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INTERIM REPORT ON HTLTR MOCKUP - RUN NUMBER 2

AUTHOR

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INTERIM REPORT ON HTLTR MOCKUP RUN NUMBER 2

By

M. R. Kreiter

Equipment Development Unit
Reactor and Material Technology Department

Classified by: D. P. Schively

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PRELIMINARY REPORT

This report contains information of a preliminary nature prepared in the course of work under Atomic Energy Commission Contract AT(45-1)-1830. This information is subject to correction or modification upon the collection and evaluation of additional data.

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RICHLAND, WASHINGTON
operated by
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UNITED STATES ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1)-1830

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INTERIM REPORT ON HTLTR MOCKUP RUN NUMBER 2

INTRODUCTION

Herein are presented results from Run Number 2 of the large mockup designed and built by Equipment Development for research and development in support of the High Temperature Lattice Test Reactor. Results from Run Number 1 have been presented in BNCC-87.

Based on high water concentrations and extensive graphite corrosion observed in Run Number 1, it was decided the primary objectives of Run Number 2 would be to, (1) investigate the effect of cleanup towers in the recirculating gas system on gas compositions within the system; (2) determine the extent of graphite damage at a reduced core temperature of 700°C, which is slightly below the threshold of the water-graphite reaction; and (3) check operability of the control rod and safety blade under heated conditions.

Additional items included for study were (1) comparison of contaminant gas removal during the initial evacuation--nitrogen fill cycles with Run Number 1; (2) performance of the graphite heating element components; and (3) integrity of Inconel-sheathed chromel-alumel thermocouples.

SUMMARY AND CONCLUSIONS

A graphite core temperature of approximately 700°C was maintained for a period of 115 hours at which time the mockup was cooled for inspection of the control rod, safety blade, and heater elements. Visual examination of the above-mentioned items revealed little or no graphite corrosion as can be seen in Figures 1, 2, 3, and 4. These conclusions were substantiated by weighing small graphite samples which remained in the mockup during the entire operating period. The interior of the mockup is shown in Figure 17.

Maximum gas contaminant concentrations observed at the blower discharge during the run were 3200 vol. ppm H_2O, 250 vol. ppm CO_2, and 100 vol. ppm CO. These concentrations decreased to 1200 vol. ppm H_2O, 220 vol. ppm CO_2, and 60 vol. ppm CO by the end of the run. Approximately 800 ml. of water were collected at the vacuum pump discharge during five system evacuations as compared to 5200 ml. collected after the first five evacuations of Run Number 1. During fourteen days of operation the molecular-sieve cleanup towers, designed and installed prior to this run, removed a total of 2.8 gallons of water from the mockup gas system.

Control rod and safety blade scrams totalled 39 and 33, respectively. Of these, 12 control rod and 13 safety blade scrams were performed above 500°C including five each at 700°C. One of the safety blade scrams was successfully performed at room temperature and a mockup pressure of 40 torr.

Some difficulty was experienced after 33 scrams when the magnetic clutch, which withdraws the safety blade, started slipping thereby preventing removal of the blade. It appears that the slippage may have been due to an oil film on the clutch facings, based on visual examination.

While at 700°C, the control rod drive mechanism met with increased frictional resistance during the last 0.1 of an inch of rod travel. When the rod was dismantled for inspection, small chips from the uranium oxide bearing, graphite outer cylinders were observed. These chips could have caused the increased resistance by lodging at the interface of the inner and outer cylinders.

Inconel sheathed, chromel-alumel thermocouples were used to monitor all graphite core and heating element temperatures during Run Number 2. Performance of the thermocouples appeared satisfactory; however, anomalous behavior of two of the heating element thermocouples was observed when gas was circulated through the mockup. The reason for the gas flow affecting only two of the four heating element thermocouples remains unexplained at present.

DISCUSSION

Gas System

The run was initiated by alternately evacuating the system and then filling with fresh nitrogen five times. Evacuation periods ranged from 2 hours to 16 hours and pressures of 19 torr to 42 torr were attained. Pressure data obtained during the first evacuation are presented in Figure 5. A total of 810 ml. of water were condensed and collected in the vacuum pump discharge line during the evacuations. Two of the evacuations were performed at the graphite core temperatures of 200°C and 230°C with 500 ml. of water being collected during the first (230°C) evacuation.

Results of an inleakage check performed at the conclusion of the third evacuation are presented in Table I.

TABLE I

Time after start, min.	Pressure, in. H_2O gage	Barometric Pressure, in. H_2O	Absolute Pressure, in. H_2O
0	-390	401	11
35	-376		25
55	-367		34
77	-358		43
100	-348		53
123	-338		63
149	-328		73
195	-307		94

For the period of time examined, the inleakage rate was calculated to be 0.9 ft^3/min.

Figure 6 depicts the gas cleanup system flowsheet. The system is comprised of two pairs of parallel, steel towers with each tower containing 100 pounds of 1/8" Linde type 5A molecular sieve pellets. In addition to the towers, two electrical heaters are included in the system to heat the cleanup tower regenerating gas. The parallel pair of towers permits regeneration of one set of towers while the other set remains in service.

Periodic sampling and analysis of the gas blower discharge stream (Mockup inlet gas) was performed throughout the run. Concentrations of water, carbon monoxide and carbon dioxide obtained from these samples are plotted in Figures 7, 8, and 9. Also included on Figure 7 is the water concentration in the molecular sieve exit gas stream.

On the 22nd of March, 1,500 cfh of 11,800 cfh leaving the gas blower was directed through the molecular sieve cleanup columns. The effect of these flows on the water concentration in the blower discharge gas can be seen in Figure 7. Water concentrations in the blower discharge and cleanup system exit gases for a short period of time after directing the recirculating as through the cleanup columns are shown in Table 2.

TABLE 2

Date	Time	H_2O Concentration, ppm vol.	
		Blower Discharge	Cleanup Exit
3/22/65	1435	2400	
	1440		1100
	1445		560
	1453	1300	
	1500		240
	1510	1100	
	1540	1100	
	1607		200
3/23/65	0830	780	
	1130		38

Electrical System

Two heating elements of a revised "Gibson Girl" geometry, shown in Figure 10, were installed for testing during this run. The design provides a higher moment of inertia cross section than that of the remaining two 1" x 1/2" rectangular elements used in the run. Consequently, the new rods are stronger in bending and column loading. To insure compatability with the HTLTR electrical supply, the resistance of the new design was matched with that of the rectangular shape by making the cross sectional areas equivalent. Resistance of each of the four heating elements was measured using a Wheatstone bridge before they were installed in the mockup with the results shown as follows:

TABLE 3

Geometry	Resistance, Ohms
Rectangular	0.049
Rectangular	0.049
Gibson Girl	0.050
Gibson Girl	0.050

After installation, the heating circuit was energized for a short period to measure current passing through the individual, parallel heating elements. Voltage drop values between the bus bars were obtained concurrently with the current measurements. These values permitted calculation of installed resistances reported in Table 4.

TABLE 4

Location	Current, amps	Volts	Resistance, ohms
TR	162	9.35	0.0577
BR	170	9.4	0.0554
BL	155	9.4	0.0606
TL	170	9.45	0.0556
TR (Recheck)	166	9.4	0.0566
BL (Recheck)	156	9.4	0.0603

The above values are not true heating element resistances due to the fact the voltage drop was measured across the bus bars rather than the elements themselves. They do, however, given an indication as to how closely the installed resistances, including contact resistances, compare.

A change in the return bus circuitry resulted in induction heating of certain portions of the steel shell. This required installation of cooling coils adjacent to the return bus shell penetration. Originally, the return bus was attached to the steel mockup shell which functioned as part of the return bus as did a portion of the graphite core. It was decided during Run Number 1 that grounding the return power bus to the mockup shell was not advisable. Otherwise, it would be necessary to insulate those components (e.g., control rods, safety blades, thermocouples) which extended into the core from the shell to prevent extraneous ground circuits. A simpler solution was to isolate the return bus from the shell such that the shell would no longer be in the return bus circuit. The a.c. conducting "return bus" was insulated from the steel shell; but, by necessity, passed near the shell thereby providing magnetic coupling which resulted in inductive losses. These losses were anticipated but the magnitude was not predictable due to the geometric complexity of the installation. Power, I^2R, generated at 700°C by the four, parallel heating elements, was estimated to be 23.6 Kw. This estimate was calculated by using a value for the current obtained during operation and applying a temperature correction factor to the measured resistances listed in Table 3. At this same time, the total power consumption, EI, was calculated to be 23.0 Kw based on the operating current and voltage. These two values agree within 3% which would indicate that induction losses were small in comparison with the total power consumption.

Figure 11 shows the total heater circuit resistance and total circuit current throughout the run.

<u>Temperature Measurement</u>

Figures 12, 13, 14, and 15 depict the temperature history during the run at various locations within the graphite core and thermal insulation. The graphite core temperatures plotted were obtained using 1/8" OD Inconel-sheathed, chromel-alumel thermocouples with grounded junctions. Wire diameter was 0.020 of an inch and was insulated from the sheath by crushed MgO beads. Thermal insulation temperatures were obtained from the same thermocouples used during Run Number 1.

Graphite core temperature data shown in Figures 12, 13, and 14 are consistent except for two heater element temperatures (TC-11 and TC-15) which appear to be affected by recirculating gas flow. This is evident if the heater element temperatures plotted in Figure 12 are examined for March 17. The gas blower was not operating at this time and it can be seen that the temperature indicated by TC-15 > TC-11 > TC-7 > TC-3. This is expected due to the location of the thermocouples axially along the heater element being monitored. If the temperatures obtained on March 17 are compared with those obtained either before or after this date while the gas blower is operating, anamalous temperature recordings will be noted. The reason for this behavior has not been definitely established as yet but will be investigated.

Samples

Small samples of graphite were placed within the mockup and remained there throughout the run to permit evaluation of the amount of corrosion occurring during the run. These samples were 1/2" x 1/2" x 3" and were slotted, forming fins approximately 1/32" thick, to provide a large, reactive surface area. Weight changes associated with these samples are reported in Table 4.

TABLE 4

Sample[1] Number	Initial weight, gms	Final weight, gms	Weight Change, gm	Weight Loss[2] rate x 10^8, gm $hr^{-1}cm^{-2}$
5-W	12.4026	12.4008	-0.0018	8.3
6-W	12.2763	12.2752	-0.0011	5.1
8-W	12.2833	12.2816	-0.0017	7.8
12-W	12.1047	12.1027	-0.0020	9.2
13-W	12.2075	12.2052	-0.0023	10.6
14-W[3]	12.4186	12.4159	-0.0027	12.4
15-W[3]	12.2594	12.2584	-0.0010	4.6
16-E	12.5129	12.5083	-0.0046	21.2
17-E	12.8719	12.8672	-0.0047	21.6
18-E	12.4343	12.4302	-0.0041	18.9
19-E[3]	12.6010	12.5964	-0.0046	21.2
20-E[3]	12.4172	12.4136	-0.0036	16.6
21-E	12.3425	12.3383	-0.0042	19.3

(1) W refers to west end of mockup
E refers to east end of mockup

(2) Based on 115 hours of exposure at 700 C and an exposed surface area of 189 cm^2.

(3) These samples were placed on the access opening floor brick.

A 2 1/2" x 1 1/16" x 3/8" B_4C sample placed between two 2 1/2" x 1 1/16" x 1/4" TD nickel plates, which remained in the mockup for the duration of the run, exhibited a weight gain of 0.0881 gm. Initial and final weights of the B_4C sample were 28.2720 gm and 28.3601 gm, respectively. Based on 115 hours of operation and the exposed surface area, a weight gain rate of 4.5×10^{-5} gm-$hr^{-1}cm^{-2}$ was obtained.

In addition to those samples which remained in the mockup throughout the run, there were samples which were periodically inserted into and removed from the heated graphite core. The data obtained from these samples are shown below:

B_4C Samples

Sample No.	1	2	2	2	2	2
Exposure time, hr	91.8	24.2	17.7	2.2	14.7	6
Core Temp, °F	520-1020	1020-1070	1260-1310	1310	1300	1300
Initial wt., gm	12.1733	11.9005	11.9852	11.8986	11.8977	11.9006
Final wt., gm	12.1687	11.8952	11.8986	11.8977	11.9006	11.9008
Weight change, gm	-0.0046	-0.0053	+0.0034	-0.0009	+0.0029	+0.0002
Weight change rate(1) x 10^6, gm-$hr^{-1}cm^{-2}$	-0.265	-1.16	+1.02	-2.16	+1.04	+0.176

Graphite Samples

Sample No.	14	14
Exposure time, hr	24.8	64
Core Temperature, °F	1070-1260	1290
Initial wt., gm	13.6483	13.6438
Final wt., gm	13.6446	13.6429(2)
Weight change, gm	-0.0037	-0.0009
Weight change rate(1) x 10^8, gm-$hr^{-1}cm^{-2}$	-79	-7.4

(1) Based on an exposed surface area of 189 cm^2

(2) One fin broke off this sample during removal. The fin was retrieved and includes in the final weight.

One item noted in the above samples is, that when a new sample was placed in the mockup, an initial "burnoff" occurred in which a high weight loss was experienced. In subsequent runs, samples which have not been used previously will be placed in the mockup for a short period of time prior to the first weighing.

Safety Blade

The safety blade was successfully scrammed a total of 33 times. Five scrams were performed at 700°C, eight from 500°C to 700°C and the remainder below 500°C.

After 33 scrams, the magnetic clutch which withdraws the safety blade started slipping and the blade could not be removed from the mockup core. Examination of the safety blade drive mechanism at the end of the run revealed significant amounts of oil around the motor, transmission and bottom of the upper housing. The oil apparently leaked from the transmission case but leak tests failed to reveal the point of origin. Some oiliness could be felt on the outside of the clutch housing although very little was detected on the clutch faces. New clutch facings were ordered for installation prior to the next run.

The possibility of small leaks being present and/or developing in the safety blade housing existed. Leaks would draw hot gases, which could damage housing gaskets, etc., from the mockup core into the safety blade housing. To circumvent this problem, a low flow (600 cfh) of cooled recirculating gas was directed into the safety blade upper housing. This stream provided a source of cool gas for any outleakage and prevented hot core gas from escaping through the safety blade housing.

Figure 2 shows the safety blade after removal from the mockup at the end of the run.

Control Rod

The control rod was scrammed a total of 39 times. Five scrams were performed at 700°C, seven from 500°C to 700°C, and the remainder at less than 500°C.

During operation at 700°C, the drive mechanism operated under much higher load during the last 0.10" of rod travel. When under this high load, the scram latch would not release. However, backing the rod out approximately 0.01" permitted the scram latch to release. Small chips from the uranium oxide bearing graphite cylinders were noted when the rod was dismantled for inspection. These chips could have lodged at the interface of the inner and outer cylinders causing the increased load noted. One of the chipped cylinders is shown in Figure 16.

Operating History

To permit comparisons between certain of the data, the following operating highlights are presented:

Date	Comment
3/12/65	Power to heating elements turned on.
3/17	Started evacuation #4.
3/19	Completed evacuations #5 and #6. Heater power on.
3/21	Gas blower tripped out.
3/22	Gas blower turned on. Cleanup system valved in.
3/23 - 3/25	Increasing core temperature.
3/26	Fuse failed in 440 v. supply. Replaced fuse and started increasing core temperature.
3/28 - 3/31	Increasing core temperature.
4/1	Leveling out core temperature.
4/2	Control panel power tripped out. Power off for approximately 45 minutes.
4/3 - 4/4	Maintaining operating temperature.
4/5	Start of cooldown

FIGURE 1

Control Rod Elements

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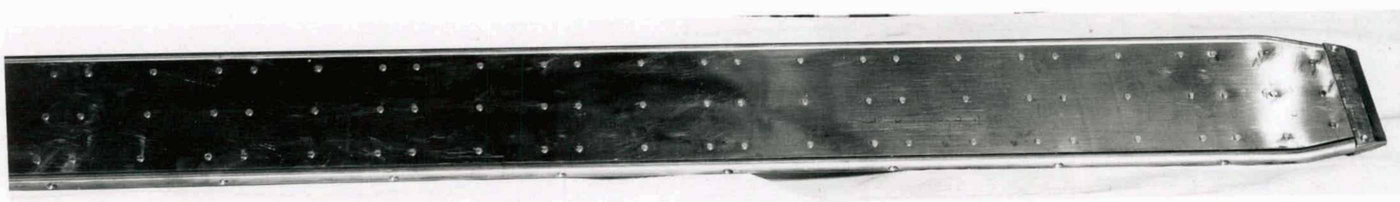

FIGURE 2

Safety Blade

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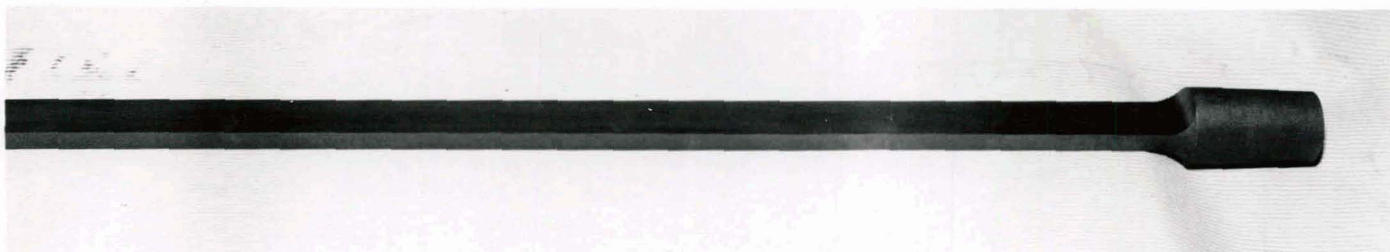

FIGURE 3

Graphite Heating Element

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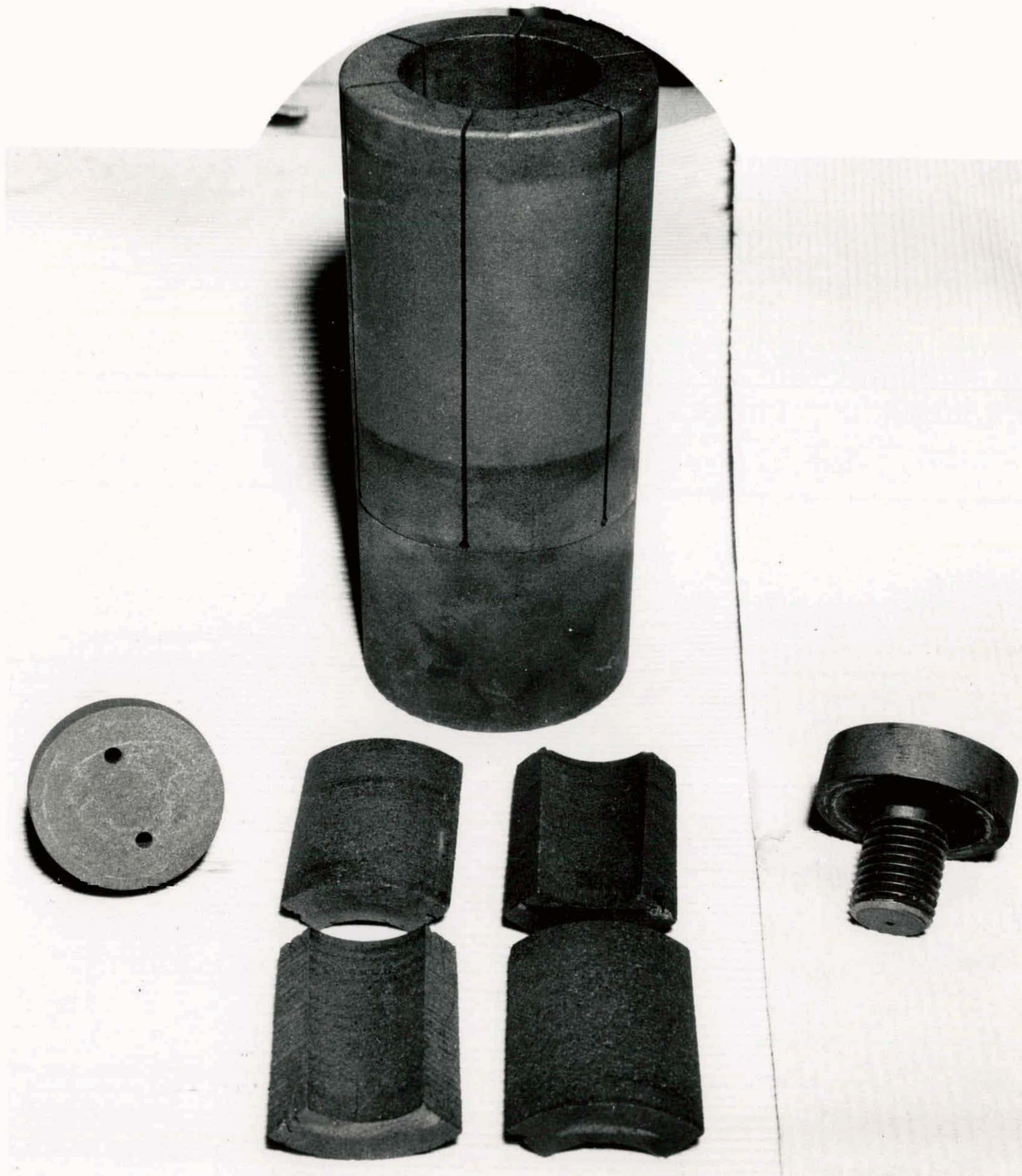

FIGURE 4

Heating Element Grounding Wedges and Sliding Collet

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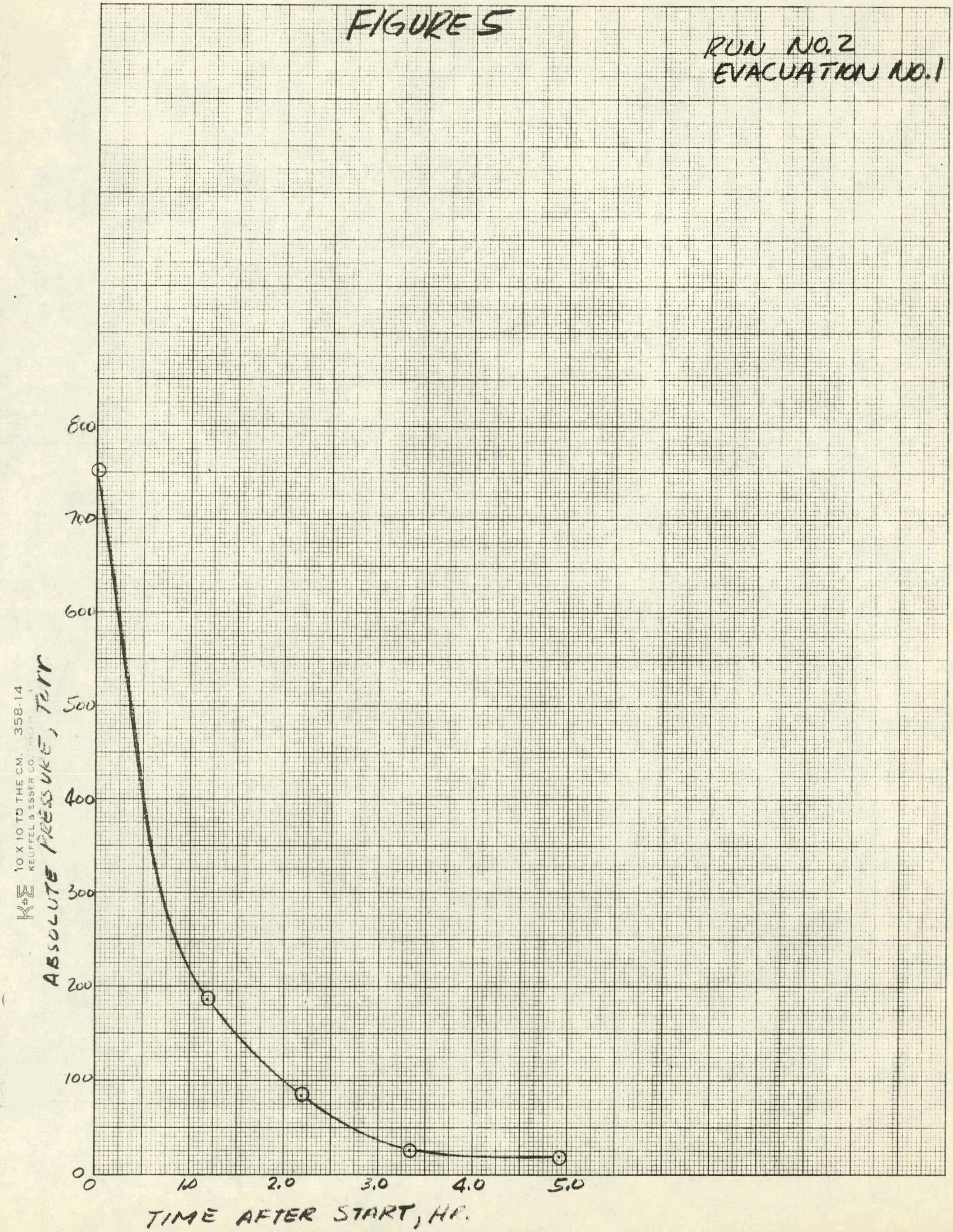


FIGURE 5
RUN NO. 2
EVACUATION NO. 1
800
700
600
500
400
300
200
100
0
ABSOLUTE PRESSURE, Torr
0
1.0
2.0
3.0
4.0
5.0
TIME AFTER START, HR.
10 X 10 TO THE CM. 358-14
KEUFFEL & ESSER CO.

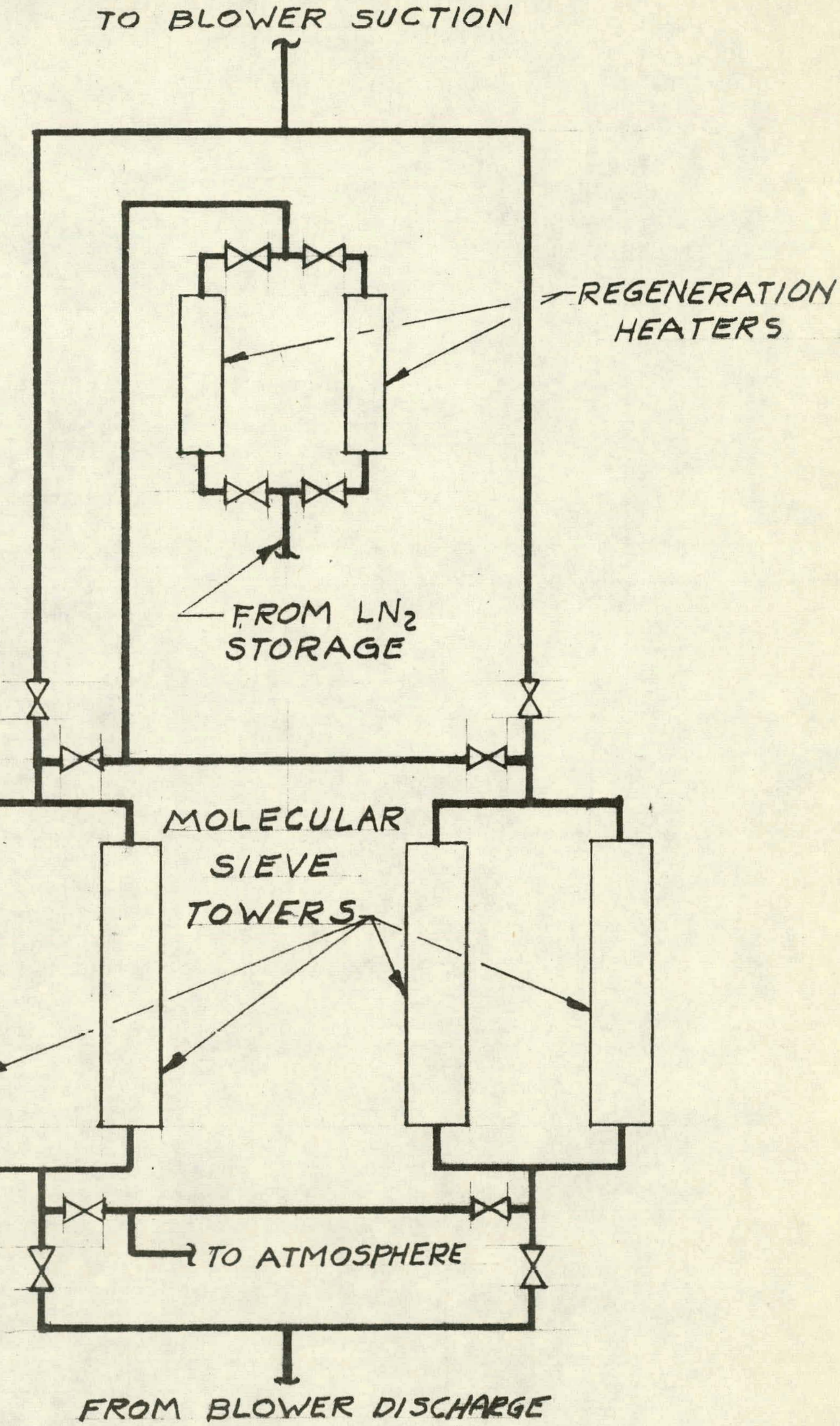
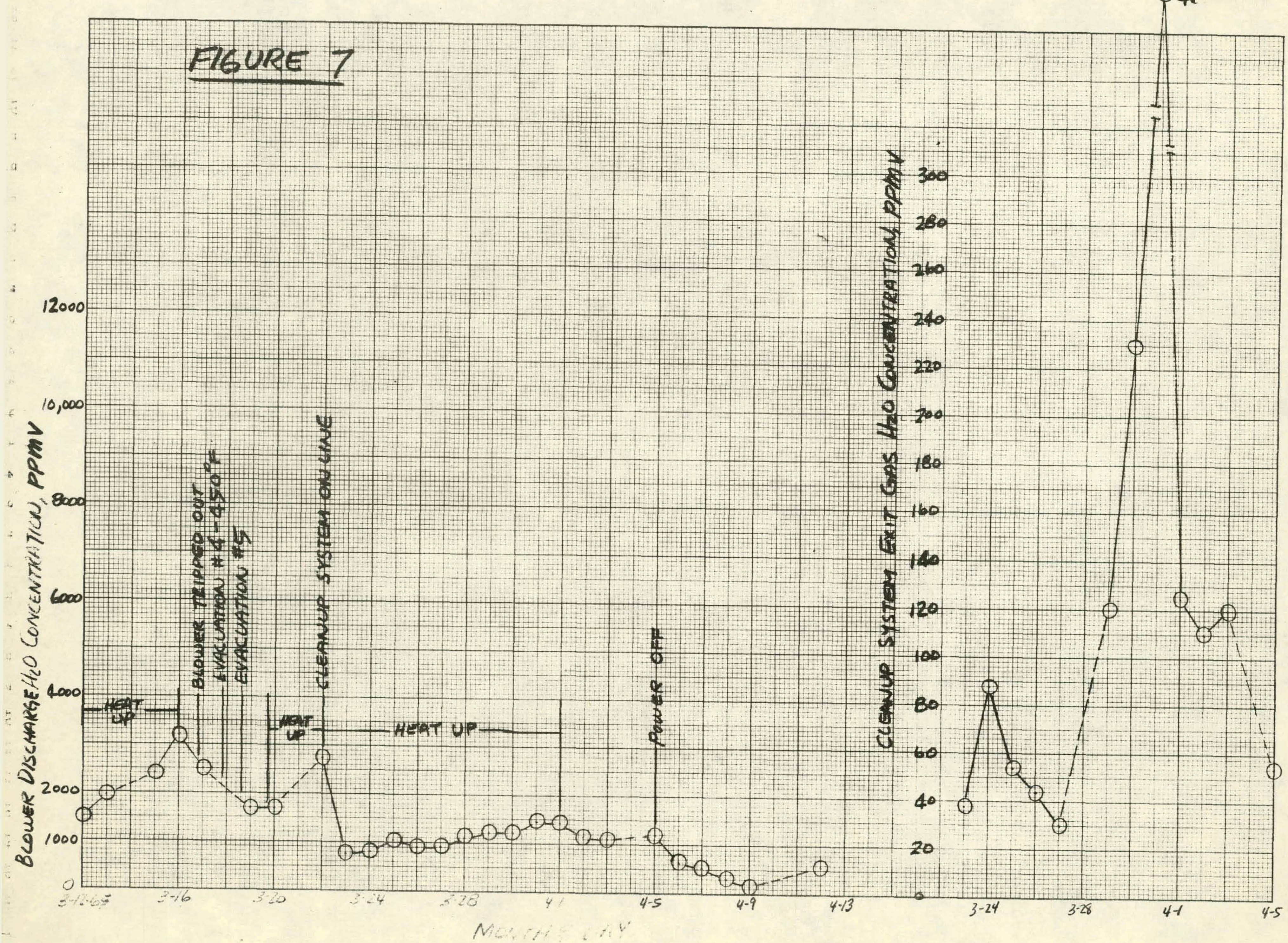


FIGURE 6

FLOW SHEET

GAS CLEANUP SYSTEM

FIGURE 7


BLOWER DISCHARGE H2O CONCENTRATION, PPMV
12000
10,000
8000
6000
4000
2000
1000
0
HEAT UP
BLOWER TRIPPED OUT
EVACUATION #4-450°F
EVACUATION #5
HEAT UP
CLEANUP SYSTEM ON LINE
HEAT UP
POWER OFF
3-12-67
3-16
3-20
3-24
3-28
4-1
4-5
4-9
4-13
CLEANUP SYSTEM EXIT GAS H2O CONCENTRATION, PPMV
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
3-24
3-28
4-1
4-5

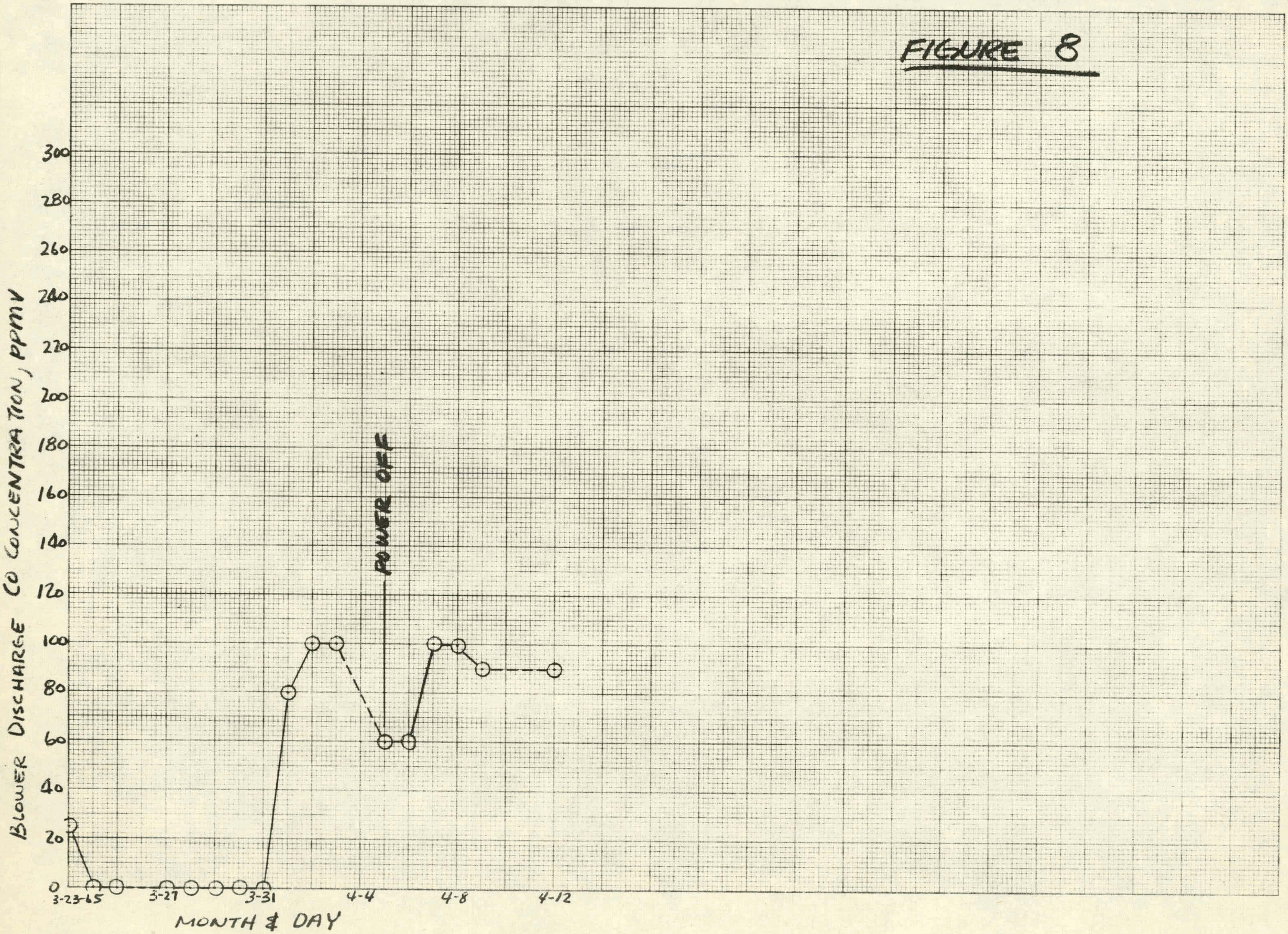


FIGURE 8
BLOWER DISCHARGE CO CONCENTRATION, PPMV
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
POWER OFF
3-23-65
3-27
3-31
4-4
4-8
4-12
MONTH & DAY

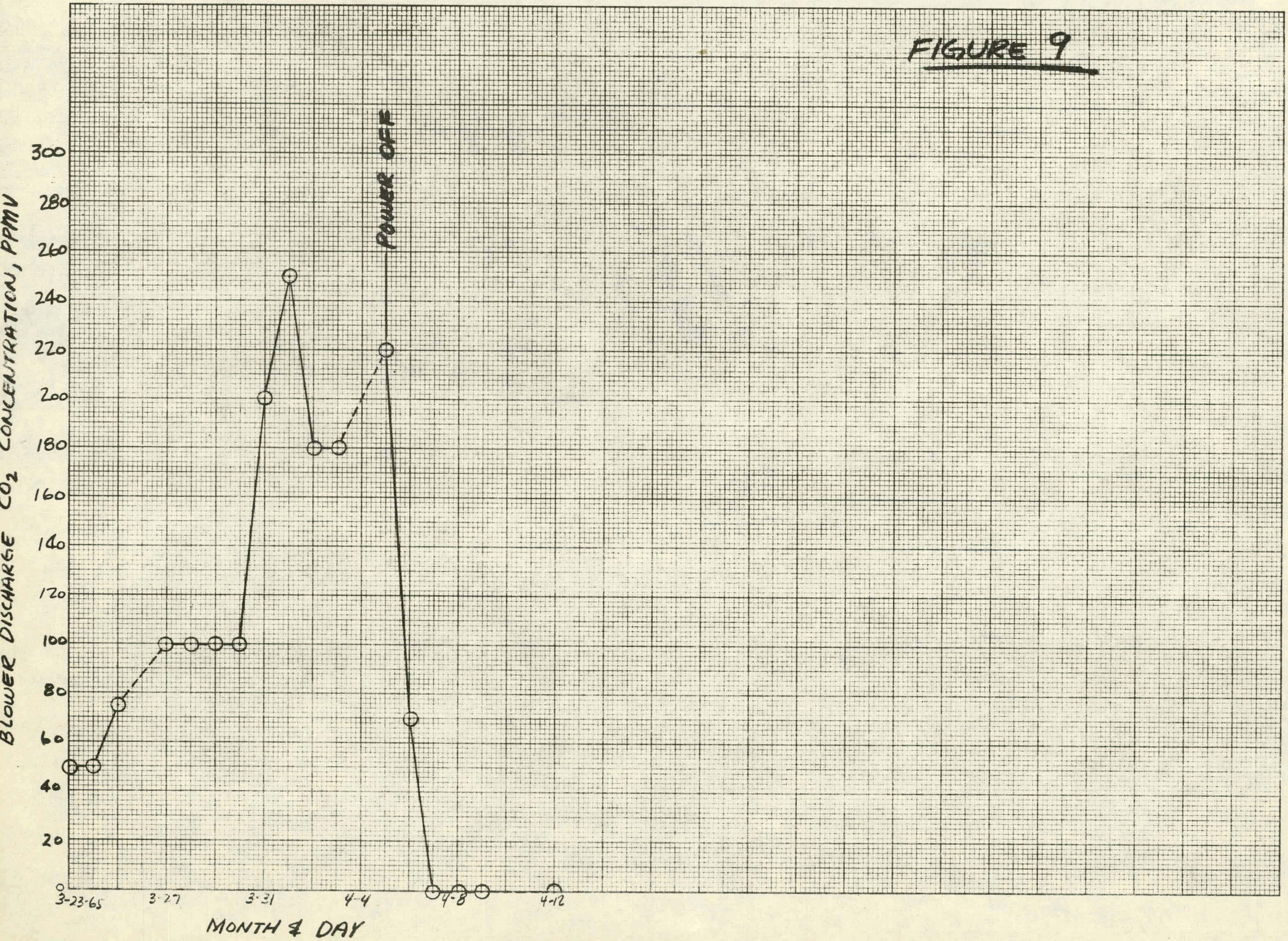

POWER OFF
BLOWER DISCHARGE CO2 CONCENTRATION, PPMV
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
3-23-65
3-27
3-31
4-4
4-8
4-12
MONTH & DAY

FIGURE 9

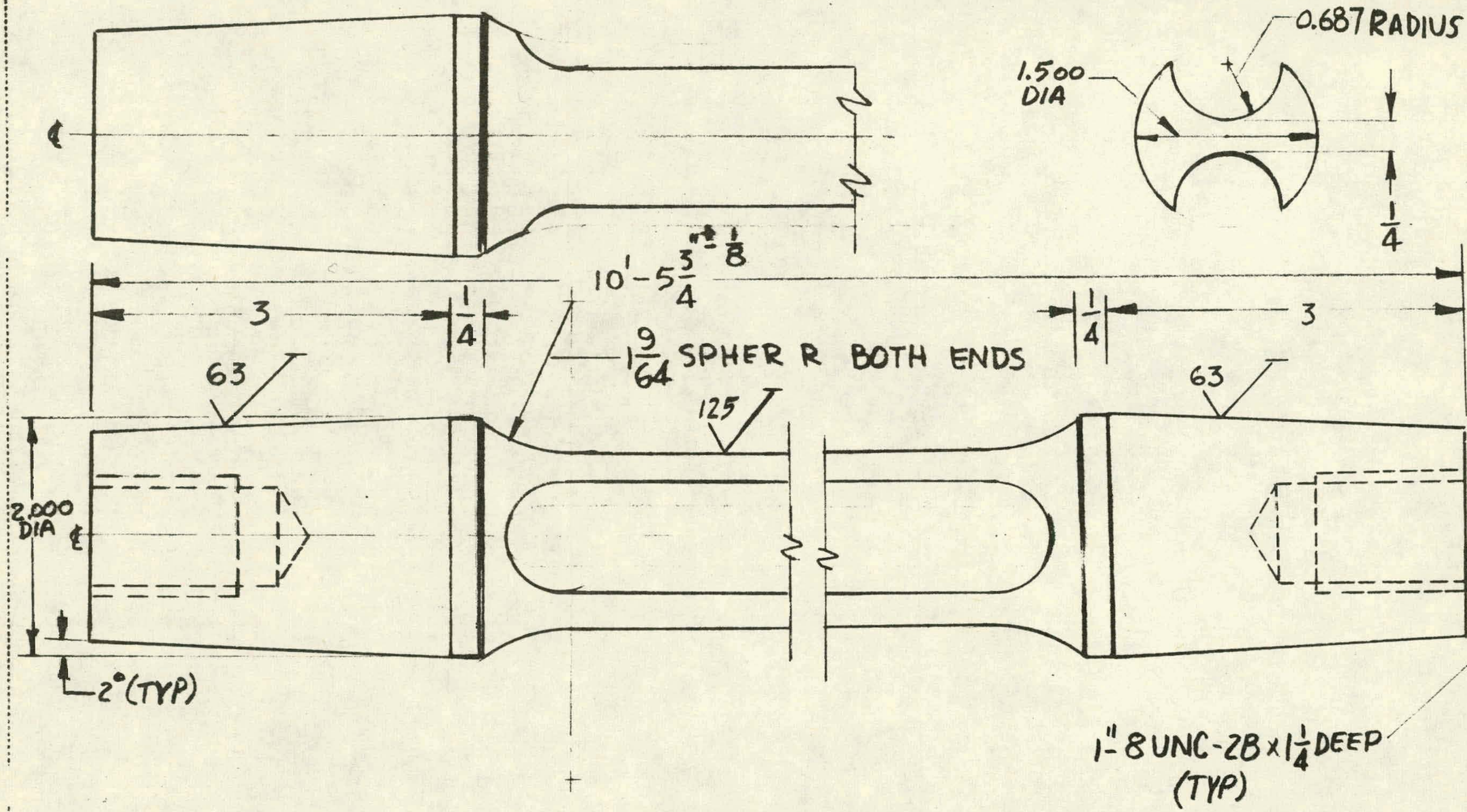
SUBJECT HTLTR MOCKUP HEATING ELEMENT

SHEET NO. 1 OF 1

JOB NO.

BY .... DATE ....

CHKD. BY .... DATE ....



MATL- GRAPHITE

FIGURE 10

NO. REQD - 5

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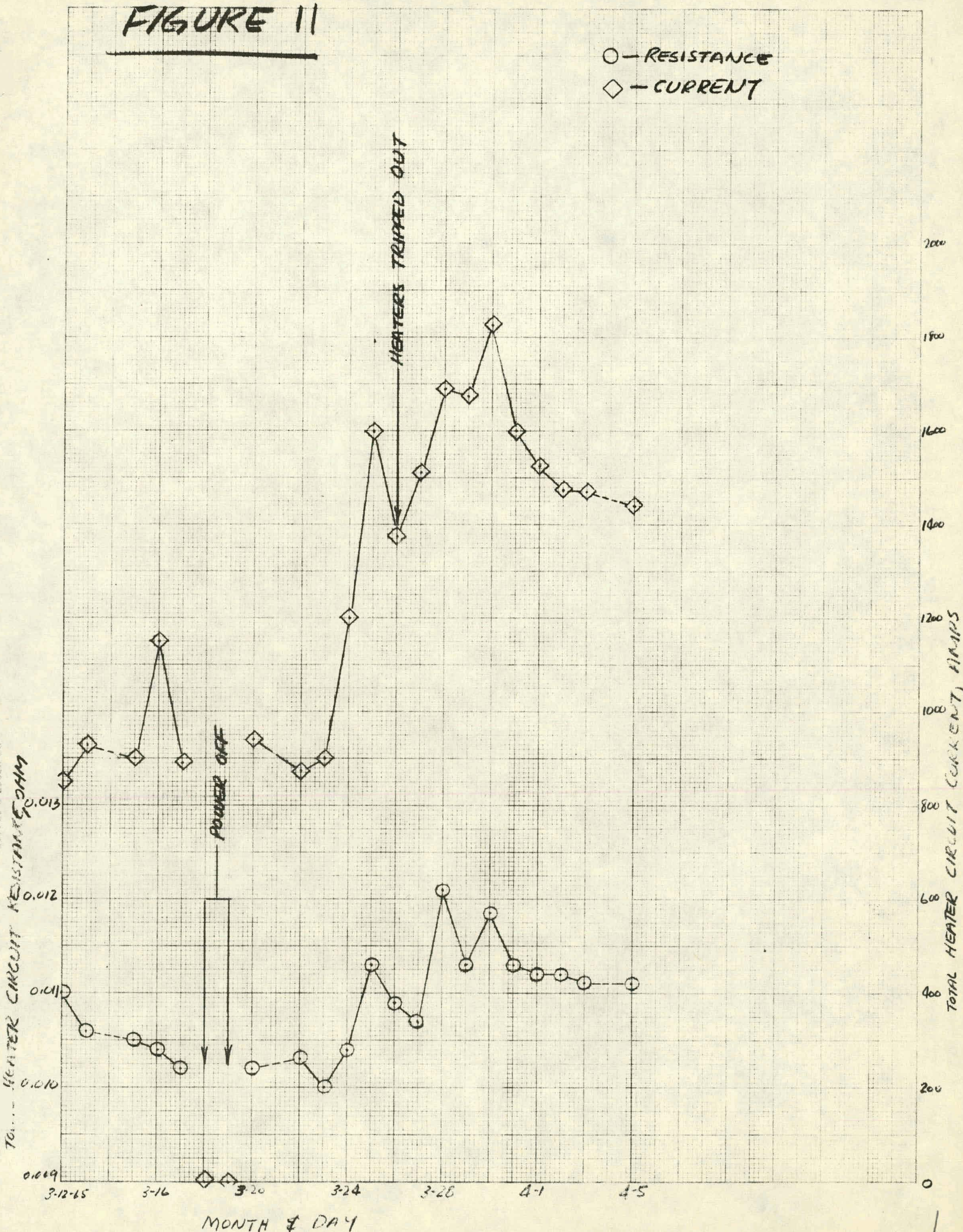
FIGURE 11


O — RESISTANCE
◇ — CURRENT
HEATERS TRIPPED OUT
POWER OFF
TOTAL HEATER CIRCUIT RESISTANCE, OHM
0.013
0.012
0.011
0.010
0.009
TOTAL HEATER CIRCUIT CURRENT, AMPS
2000
1800
1600
1400
1200
1000
800
600
400
200
0
3-12-65
3-16
3-20
3-24
3-28
4-1
4-5
MONTH & DAY

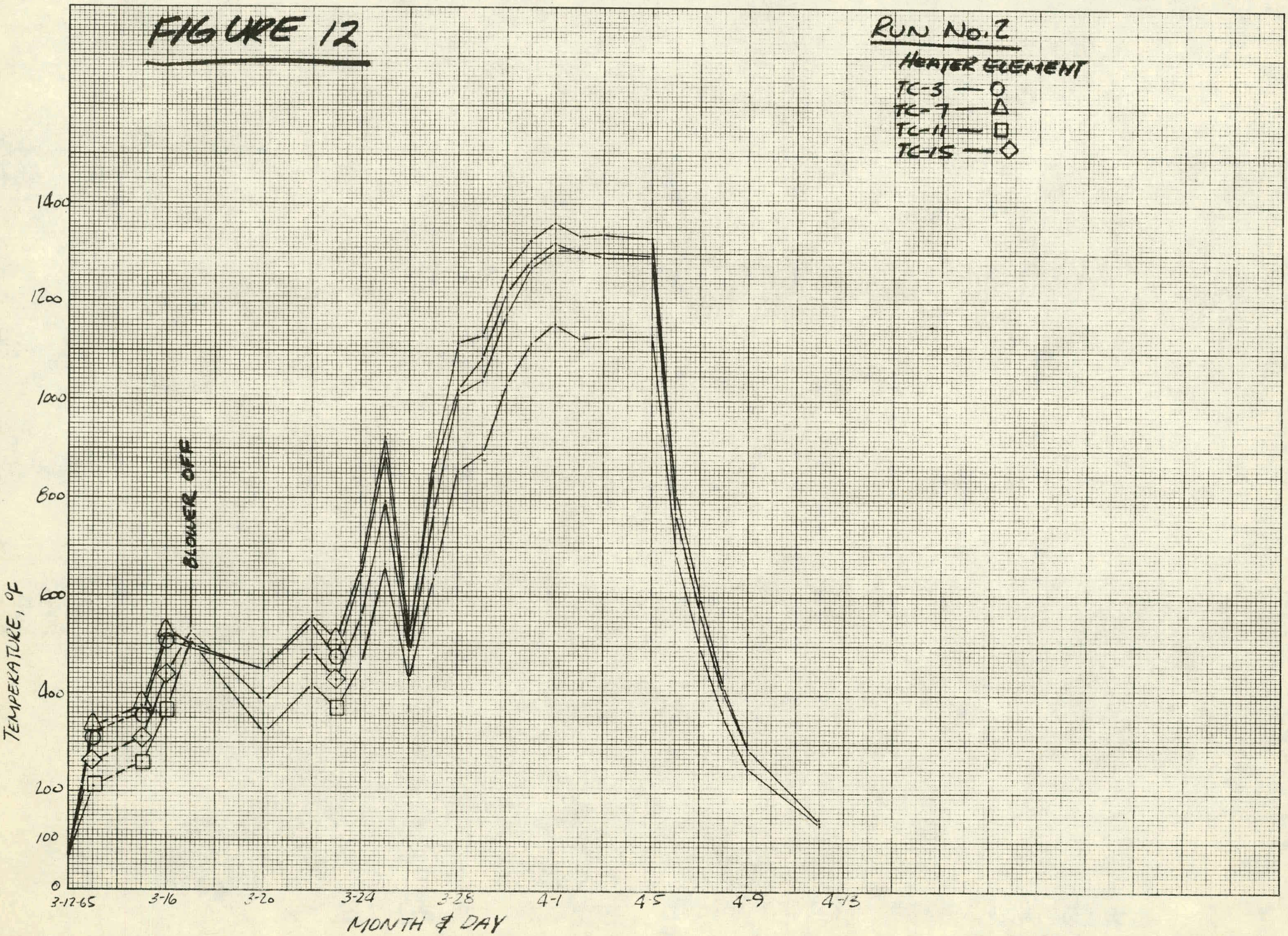
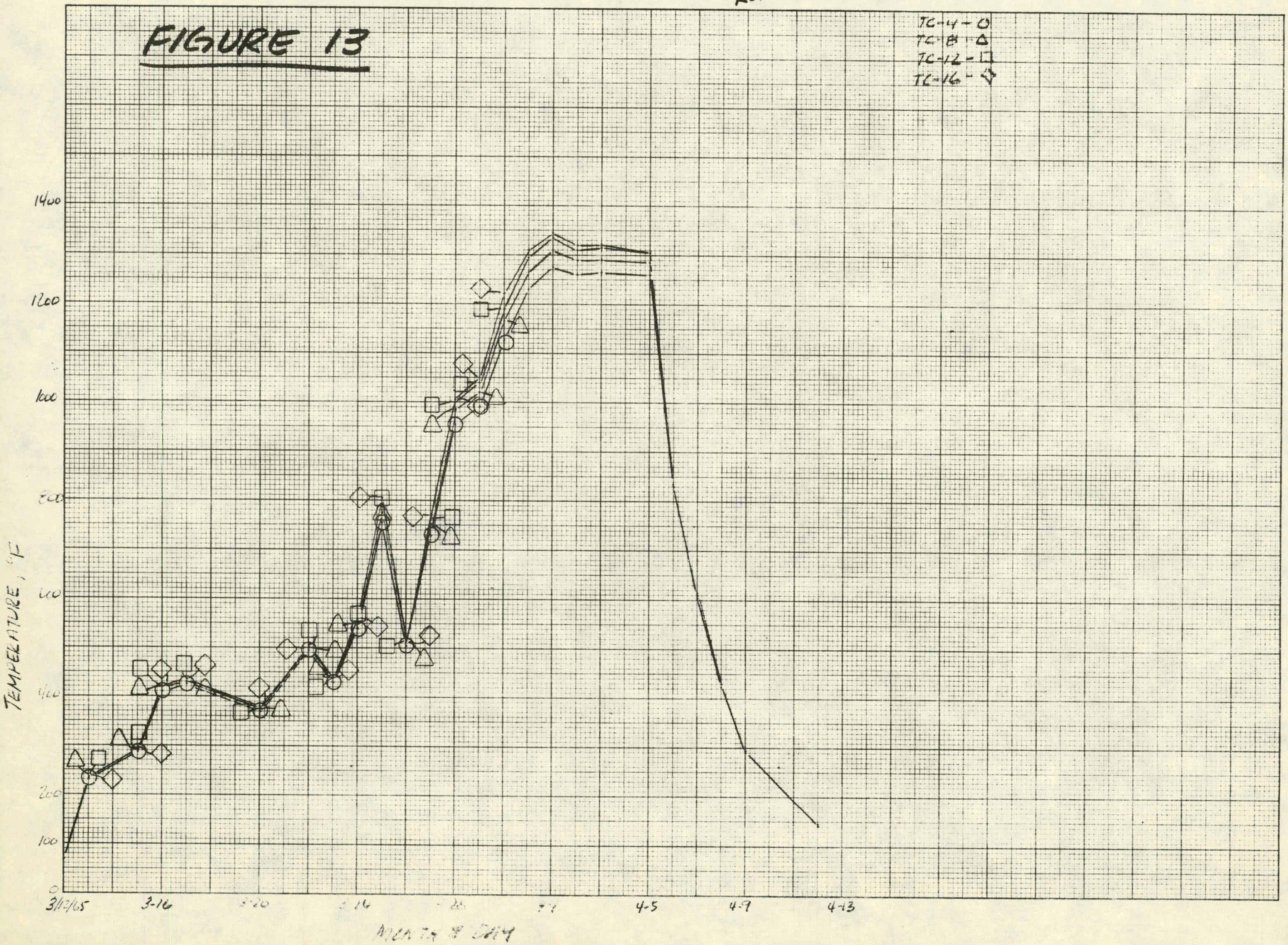

RUN No. 2
HEATER ELEMENT
TC-3 — O
TC-7 — △
TC-11 — □
TC-15 — ◇
BLOWER OFF
TEMPERATURE, °F
0
100
200
400
600
800
1000
1200
1400
3-12-65
3-16
3-20
3-24
3-28
4-1
4-5
4-9
4-13
MONTH & DAY

FIGURE 12

RUN #2 Control Rod



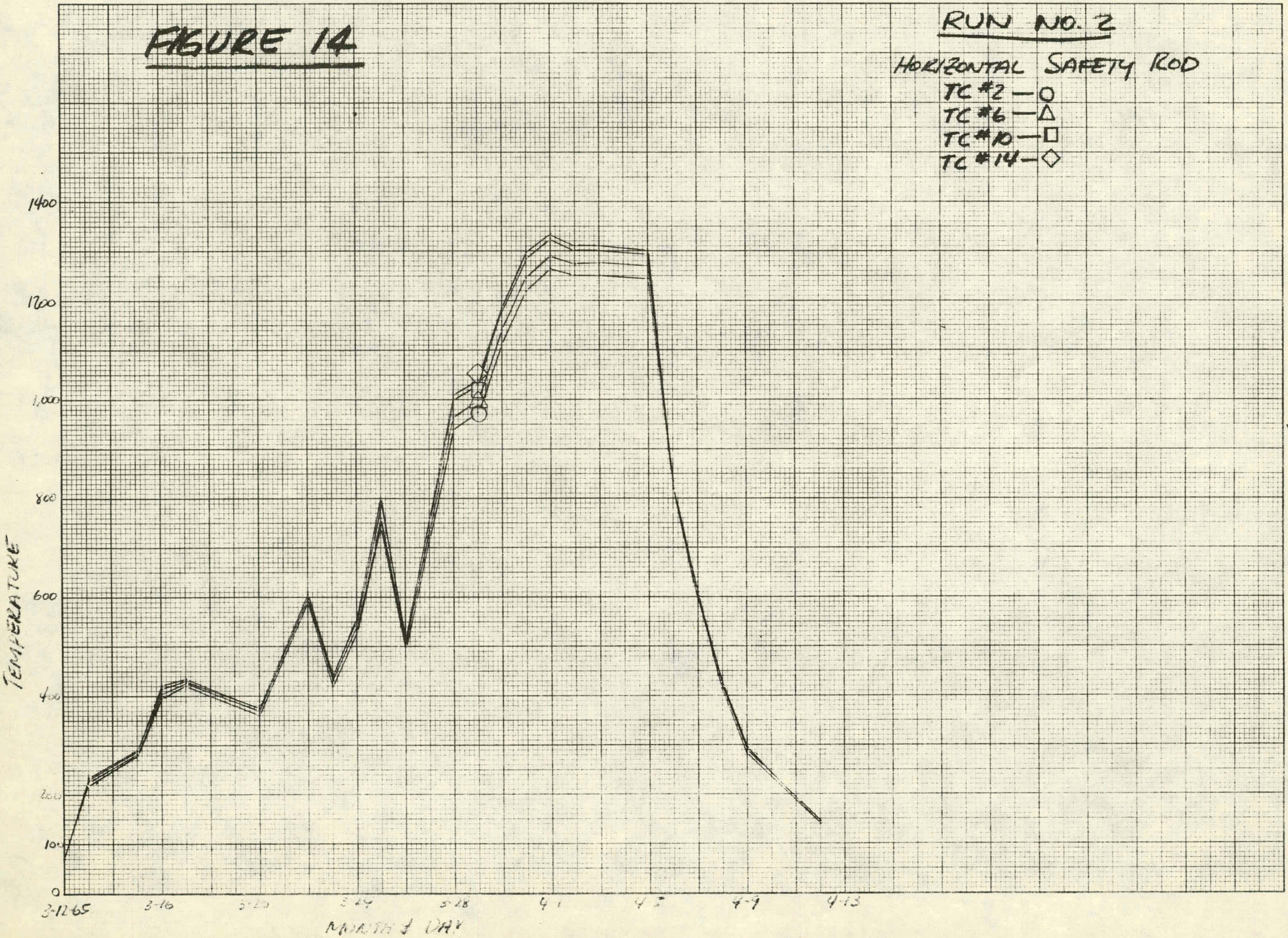


FIGURE 14
RUN NO. 2
HORIZONTAL SAFETY ROD
TC #2 — ○
TC #6 — △
TC #10 — □
TC #14 — ◇
TEMPERATURE
1400
1200
1,000
800
600
400
200
100
0
3-12-65
3-16
3-20
3-24
3-28
4-1
4-5
4-9
4-13
MONTH & DAY

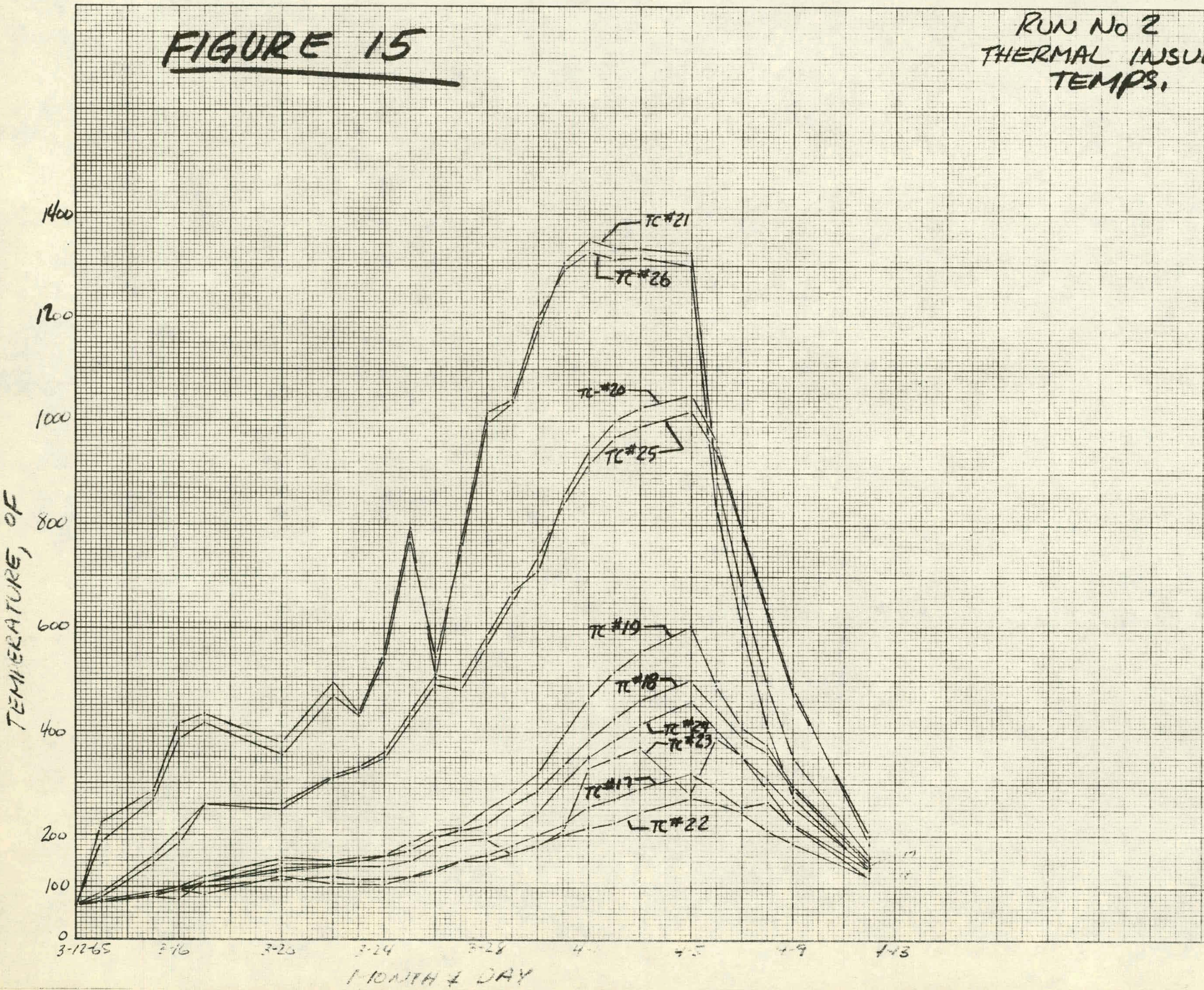

RUN No 2
THERMAL INSULATION
TEMPS.
TC #21
TC #26
TC-#20
TC #25
TC #19
TC #18
TC #24
TC #23
TC #17
TC #22
1400
1200
1000
800
600
400
200
100
0
TEMPERATURE, °F
3-12-65
3-16
3-20
3-24
3-28
4-1
4-5
4-9
4-13
MONTH & DAY

FIGURE 15

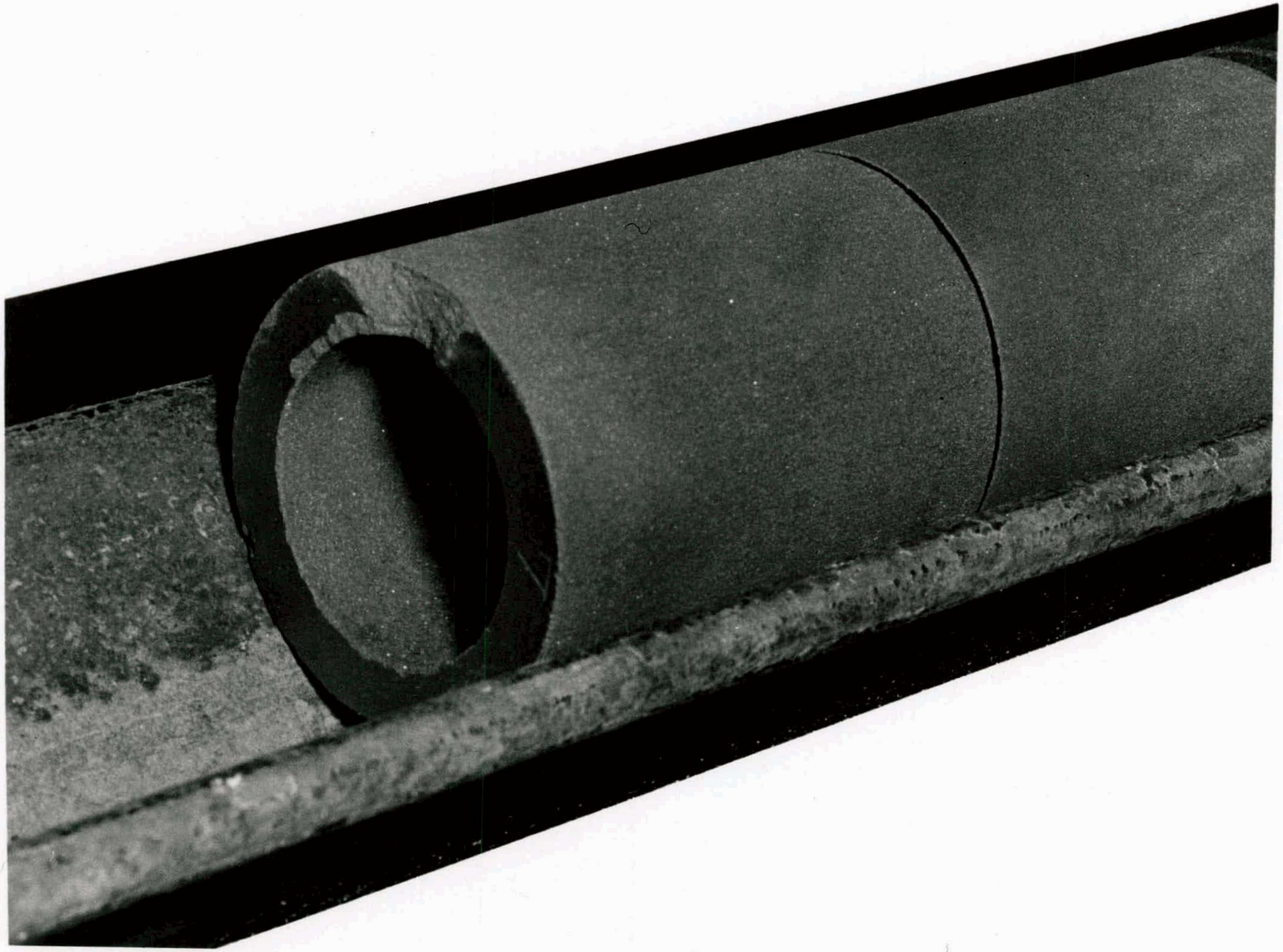


FIGURE 16

Chipped Control Rod Element

PLEASE CREDIT

PACIFIC NORTHWEST LABORATORY
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BATTELLE MEMORIAL INSTITUTE
FOR THE
[illegible] ENERGY COMMISSION

[illegible] AREA

ORDER NO. ____________

0653311-2

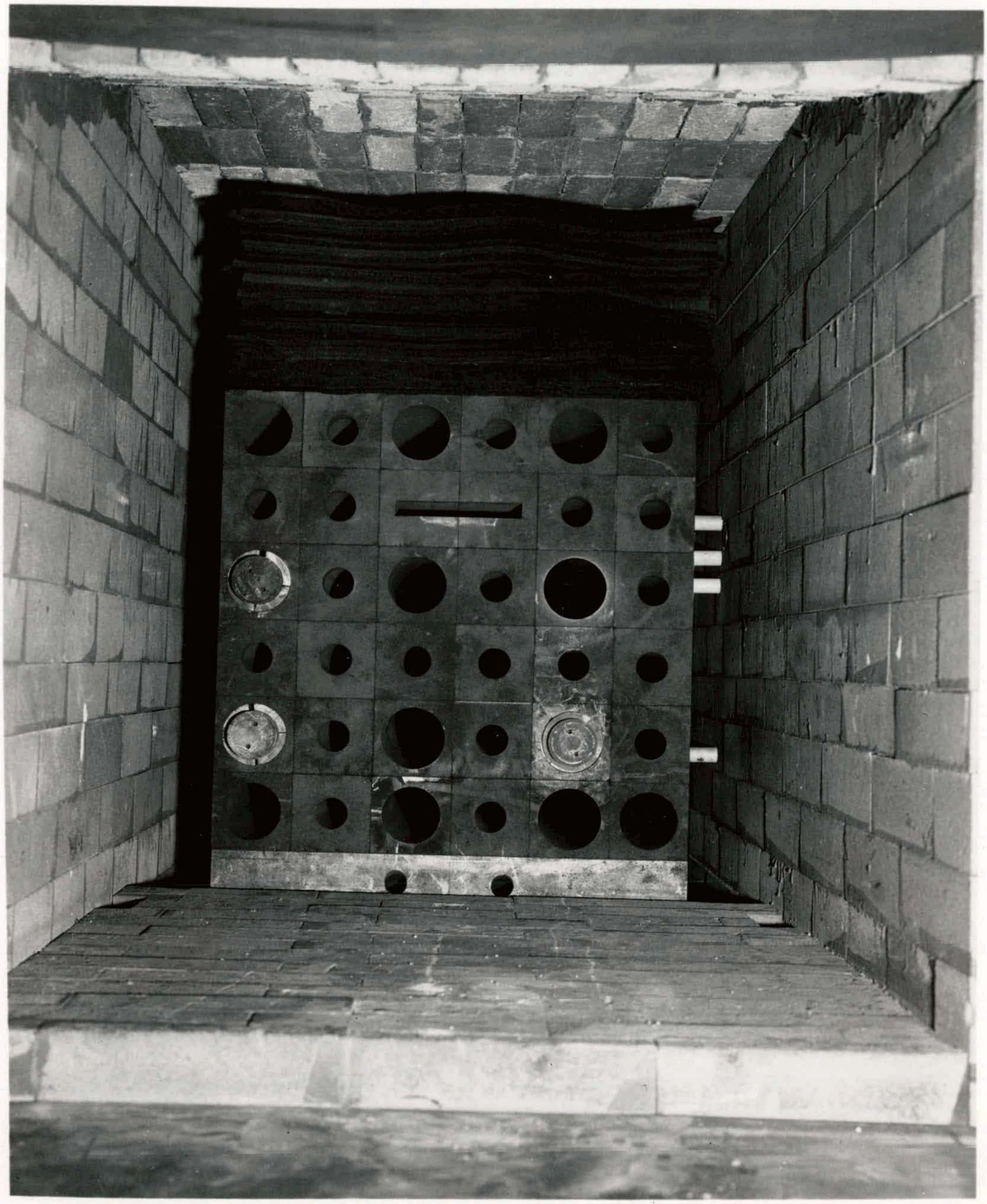

FIGURE 17

Mockup Interior After Run Number 2

0653311-1