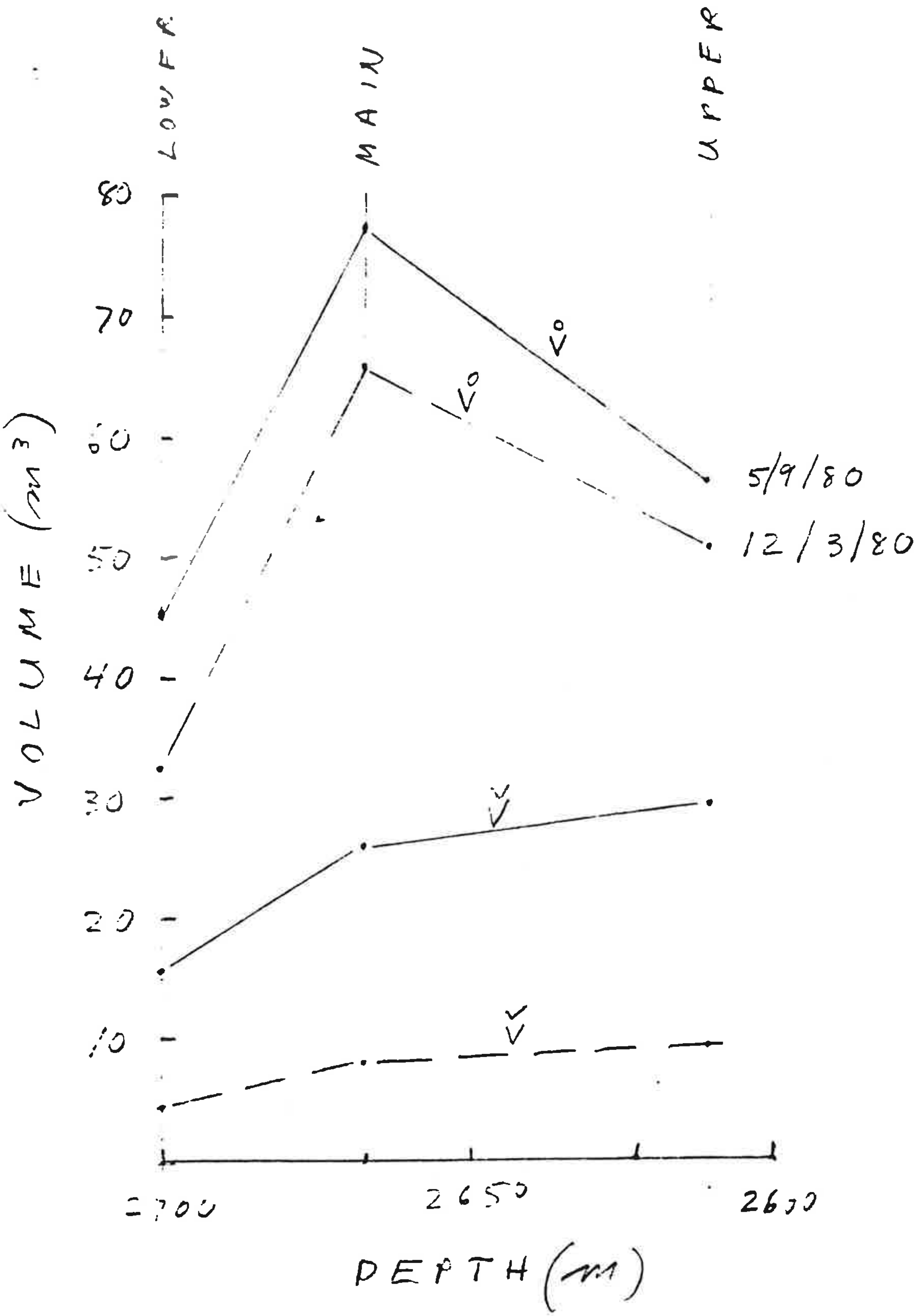


FIG. 6 Two Dimensional Reservoir Model

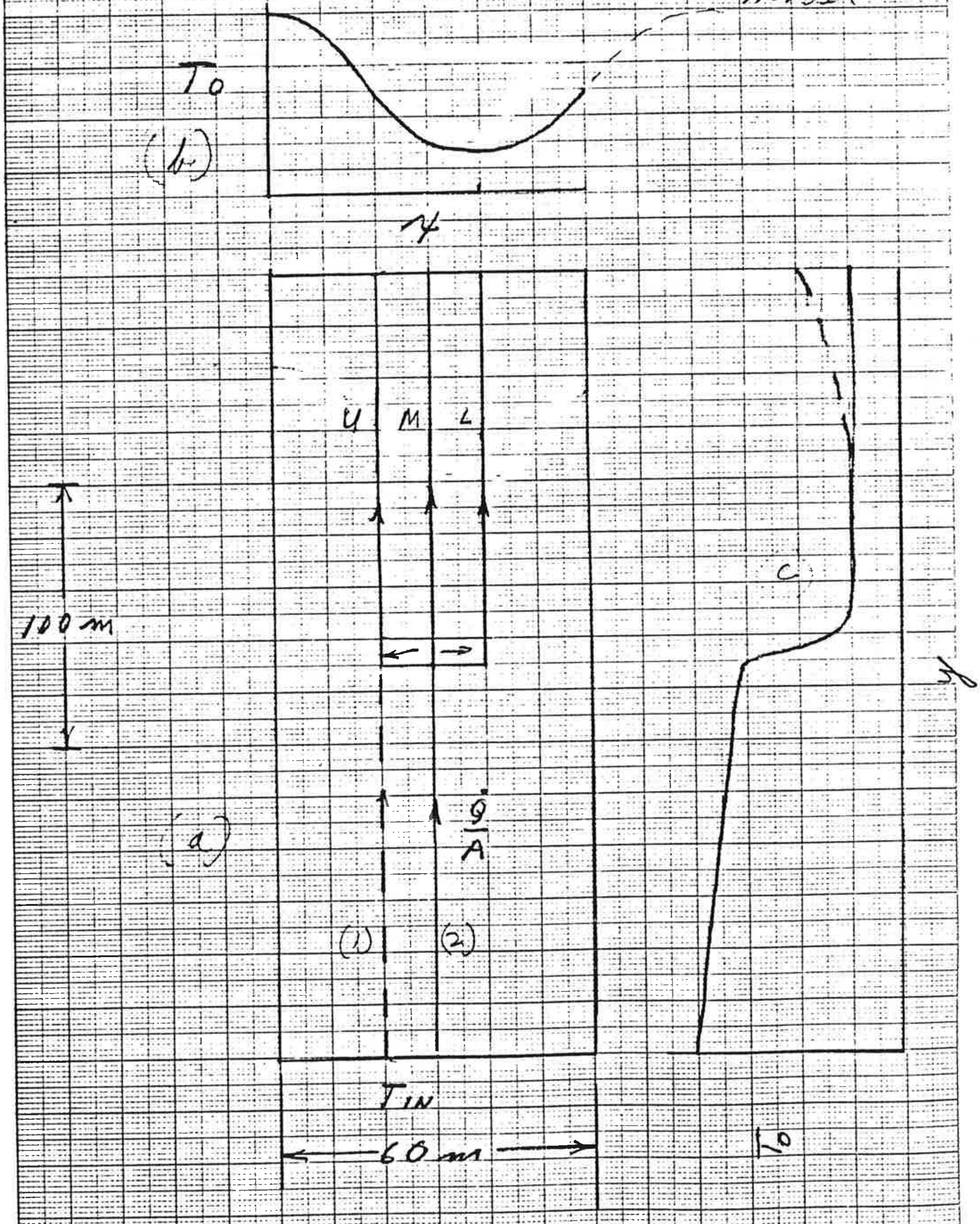


FIG 7. EXPT 217 TEMPERATURES

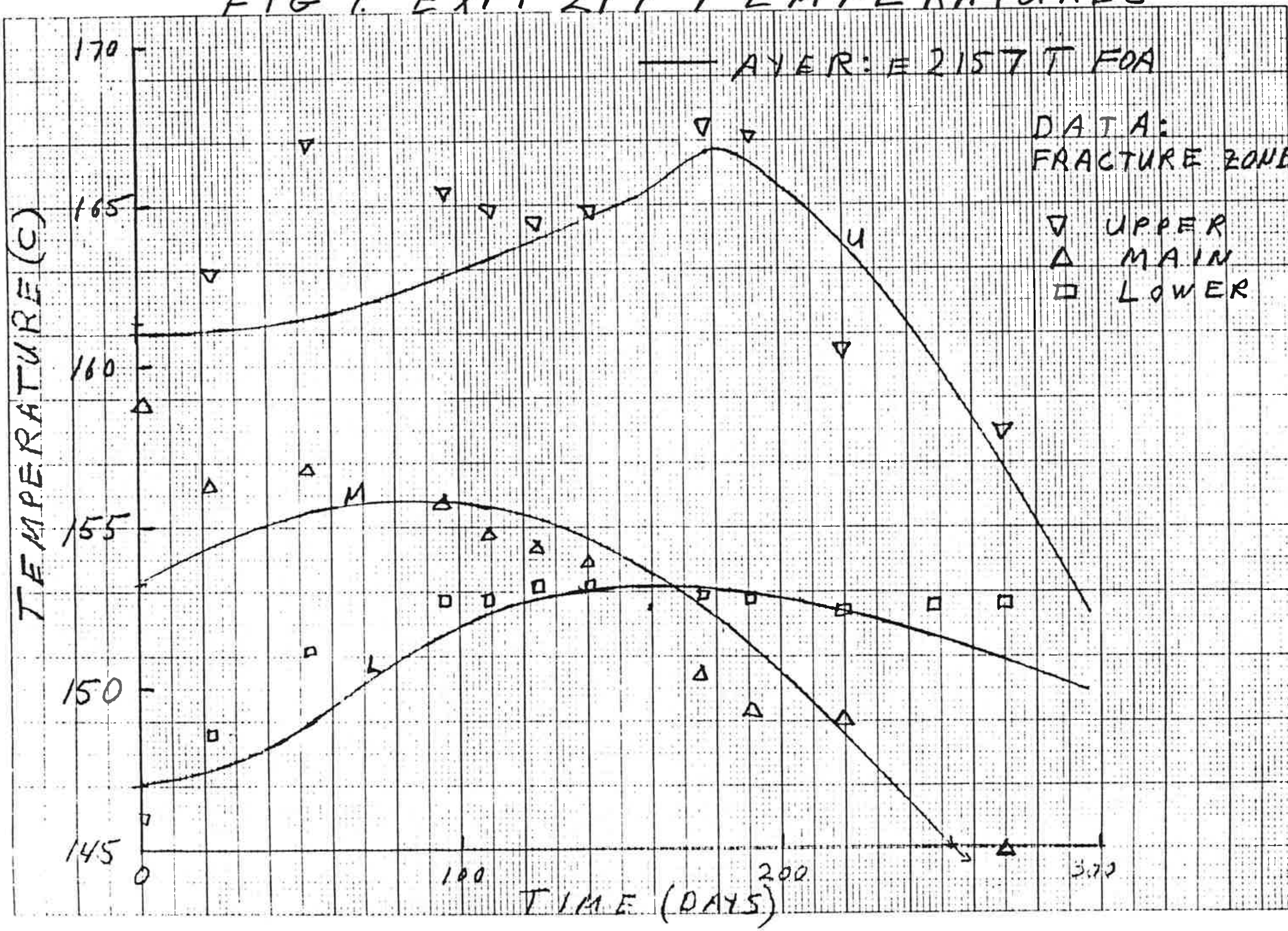


FIG. 8 EXPT 217 TEMPERATURES