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2 November 1970

**Remote Activated Silver-Zinc
Battery Performance**

INTERIM REPORT

**CASE FILE
COPY**



**PREPARED BY
QUALITY EVALUATION DEPARTMENT
Naval Ammunition Depot, Crane, Indiana**

DEPARTMENT OF THE NAVY
NAVAL AMMUNITION DEPOT
CRANE, INDIANA 47522

IN REPLY REFER TO:

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30 NOV 1970

From: Commanding Officer, Naval Ammunition Depot, Crane, Indiana
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California 91103

Subj: Report QE/C 70-807; Interim Report of Remote Activated Silver-
Zinc Battery Performance

Ref: (a) JPL Work Request DPR W0-5150, Amend 3 of 30 Aug 1968 to
NAD Crane

1. In compliance with reference (a), enclosure (1) is forwarded for
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D. G. MILEY
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DEPARTMENT OF THE NAVY
NAVAL AMMUNITION DEPOT
QUALITY EVALUATION LABORATORY DEPARTMENT
CRANE, INDIANA 47522

REMOTE ACTIVATED SILVER-ZINC
BATTERY PERFORMANCE

INTERIM REPORT

QE/C 70-807 2 NOV 1970

THIS WORK WAS PERFORMED FOR THE
JET PROPULSION LABORATORY,
CALIFORNIA INSTITUTE OF TECHNOLOGY,
UNDER THE DIRECTION OF MR. R. S. BOGNER,
SPONSORED BY THE NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION UNDER
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Enclosure (1)

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REPORT BRIEF

BATTERY PERFORMANCE
VERSUS
STORAGE TIME AND TEMPERATURE
REMOTE ACTIVATED, SILVER-ZINC BATTERIES
STORED IN THE UNACTIVATED CONDITION

Ref: (a) JPL Work Request DPR WO-5150, Amend 3 of 30 Aug 1968
(b) JPL Test Outline of 16 Aug 1968
(c) NAD Crane Report QE/C 69-182 of 1 April 1969
(d) NAD Crane Report QE/C 69-386 of 19 May 1969
(e) NAD Crane Report QE/C 69-438 of 23 June 1969
(f) NAD Crane Report QE/C 70-5 of 25 Feb 1970

I. TEST ASSIGNMENT BRIEF

A. As authorized under Jet Propulsion Laboratory work request, reference (a), remote activated, silver-zinc batteries, Eagle-Picher Industries Part Number GAP 4184, are being tested to determine:

1. The effects of wet-stand time after activation on battery performance.
2. The effect of storage temperature and time on battery performance prior to activation.
3. The capability of the battery to be recharged and cycled.

B. To date, tests are complete on 14 of the 18 batteries submitted. The four remaining batteries are in storage; two at 68° F for 3 years and 6 years respectively, one at 105° F for 3 years and one at 150° F for 2 years.

C. All batteries were given preliminary electrical checks before activation. All batteries were activated and performance tested with the same load after 12 to 16 hours equalization at 75° ± 2° F.

D. Five batteries were utilized for an activated stand test. The test load was applied at 5 minutes, 5, 24, 48 and 96 hours, respectively, after application of the activation signal. The remaining batteries were evaluated by applying the test load 5 minutes after the activation signal.

II. CONCLUSIONS

A. Based on the test results to date, the following conclusions are made:

1. The performance of the five batteries following wet-stand periods for 5 minutes to 96 hours showed no definite relationship to the wet-stand periods.

2. The residual capacities of the batteries stored unactivated at 68°, 105° and 150° F for different time periods showed ambiguous results. Except for the battery stored at 150° F for 1 year, the rest of the batteries give capacities within or above the range of the capacities obtained from the five batteries on the wet-stand test.

3. One battery subjected to a temperature of 257° F for 24 hours, failed to activate due apparently to degradation of the match mix around the bridgewire. The plastic monobloc was extensively warped but it is felt it would have activated if the squib would have functioned.

4. The battery can be cycled a limited number of times.

BATTERY PERFORMANCE
VERSUS
STORAGE TIME AND TEMPERATURE
REMOTE ACTIVATED, SILVER-ZINC BATTERIES
STORED IN THE UNACTIVATED CONDITION

I. INTRODUCTION

A. In compliance with reference (a), the test program of reference (b), for the 18 remotely activated, silver-zinc batteries submitted by Jet Propulsion Laboratory, was begun on 1 December 1968 following completion of a detailed test procedure. These batteries, manufactured in June 1968 by Eagle-Picher Industries, Inc., were identified as part number GAP 4184. This report is a summary of the progress of the tests reported in references (c), (d), (e) and (f).

II. BATTERY IDENTIFICATION AND DESCRIPTION

A. Identification:

1. Each battery, part number GAP 4184, was identified by the manufacturer's serial number. They were assigned sample numbers 1 through 18 for duration of the test program. The sample numbers with the respective serial numbers are listed in Table I.

B. Description:

1. This remotely activated primary silver-zinc battery is shown in Figure 1. It consists of a monobloc of 20 cells in series. The cell monobloc is surrounded with a coiled copper tube electrolyte reservoir and activation system and is potted into a stainless steel case 6" x 4" x 6.5" high. The battery weighs 10.25 pounds.

2. Figure 2 is a view of the potted assembly with the stainless steel case removed.

3. Figure 3 shows the monobloc assembly within the coiled tube electrolyte assembly with the potting partially removed.

4. Figure 4 is a view of the monobloc assembly showing the fiber-glass reinforcement.

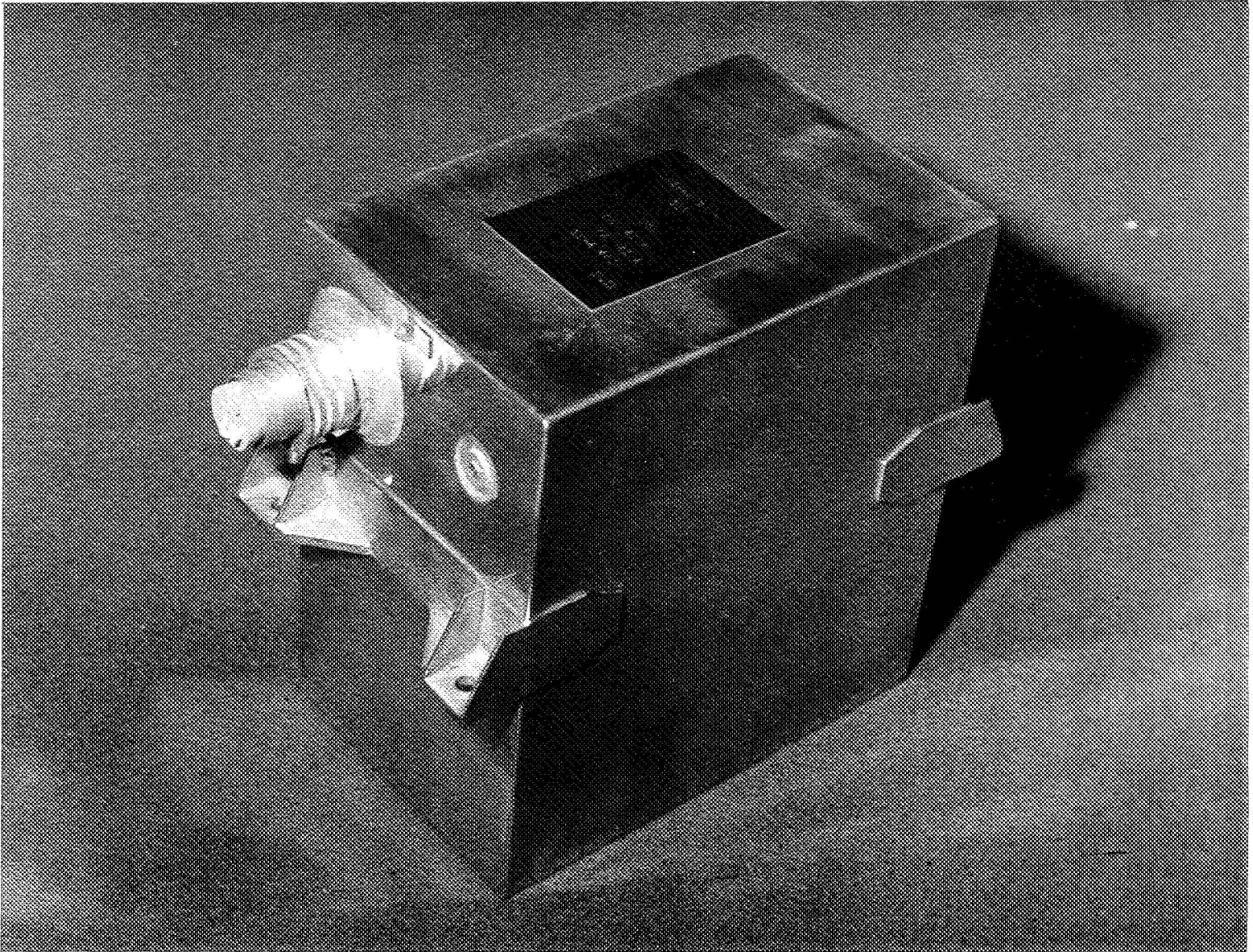


FIGURE 1

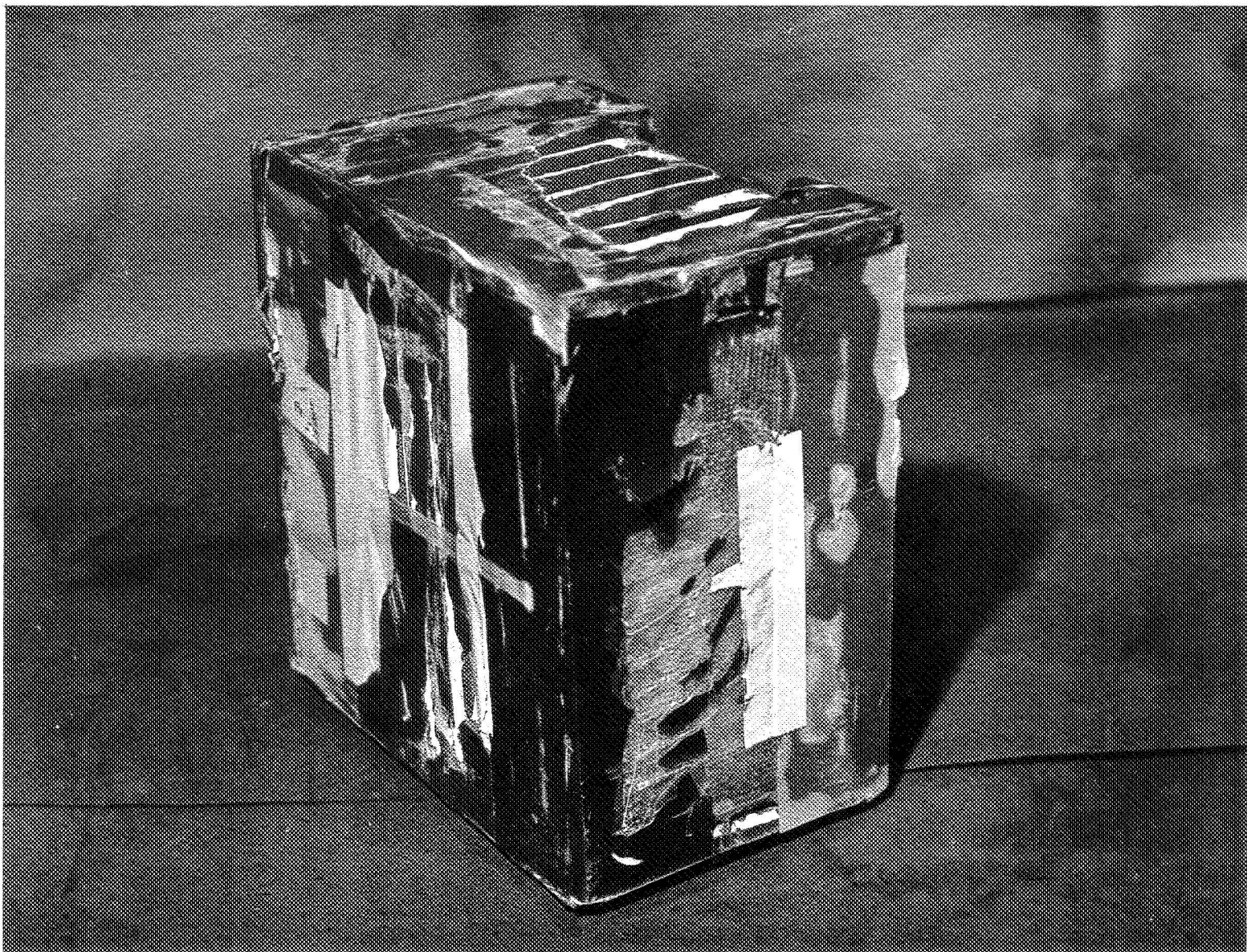
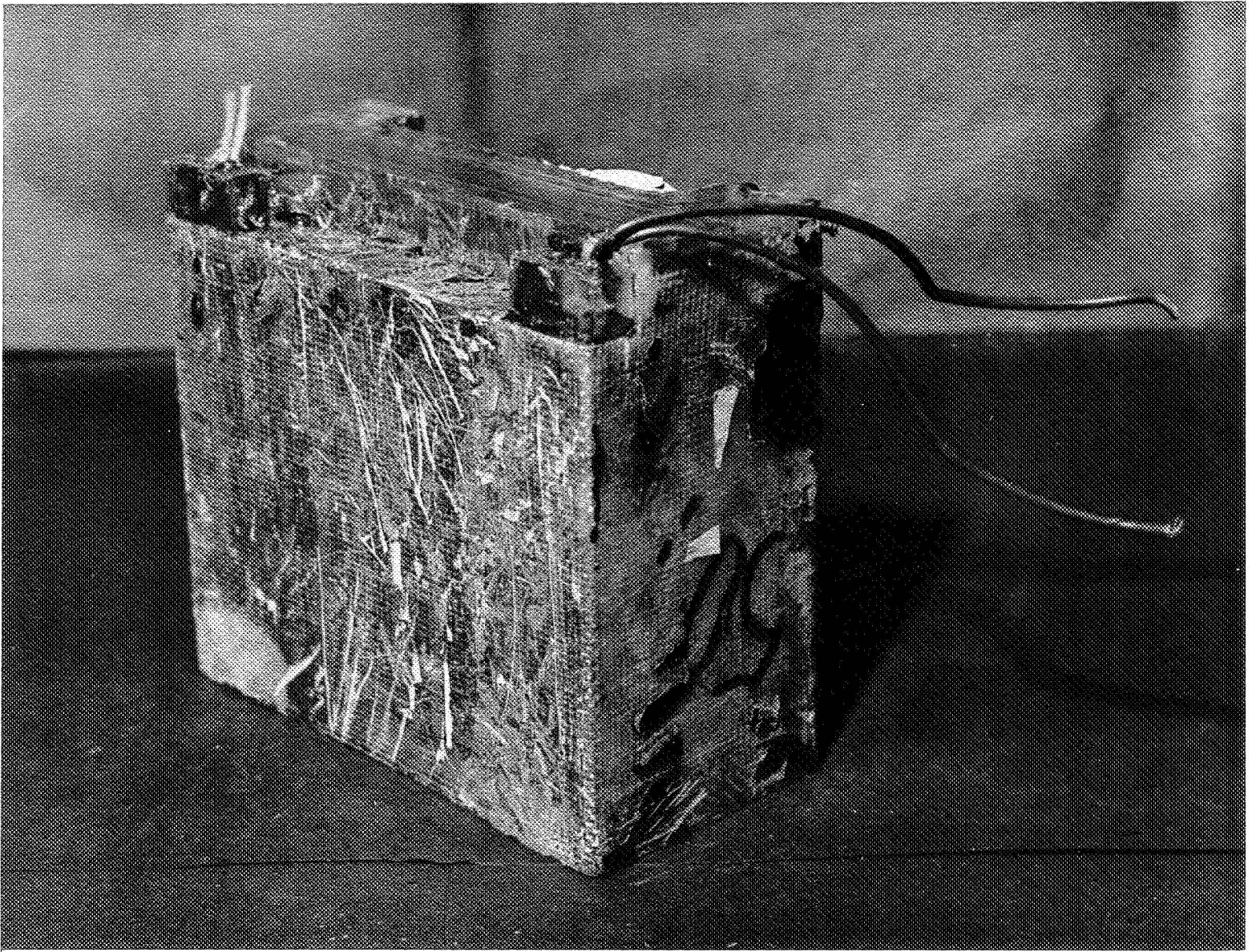


FIGURE 2



FIGURE 3



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FIGURE 4

III. TEST EQUIPMENT DESCRIPTION

A. The test equipment used during battery performance test is illustrated in Figure 5. The equipment consists of three sections; activation system, monitor-recording system, and discharge system.

1. The activation system consists of an elapse time clock, a 15-volt, 30-ampere power supply, and a battery activation control unit. The control unit applies the 15-volt activation signal from the power supply to the battery squibs. The clock records the elapsed time from the point of activation to the beginning of the battery load.

2. The monitor-recording system consists of a data acquisition system, two oscillograph recorders, a digital clock, and a digital voltmeter. The data acquisition system measures and records the battery voltage and current. The two oscillographs records activation voltage and current, and the battery voltage and current. The digital voltmeter is used to measure the electrical leakage from the positive and negative terminals of the battery pack to the battery case; and to visually monitor the pack voltage during the discharge.

3. The discharge system consists of a 60-volt, 15-ampere power supply, and a discharge current control-limit unit. When the battery is discharged, the control-limit unit switches the battery in series with the 15-ampere power supply and a resistor. The battery current is limited by the resistor and power supply to the proper constant-current load.

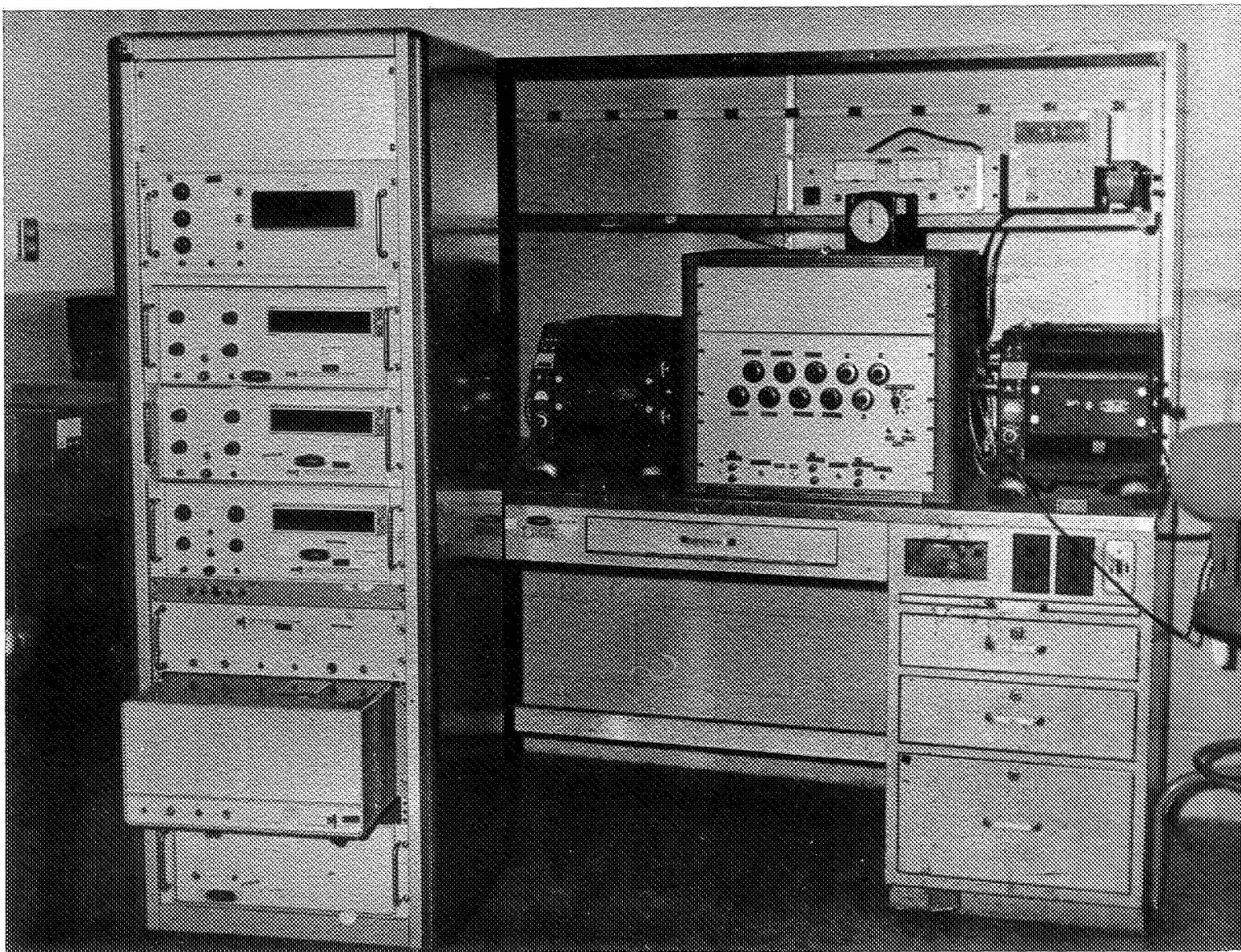


FIGURE 5

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IV. TEST PROCEDURE AND RESULTS

A. Preliminary Tests and Conditioning:

1. Each battery was visually examined for any obvious defects in material and workmanship; and tested for unactivated voltage, insulation resistance and activation circuit resistance before and after storage. No significant changes were noted after storage.

a. No defects were noted during visual examination.

b. The voltage measured across the pack of the unactivated battery was less than 0.005 VDC.

c. The insulation resistance was greater than 100 megohms from the battery connector pins 1 and 6 to case and 2 and 7 to case.

d. The typical activation circuit resistance was 0.30 ohms.

e. The results are summarized in Table II.

2. The batteries were stored in temperature controlled chambers at different test temperatures for storage or temperature conditioning prior to activation. The storage conditions and temperature conditioning are itemized in Table I and summarized below.

a. Four batteries were stored at 68° F. Two of these batteries have completed their respective storage periods of 6 months and 1 year.

b. Four batteries were stored at 105° F. Three of these batteries have completed their respective storage periods of 3 months, 6 months, and 1.5 years.

c. Four batteries were stored at 150° F. Three of these batteries have completed their respective storage periods of 2 months, 4 months and 1 year.

d. One battery was subjected to a temperature of 257° F for 24 hours.

e. The nine batteries which have completed their specified temperature-storage and five batteries which were not scheduled for temperature storage were temperature stabilized at $75^{\circ} \pm 2^{\circ}$ F for 12 to 16 hours before activation.

B. Functional Tests (14 of 18 batteries):

1. Activation:

a. A potential of 15.0 VDC was applied across each of the two activation circuits of each battery for 30 seconds in accordance with the test procedure.

(1) Thirteen of the 14 batteries activated normally. The open circuit voltages were greater than 24.0 volts within 20 seconds after application of the activation signal.

(2) Battery, S/N 690, did not activate. The resistance of each activation circuit was found to be greater than 10,000 ohms; indicating that the bridgewires had burned open.

2. Electrical Leakage:

a. Two minutes after activation of each battery, a voltage check was made from each terminal to the case for electrical leakage.

b. The voltages measured during this voltage check ranged from 3.0 to 6.0 volts, indicating the battery has a high impedance electrical current path from the battery pack to the case.

3. Application of Load After Activation:

a. The five batteries not subjected to temperature-storage conditions were allowed to wet stand for 5 minutes, 5, 24, 48 and 96 hours respectively between application of the activation signal and application of the programmed load.

(1) The wet-stand periods of 10, 17 and 24 hours originally specified in reference (b) were increased to 24, 48 and 96 hours respectively by JPL representative, Mr. Sam Bogner, during phonecons with NAD Crane representative, Mr. Bill Van Tine.

b. The nine batteries which completed their respective temperature-storage conditions and succeeding temperature conditioning were allowed to wet stand for 5 minutes between application of the activation signal and application of the programmed load.

4. Load Performance:

a. Each battery was discharged in accordance with the specified load profile shown in Table III. The discharge time to

20.00 volts and the capacity in ampere-hours for each battery is given in Table I. Figures 6 through 18 show the discharge curves and load profile for each battery.

5. Cycling:

a. In compliance with the requests of the JPL representative, Mr. Bogner, during fonecon of 30 October 1969, three of the remaining seven batteries were cycled to failure after their initial capacity test.

b. Each cycle consisted of a constant current recharge at 300 milliamperes to a voltage limit of 39.00 volts (38.00 volts for third battery) followed immediately by a constant current discharge at 2.00 amperes to a cutoff of 24.00 volts. The charge-discharge curves are presented in Figures 19 through 45. Charge-discharge cycling was continuous without any open-circuit periods. The first two batteries, serial numbers 626 and 483, failed to reach the upper limit of the charging voltage during recharge of the fourth cycle; whereas, the third battery, serial number 692, failed in like manner during the seventh cycle.

(1) During the recharge of batteries, serial numbers 626 and 483, a gas sample was taken via the vent port and analyzed. The gas sample during the first charge consisted of 7.5 percent hydrogen, 23.5 percent oxygen and 69 percent nitrogen. The hydrogen level increased and the oxygen decreased during the subsequent recharges, reaching approximately 85 percent hydrogen and 6 percent oxygen during the fourth cycle.

c. The remaining four batteries, upon successful completion of their respective temperature-storage conditions and capacity test, will also be cycled to failure.

TABLE I
BATTERY STORAGE SCHEDULE
WITH
RESULTS TO DATE

Sample Number	Serial Number	° F	Storage Time		Temperature Conditioned @ 75° ± 2°F	Wet-Stand Time After Activation Signal	Discharge Time to 20.00 Volts	Discharge Capacity AH	Cycling Capacities Ampere-Hours at 2.0 Amperes to 24.00 Volts					
			Ending						1st Cycle	2nd Cycle	3rd Cycle	4th Cycle	5th Cycle	6th Cycle
1	482	--	--	--	12-16 Hr	5 Minutes	1 Hr 53 Min	5.03						
2	479	--	--	--	12-16 Hr	5 Hours	1 Hr 50 Min	4.93						
3	475	--	--	--	12-16 Hr	24 Hours	1 Hr 37 Min	4.50						
4	620	--	--	--	12-16 Hr	48 Hours	1 Hr 51 Min	4.97						
5	691	--	--	--	12-16 Hr	96 Hours	1 Hr 37 Min	4.50						
6	690	257	24 Hr	--	12-16 Hr	5 Minutes	Failed to Activate							
7	477	68	6 Mo	6-69	12-16 Hr	5 Minutes	1 Hr 45 Min	4.77						
8	626	68	1 Yr	12-69	12-16 Hr	5 Minutes	1 Hr 41 Min	4.60	4.63	4.20	5.07			
9	484	68	3 Yr	12-71	12-16 Hr	5 Minutes								
10	618	68	6 Yr	12-74	12-16 Hr	5 Minutes								
11	621	105	3 Mo	3-69	12-16 Hr	5 Minutes	2 Hr 1 Min	5.30						
12	619	105	6 Mo	6-69	12-16 Hr	5 Minutes	2 Hr 1 Min	5.30						
13	692	105	1.5 Yr	6-70	12-16 Hr	5 Minutes	1 Hr 40 Min	4.60	3.60	2.70	2.60	2.63	2.50	2.40
14	625	105	3 Yr	12-71	12-16 Hr	5 Minutes								
15	480	150	2 Mo	2-69	12-16 Hr	5 Minutes	1 Hr 38 Min	4.53						
16	623	150	4 Mo	4-69	12-16 Hr	5 Minutes	1 Hr 49 Min	4.90	3.33	3.00	2.50			
17	483	150	1 Yr	12-69	12-16 Hr	5 Minutes	1 Hr 28 Min	4.20						
18	624	150	2 Yr	12-70	12-16 Hr	5 Minutes								

TABLE II
PRELIMINARY ELECTRICAL TEST RESULTS

Ser No	Date	Pins 2 & 7 to Case	Pins 1 & 6 to Case	Pin 3 to 4	Pin 4 to 5	Unactivated Voltage	Comments
482	12-2-68	105,000 megohms	90,000 megohms	0.30 ohm	0.29 ohm	0.000 volt	Prior to Activation
479	12-2-68	Inf	Inf	0.23 "	0.23 "	0.001 "	Prior to Activation
475	12-2-68	Inf	Inf	0.26 "	0.24 "	0.000 "	Prior to Activation
620	12-2-68	Inf	Inf	0.24 "	0.24 "	0.000 "	Prior to Activation
691	12-2-68	Inf	Inf	0.33 "	0.33 "	0.002 "	Prior to Activation
690	12-2-68	Inf	Inf	0.31 "	0.30 "	0.001 "	Prior to Storage
480	12-2-68	250,000 megohms	190,000 megohms	0.25 "	0.30 "	0.001 "	Prior to Storage
*480	2-4-69	270,000 megohms	225,000 megohms	0.24 "	0.31 "	0.000 "	After Storage
621	12-2-68	Inf	Inf	0.31 "	0.30 "	0.000 "	Prior to Storage
*621	3-5-69	Inf	Inf	0.46 "	0.33 "	0.000 "	After Storage
623	12-2-68	200,000 megohms	200,000 megohms	0.32 "	0.32 "	0.000 "	Prior to Storage
*623	4-4-69	200,000 megohms	200,000 megohms	0.25 "	0.23 "	0.000 "	After Storage
477	12-2-68	500,000 megohms	250,000 megohms	0.30 "	0.30 "	0.000 "	Prior to Storage
*477	6-3-69	Inf	500,000 megohms	0.28 "	0.27 "	0.000 "	After Storage
619	12-3-68	Inf	500,000 megohms	0.30 "	0.32 "	0.000 "	Prior to Storage
*619	6-3-69	Inf	600,000 megohms	0.34 "	0.35 "	0.000 "	After Storage
626	12-2-68	Inf	Inf	0.32 "	0.30 "	0.000 "	Prior to Storage
*626	12-9-69	Inf	Inf	0.32 "	0.31 "	0.000 "	After Storage
483	12-2-68	23,000 megohms	30,000 megohms	0.23 "	0.23 "	0.000 "	Prior to Storage
*483	12-3-69	Inf	Inf	0.32 "	0.33 "	0.000 "	After Storage
692	12-2-68	90,000 megohms	Inf	0.25 "	0.24 "	0.001 "	Prior to Storage
*692	6-2-70	Inf	Inf	0.25 "	0.28 "	0.002 "	After Storage
624	12-2-68	Inf	Inf	0.30 "	0.25 "	0.001 "	Prior to Storage
**624							
618	12-2-68	100,000 megohms	55,000 megohms	0.34 "	0.34 "	0.000 "	
**618							
625	12-2-68	Inf	Inf	0.29 "	0.30 "	0.000 "	
*625							
484	12-2-68	Inf	Inf	0.31 "	0.38 "	0.000 "	
**484							

* After storage and prior to activation.

** Storage-temperature test incomplete--preliminary electrical test will be completed prior to activation.

TABLE III

CONSTANT CURRENT LOAD SEQUENCE

TIME (MINUTES)	RATE (AMPERES)
0 - 10	2
10 - 20	5
20 - 22	10
22 - 32	5
32 - to 20.00 Volts	2

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Storage: None

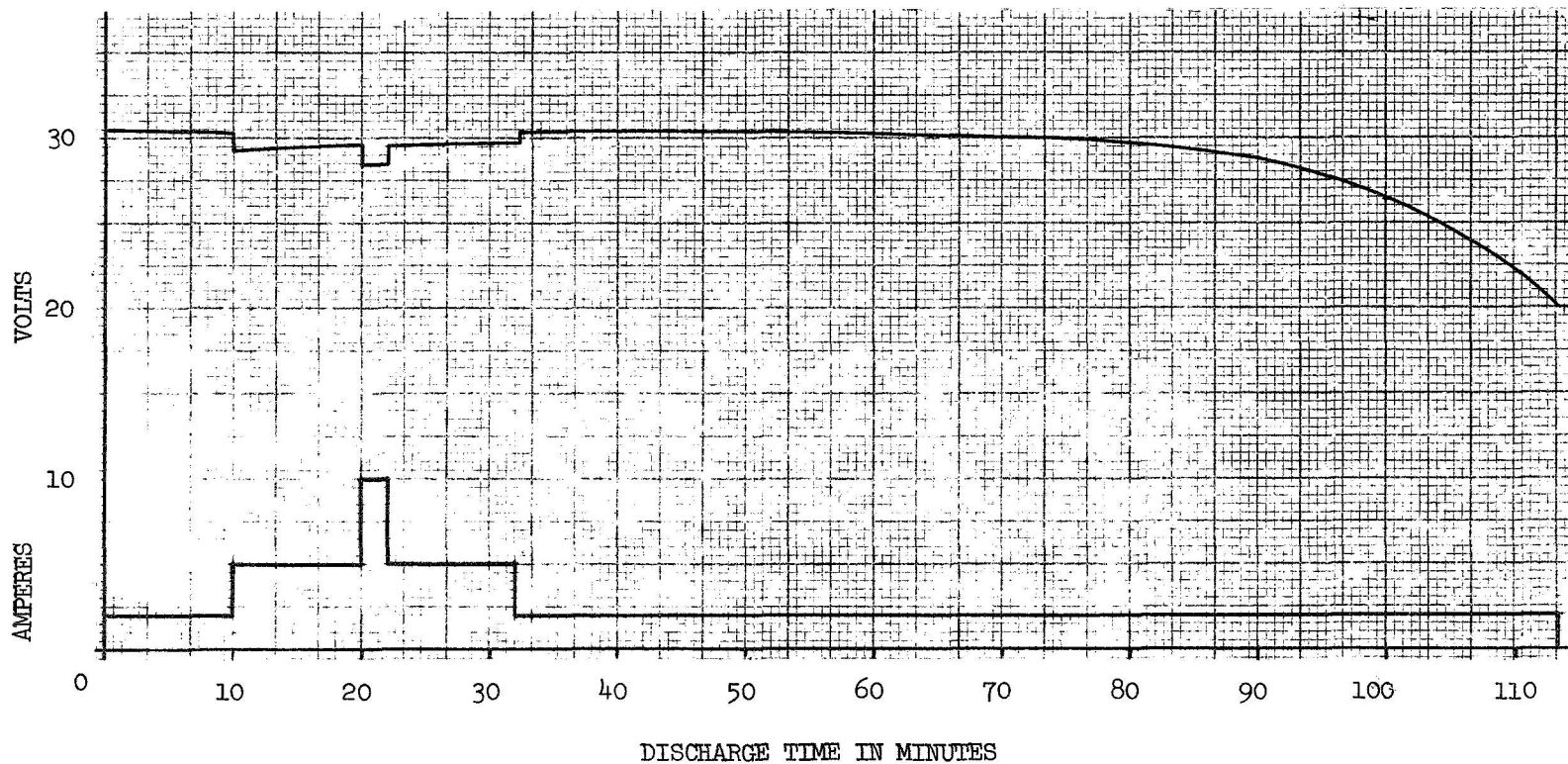
Date: 12-6-68

Wet-Stand Time: 5 Min.

Battery Serial No: 482

Discharge Capacity
to 20.00 Volts: 5.03 ah

Time to 20 Volts:
1 Hr. 53 Min.



DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY
FIGURE 6

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JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Storage: None

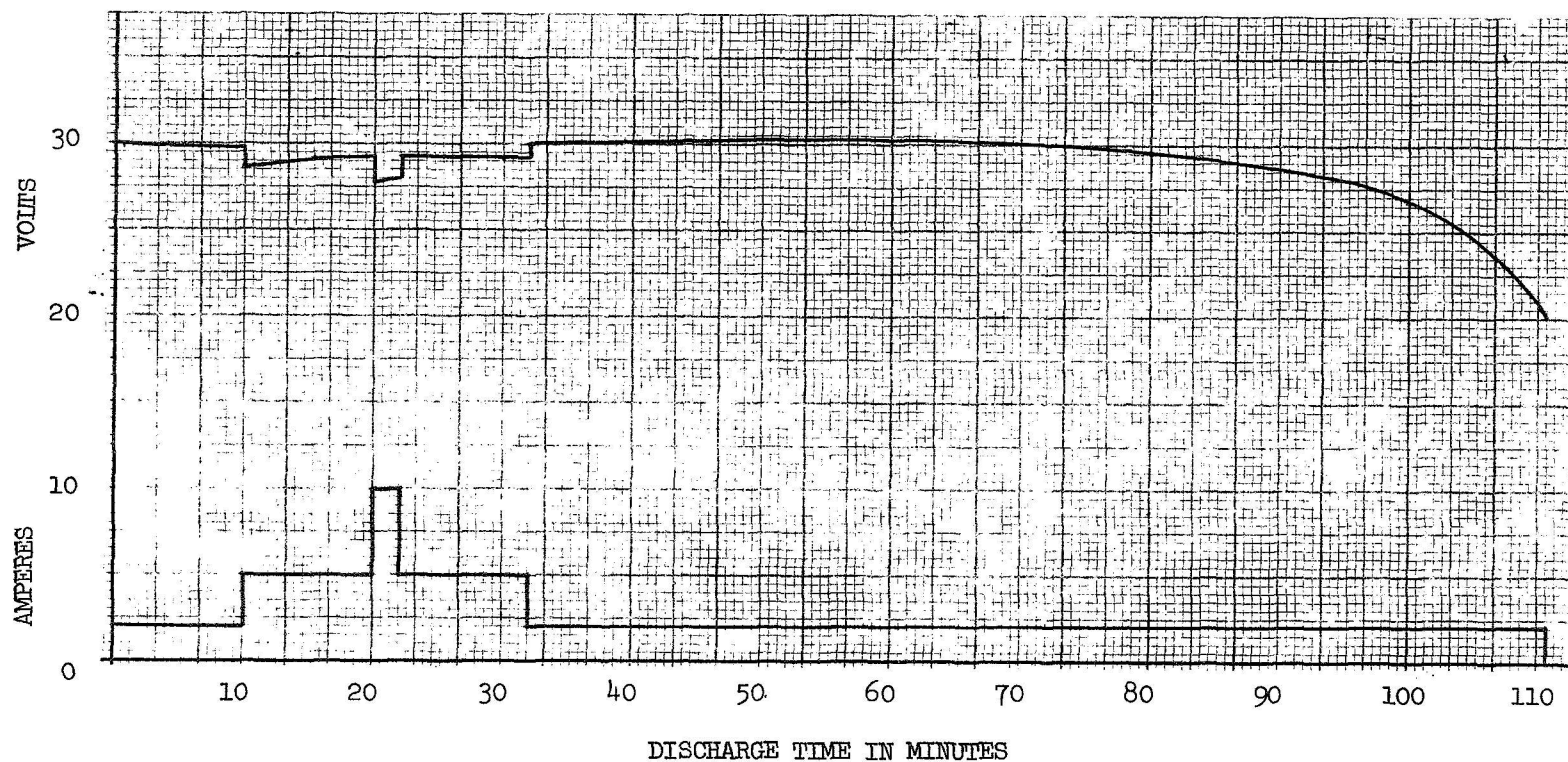
Date: 12-9-68

Wet-Stand Time: 5 Hr.

Battery Serial No: 479

Discharge Capacity
to 20.00 Volts: 4.93 ah

Time to 20 Volts:
1 Hr. 50 Min.



DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY
FIGURE 7

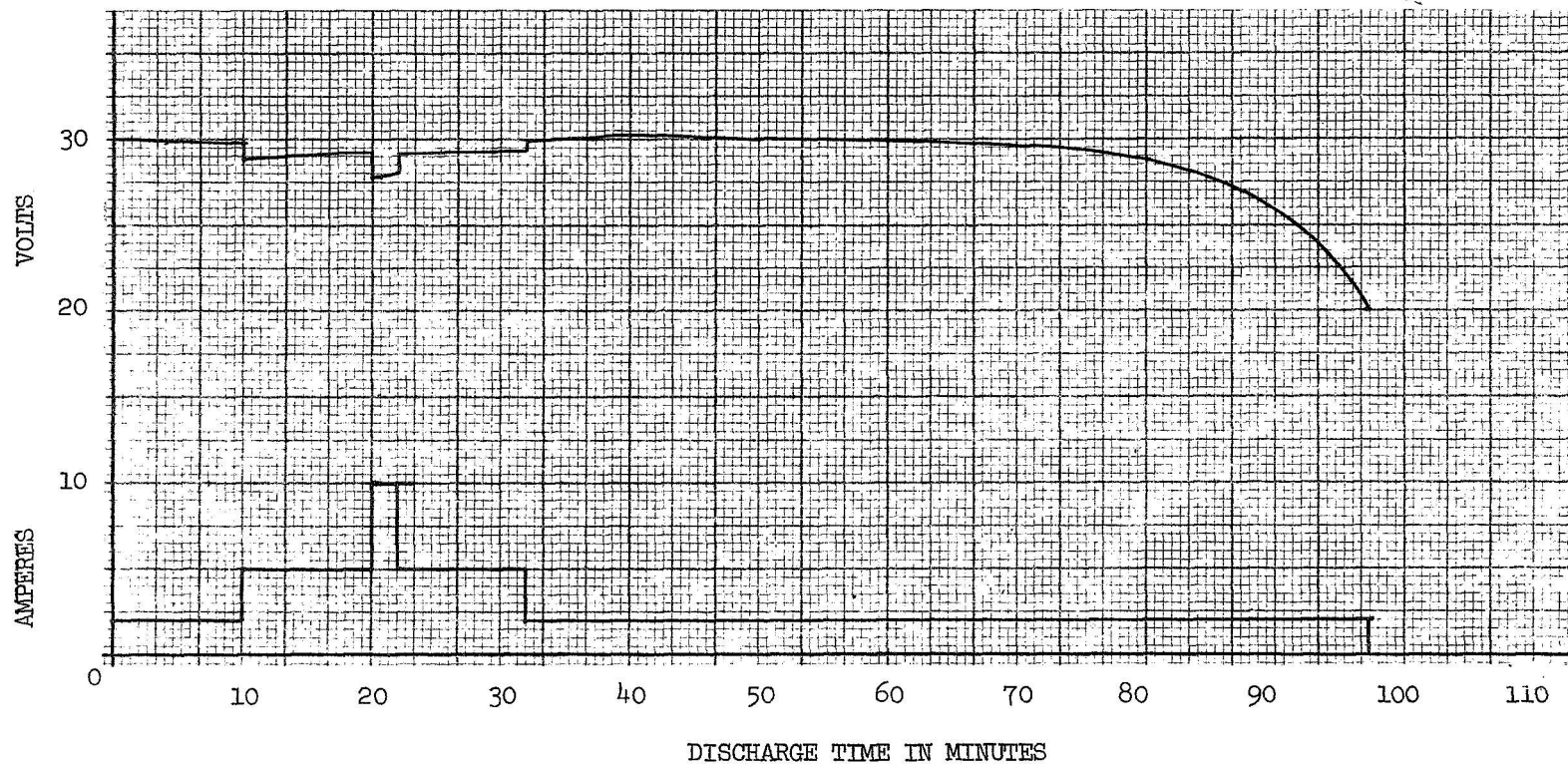
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Storage: None

Date: 12-16-68

Wet-Stand Time: 24 Hr.

Battery Serial No: 475

Discharge Capacity
to 20.00 Volts: 4.50 ahTime to 20 Volts:
1 Hr. 37 Min.

DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 8

QE/C 70-807

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Storage: None

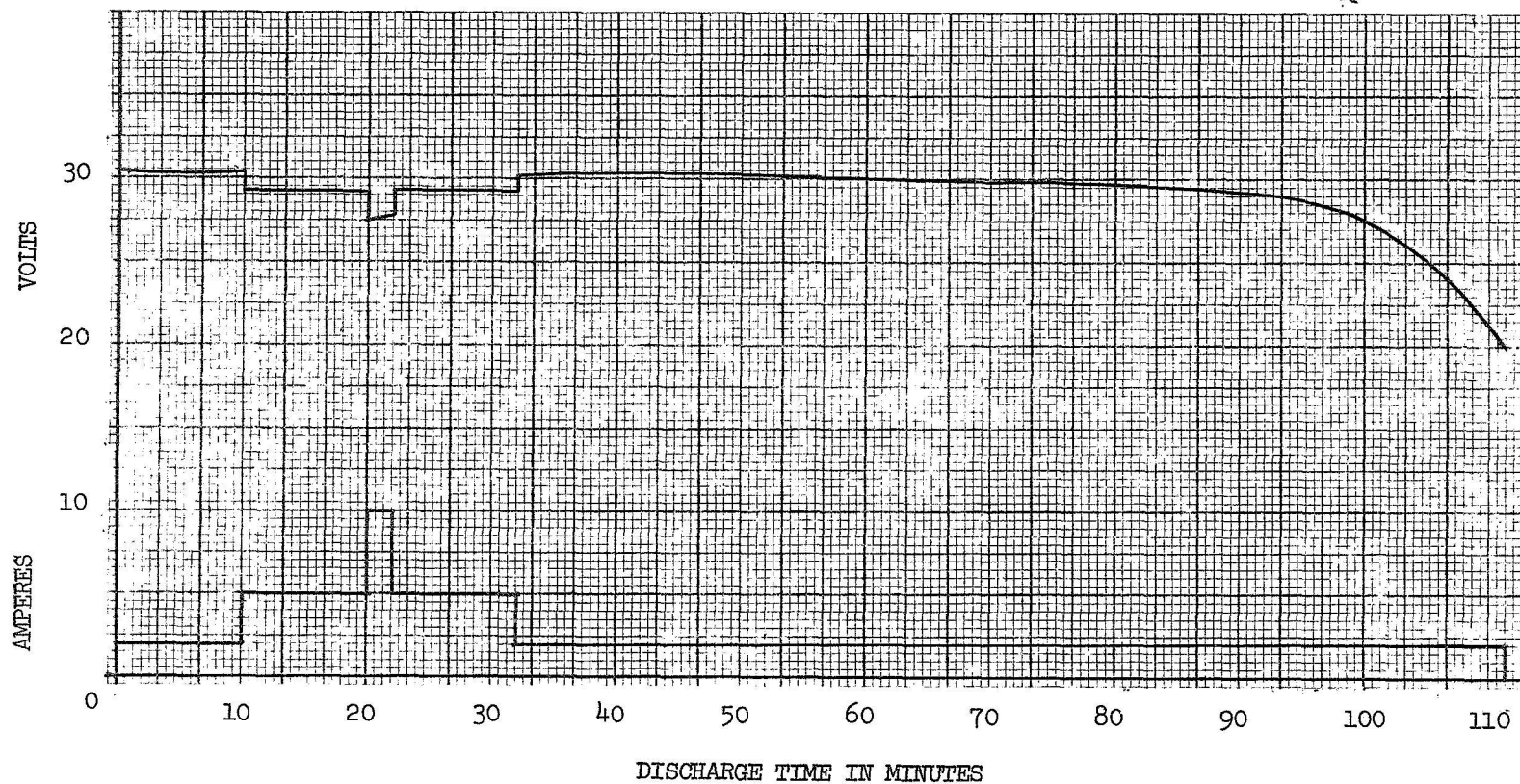
Date: 1-6-69

Wet-Stand Time: 48 Hr.

Battery Serial No: 620

Discharge Capacity
to 20.00 Volts: 4.97 ah

Time to 20 Volts:
1 Hr. 51 Min.



DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 9

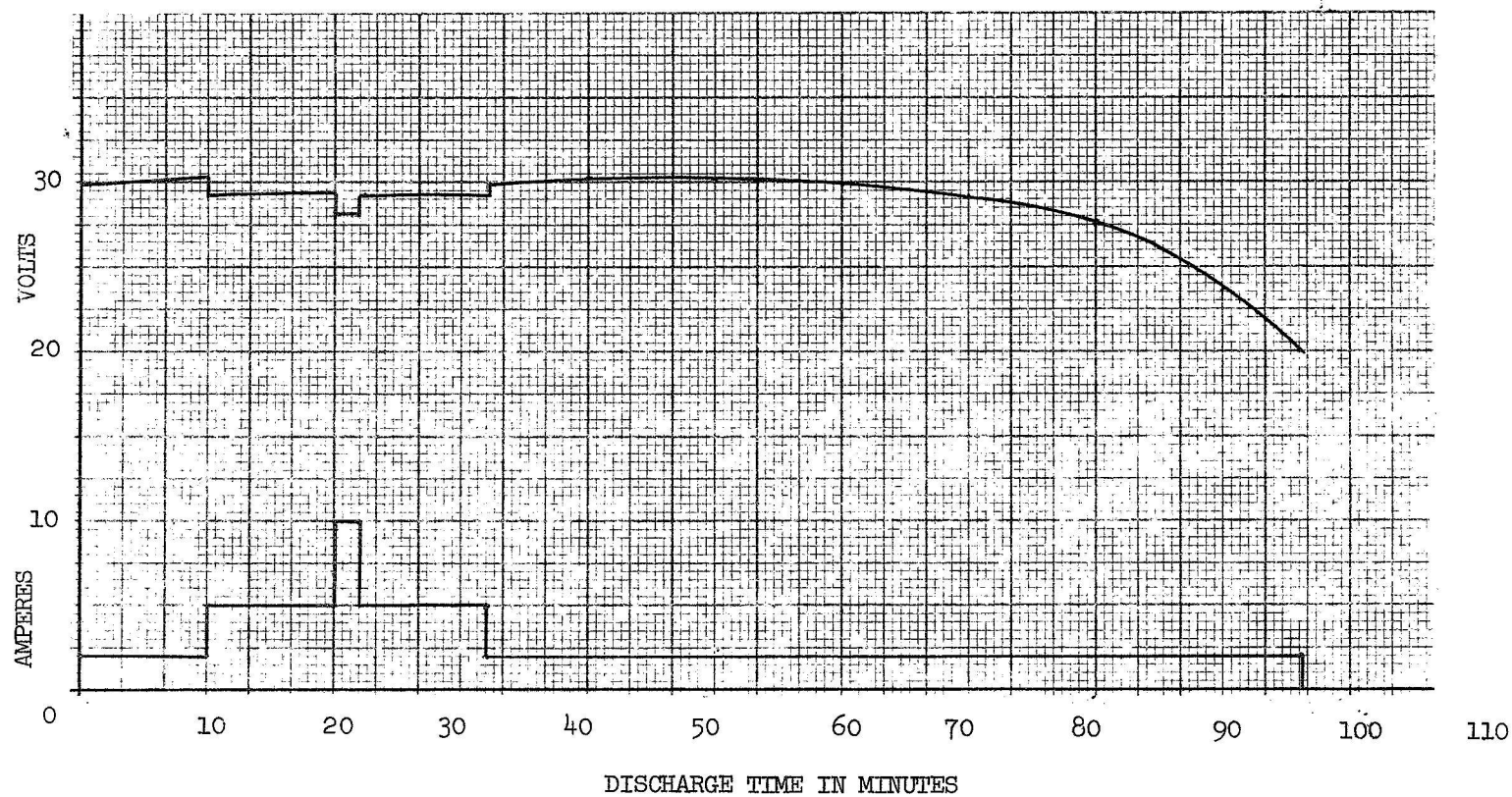
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Storage: None

Date: 1-13-69

Wet-Stand Time: 96 Hr.

Battery Serial No: 691

Discharge Capacity
to 20.00 Volts: 4.50 ahTime to 20 Volts:
1 Hr. 37 Min.

DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 10

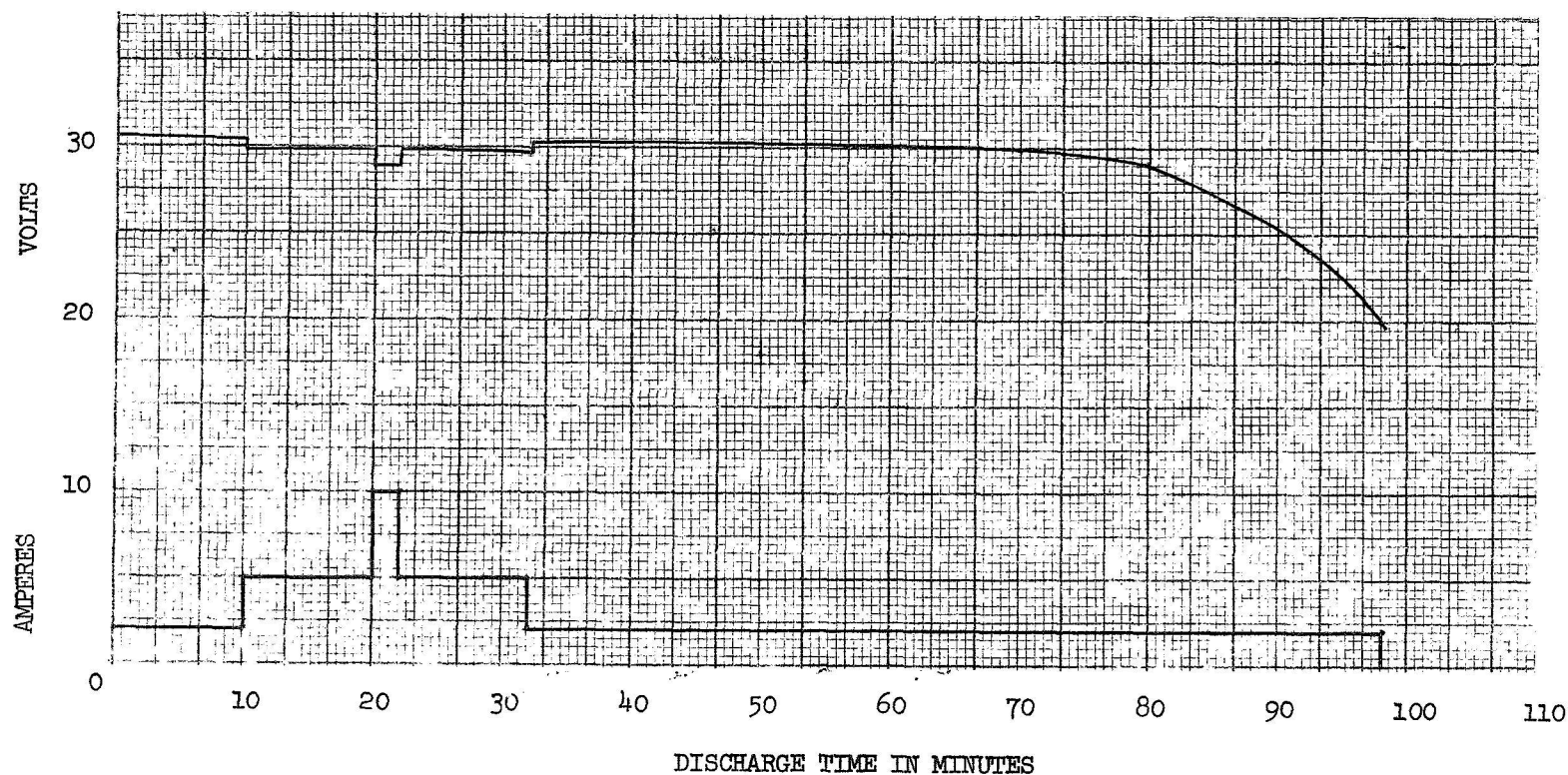
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Storage: 150° F for 2 Mo.

Date: 2-5-69

Wet-Stand Time: 5 Min.

Battery Serial No: 480

Discharge Capacity
to 20.00 Volts: 4.53 ahTime to 20 Volts:
1 Hr. 38 Min.

DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 11

QE/C 70-807

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Storage: 105° F for 3 Mo.

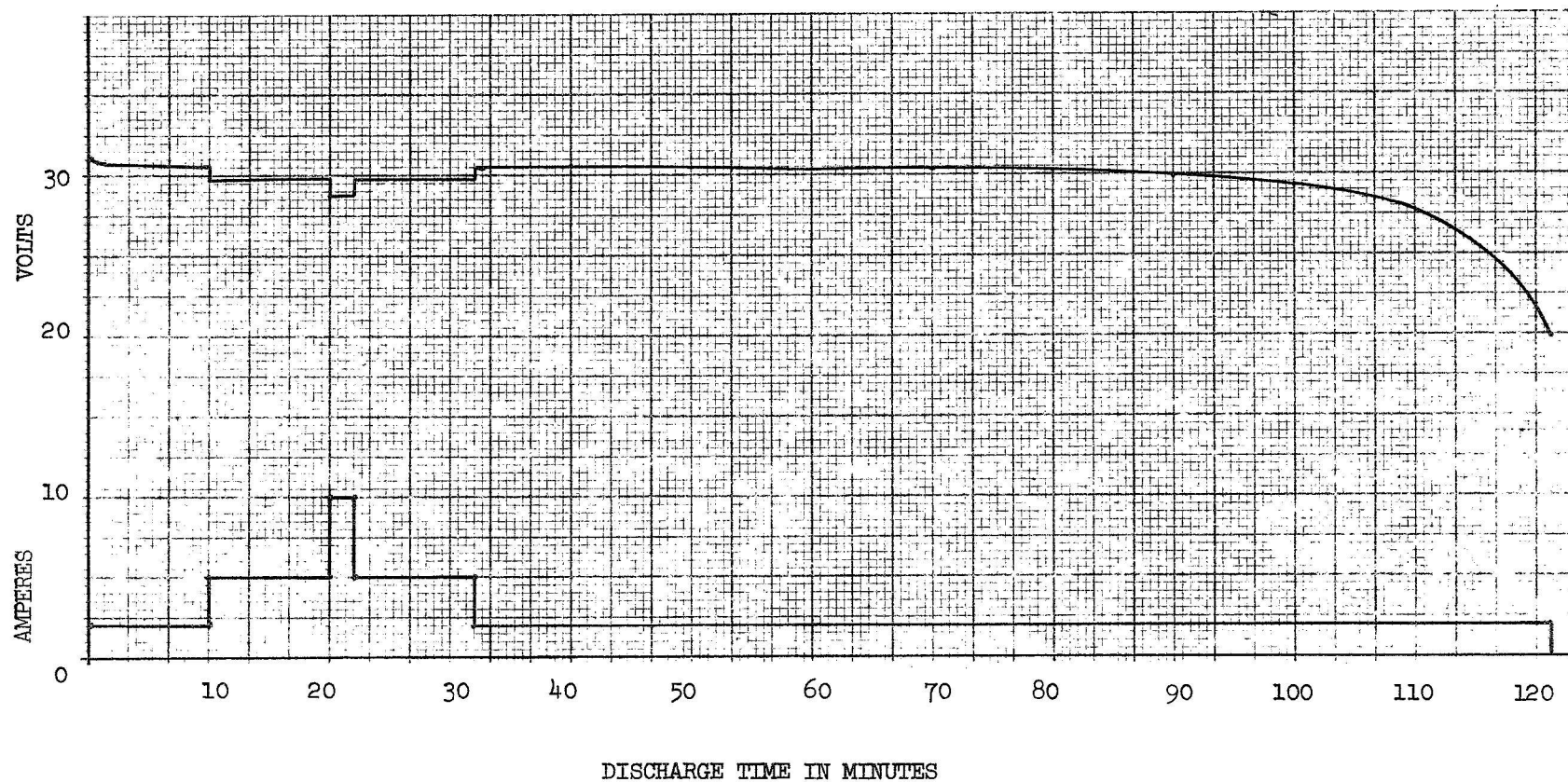
Date: 3-6-69

Wet-Stand Time: 5 Min.

Battery Serial No: 621

Discharge Capacity
to 20.00 Volts: 5.30 ah

Time to 20 Volts:
2 Hr. 1 Min.



DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 12

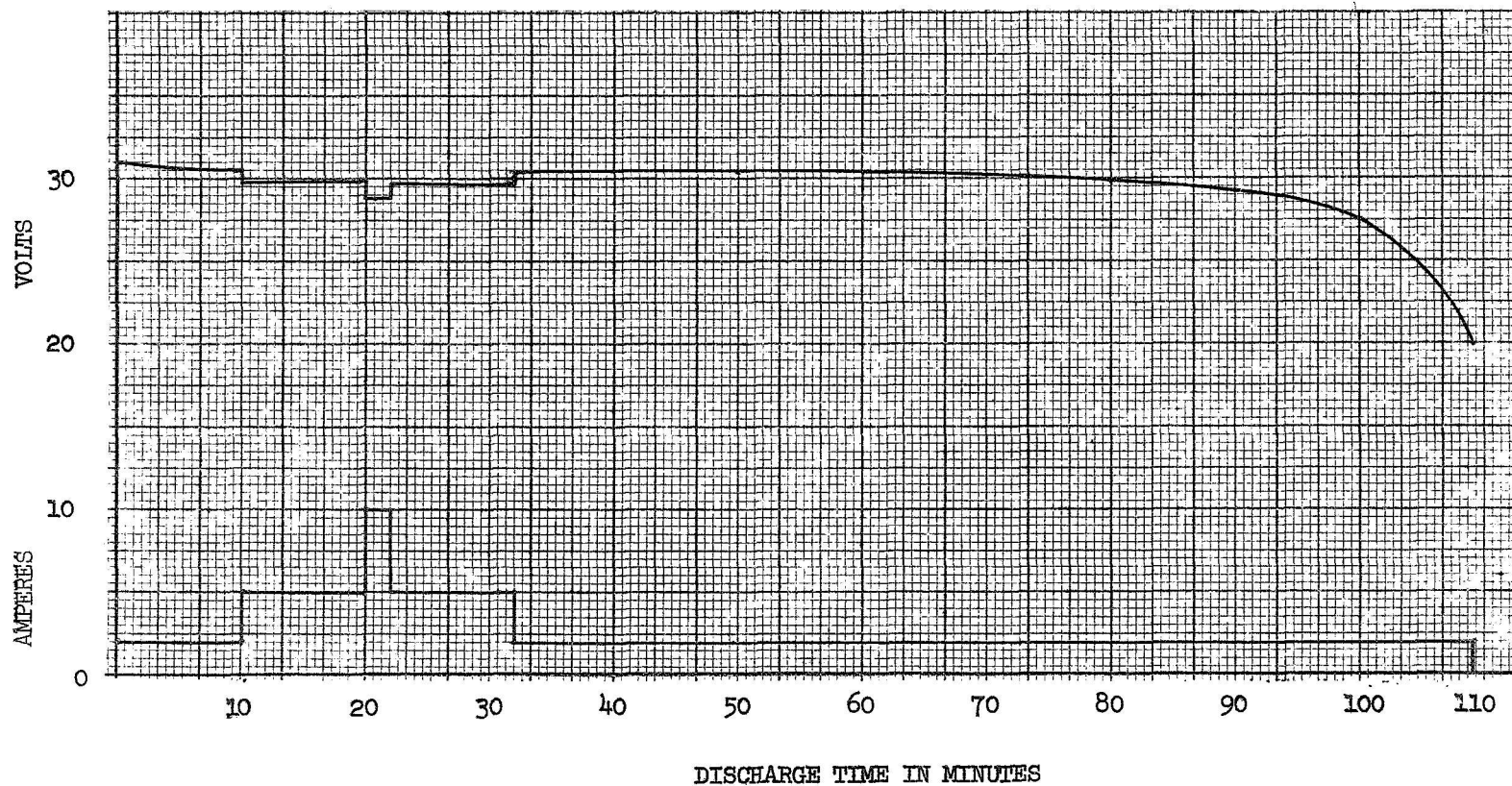
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Storage: 150° F for 4 Mo.

Date: 4-4-69

Wet-Stand Time: 5 Min.

Battery Serial No: 623

Discharge Capacity
to 20.00 Volts: 4.90 ahTime to 20 Volts:
1 Hr. 49 Min.

DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 13

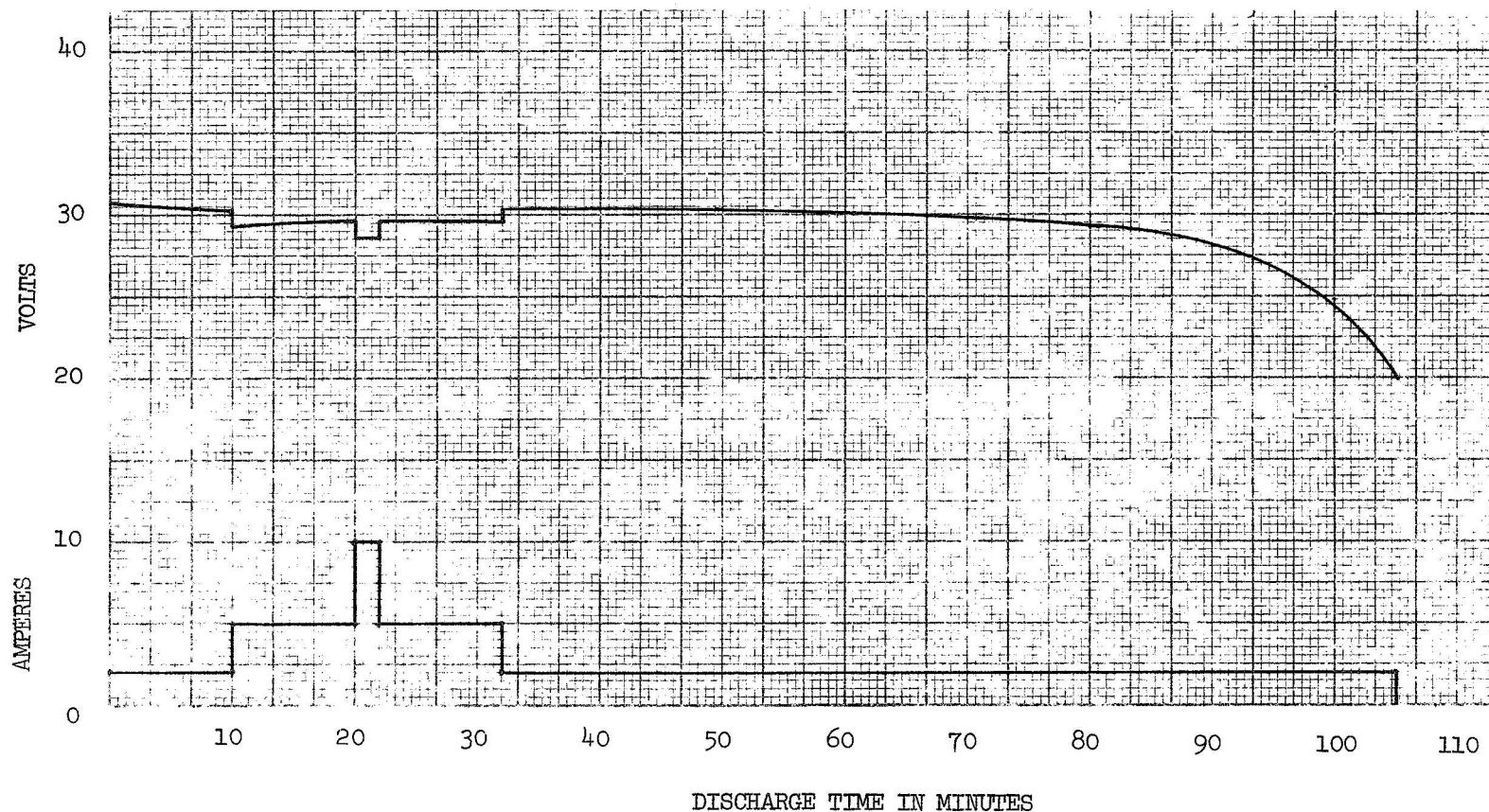
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Storage: 68° F for 6 Mo.

Date: 6-9-69

Wet-Stand Time: 5 Min.

Battery Serial No: 477

Discharge Capacity
to 20.00 Volts: 4.77 ahTime to 20 Volts:
1 Hr. 45 Min.DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY
FIGURE 14

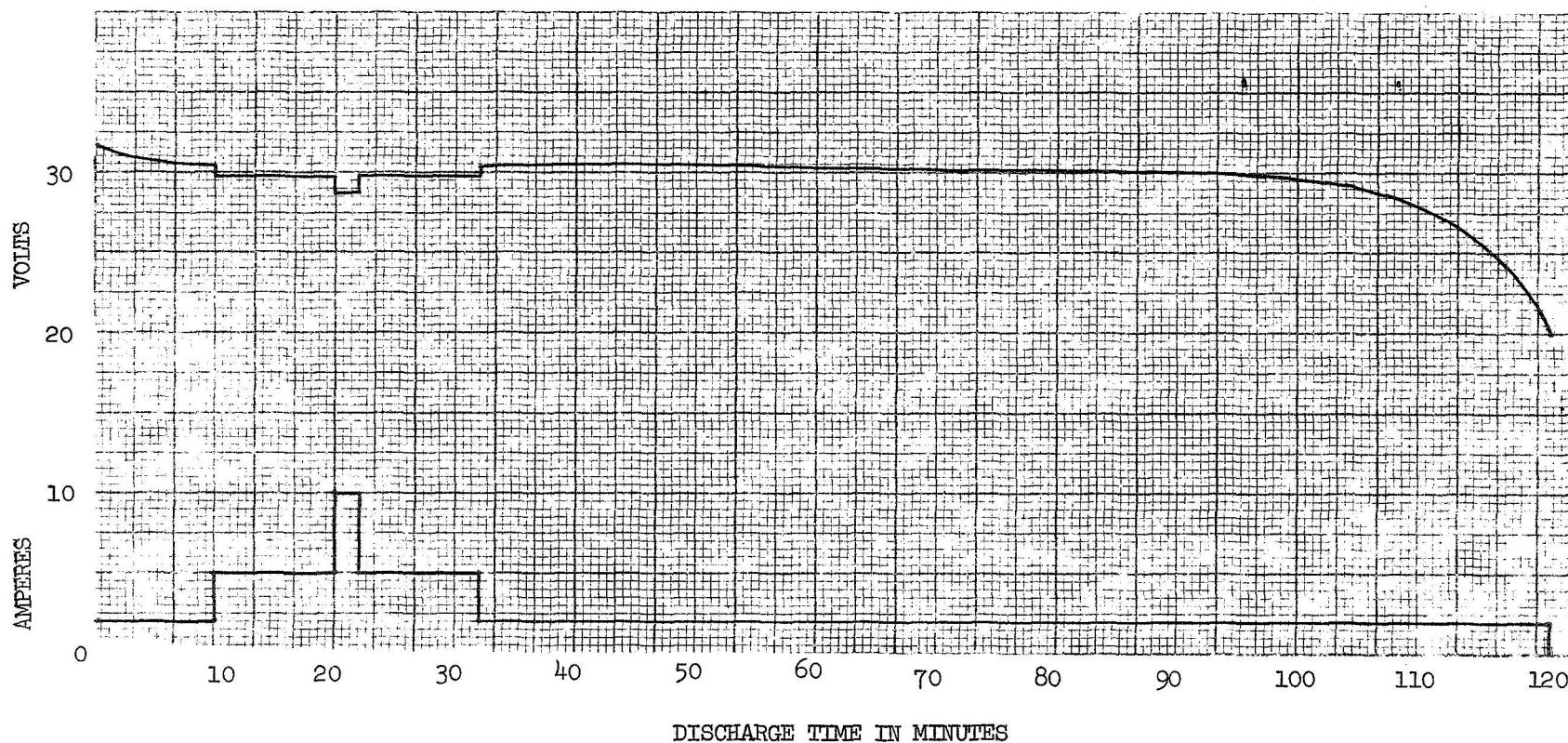
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Storage: 105° F for 6 Mo.

Date: 6-9-69

Wet-Stand Time: 5 Min.

Battery Serial No: 619

Discharge Capacity
to 20.00 Volts: 5.30 ahTime to 20 Volts:
2 Hr. 1 Min.

DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 15

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Storage: 68° F for 12 Mo.

Date: 12-9-69

Wet-Stand Time: 5 Min.

Battery Serial No: 626

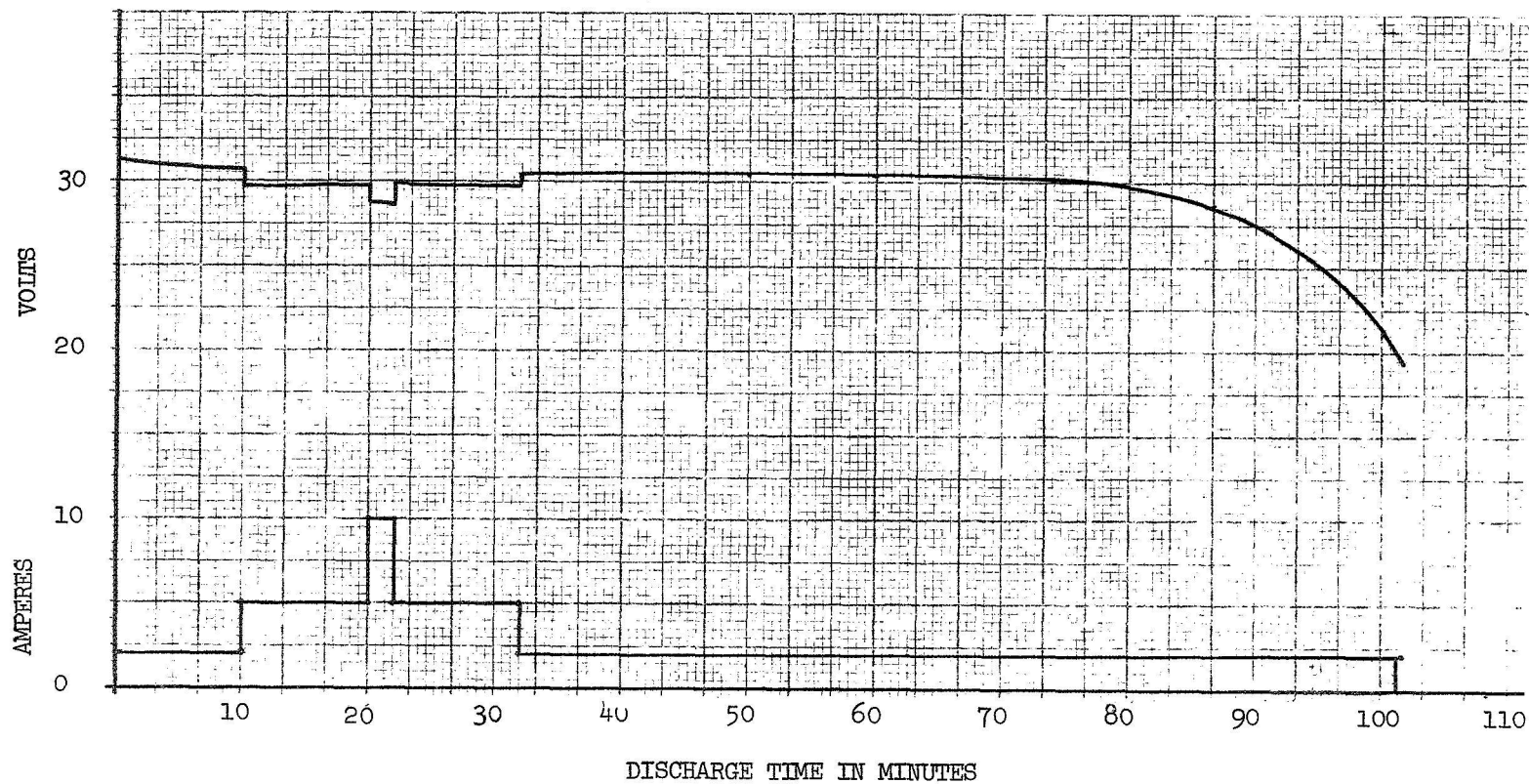
Discharge Capacity
to 20.00 Volts: 4.60 ahTime to 20 Volts:
1 Hr. 41 Min.DISCHARGE TIME IN MINUTES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 16

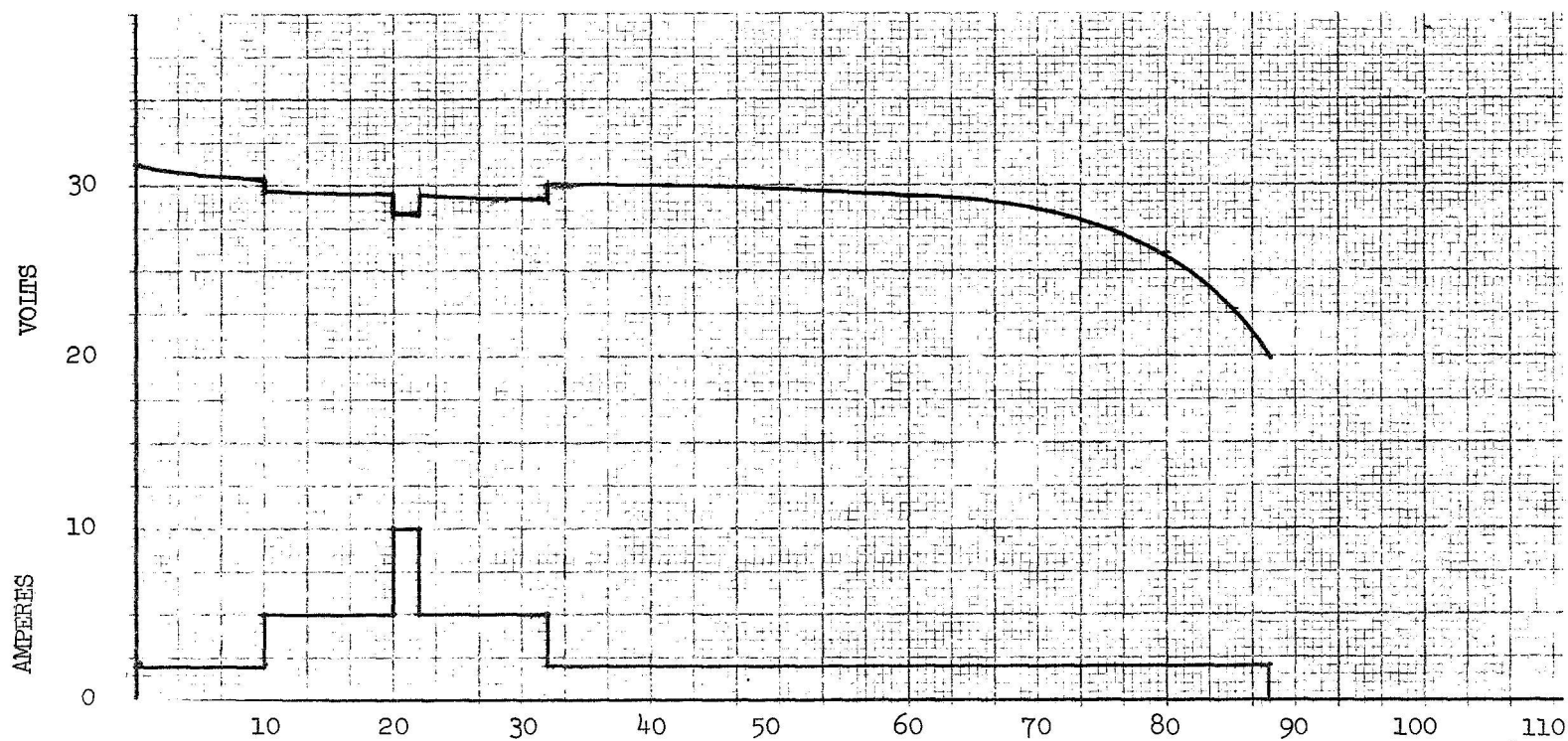
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Storage: 150° F for 12 Mo.

Date: 12-3-69

Wet-Stand Time: 5 Min.

Battery Serial No: 483

Discharge Capacity
to 20.00 Volts: 4.20 ahTime to 20 Volts:
1 Hr. 28 Min.

DISCHARGE TIME IN MINUTES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 17

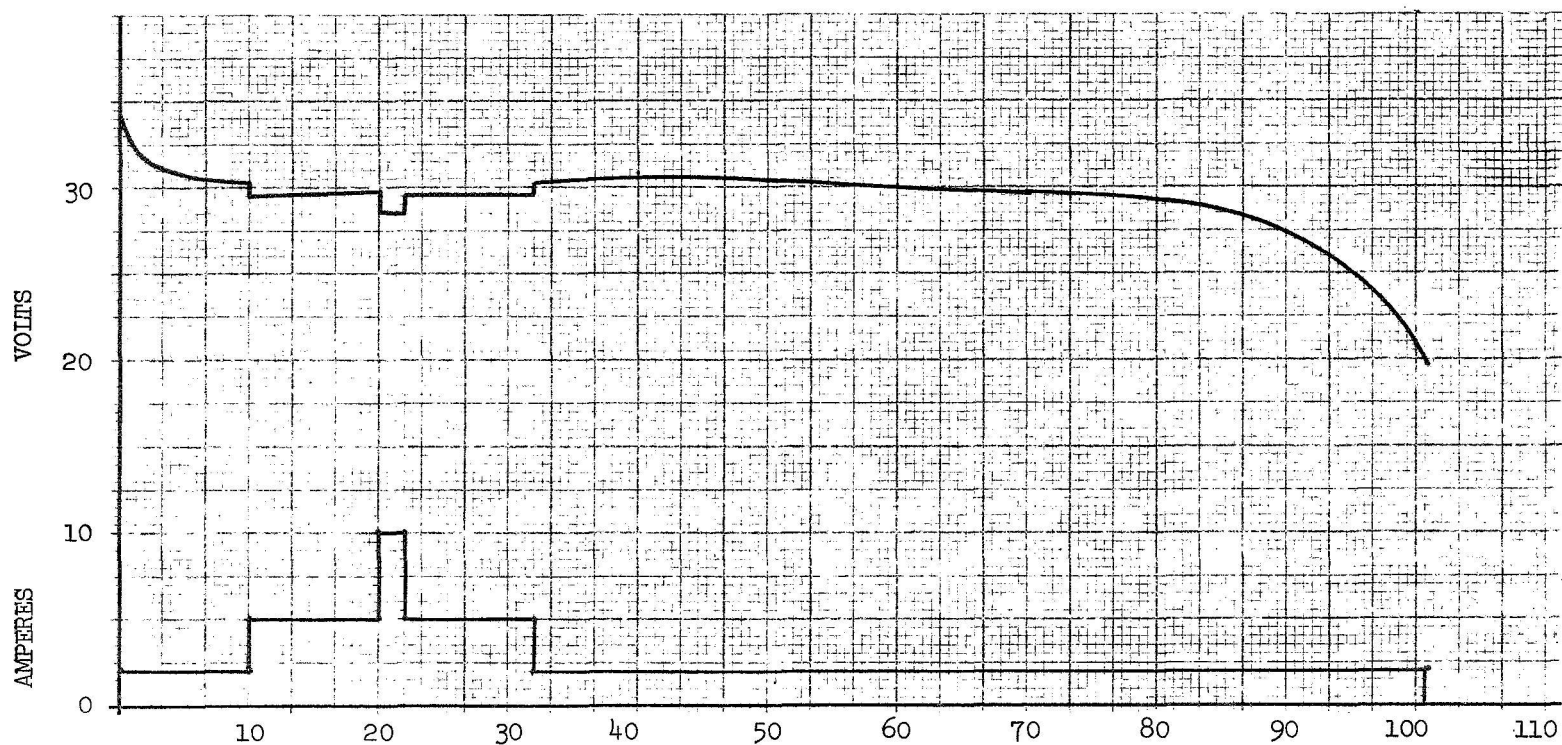
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Storage: 105° F for 18 Mo.

Date: 6-8-70

Wet-Stand Time: 5 Min.

Battery Serial No: 692

Discharge Capacity
to 20.00 Volts: 4.60 ahTime to 20 Volts:
1 Hr. 41 Min.

DISCHARGE TIME IN MINUTES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 18

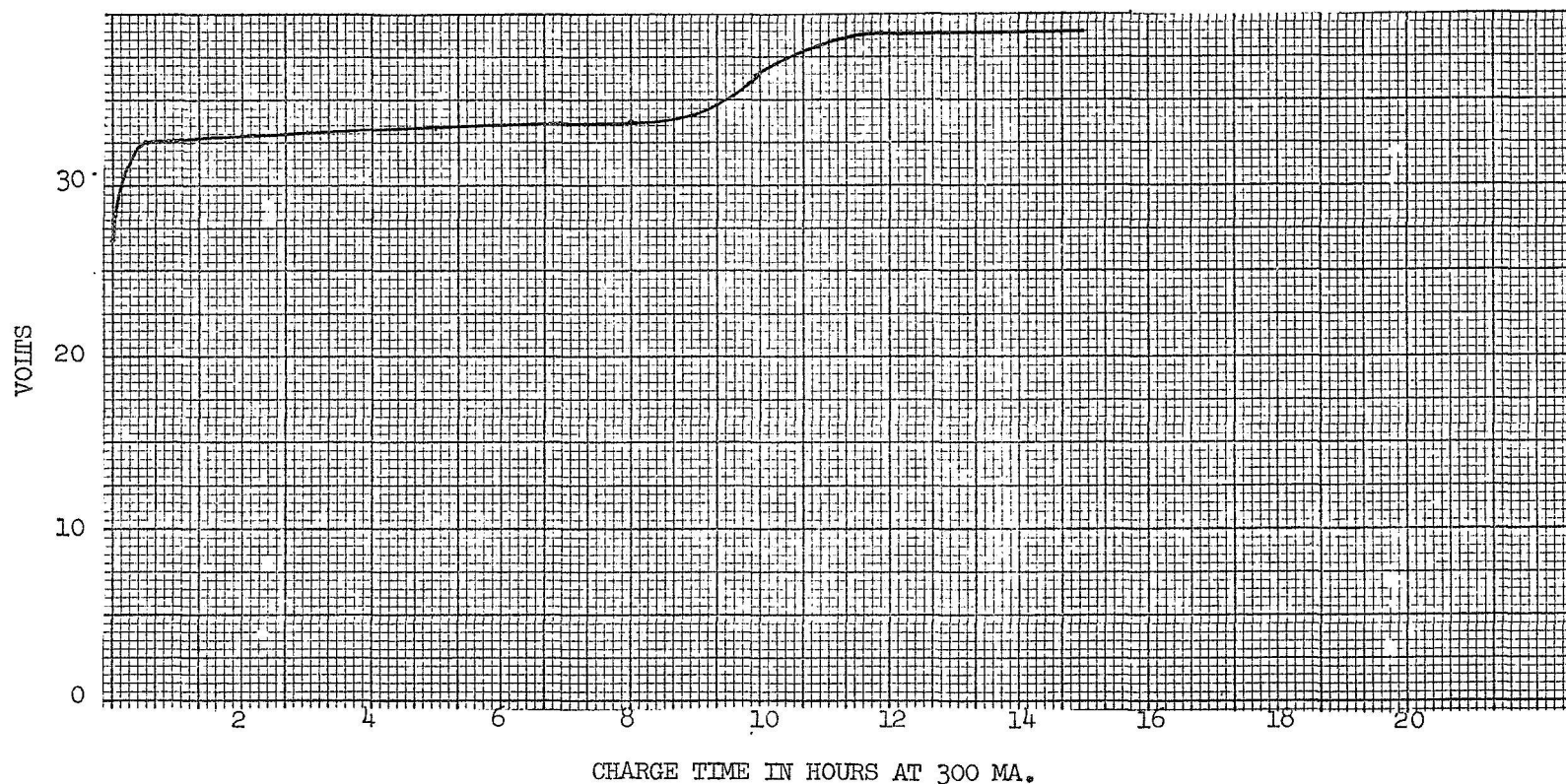
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Recharge No. 1: 4.67 ah at 300 milliamperes

Date of Recharge: 12-10-69

Charge time to 39.00 Volts: 15 Hr. 33 Min.

Battery Serial No.: 626



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 19

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

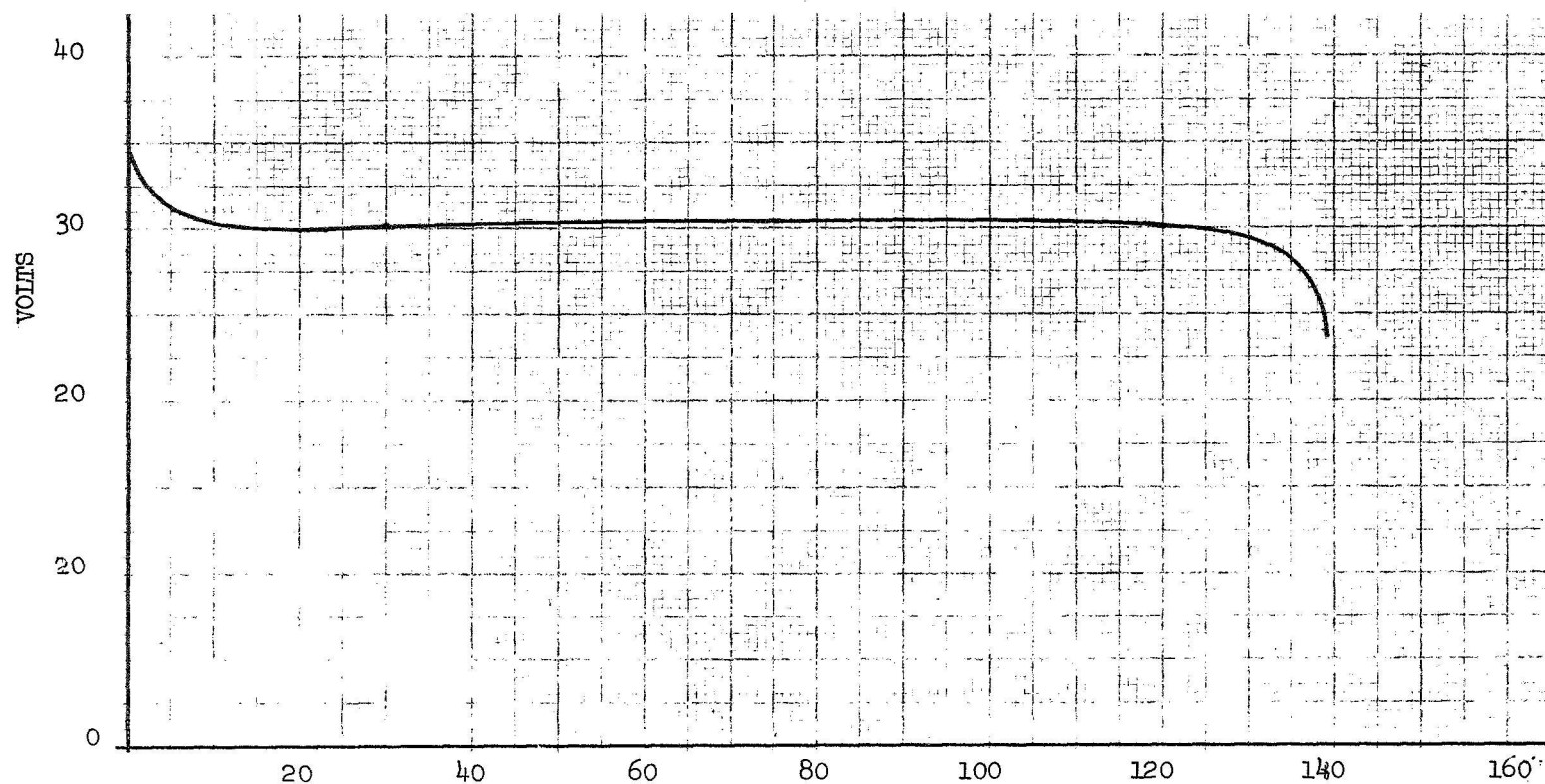
Discharge No. 1: 4.63 ah at 2.0 amps

Date of Discharge: 12-10-69

Time of Previous Charge: 12 Hr. 33 Min.

Battery Serial No: 626

Discharge Time to 24.00 Volts: 2 Hr. 19 Min.



DISCHARGE TIME IN MINUTES AT 2.0 AMPERES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 20

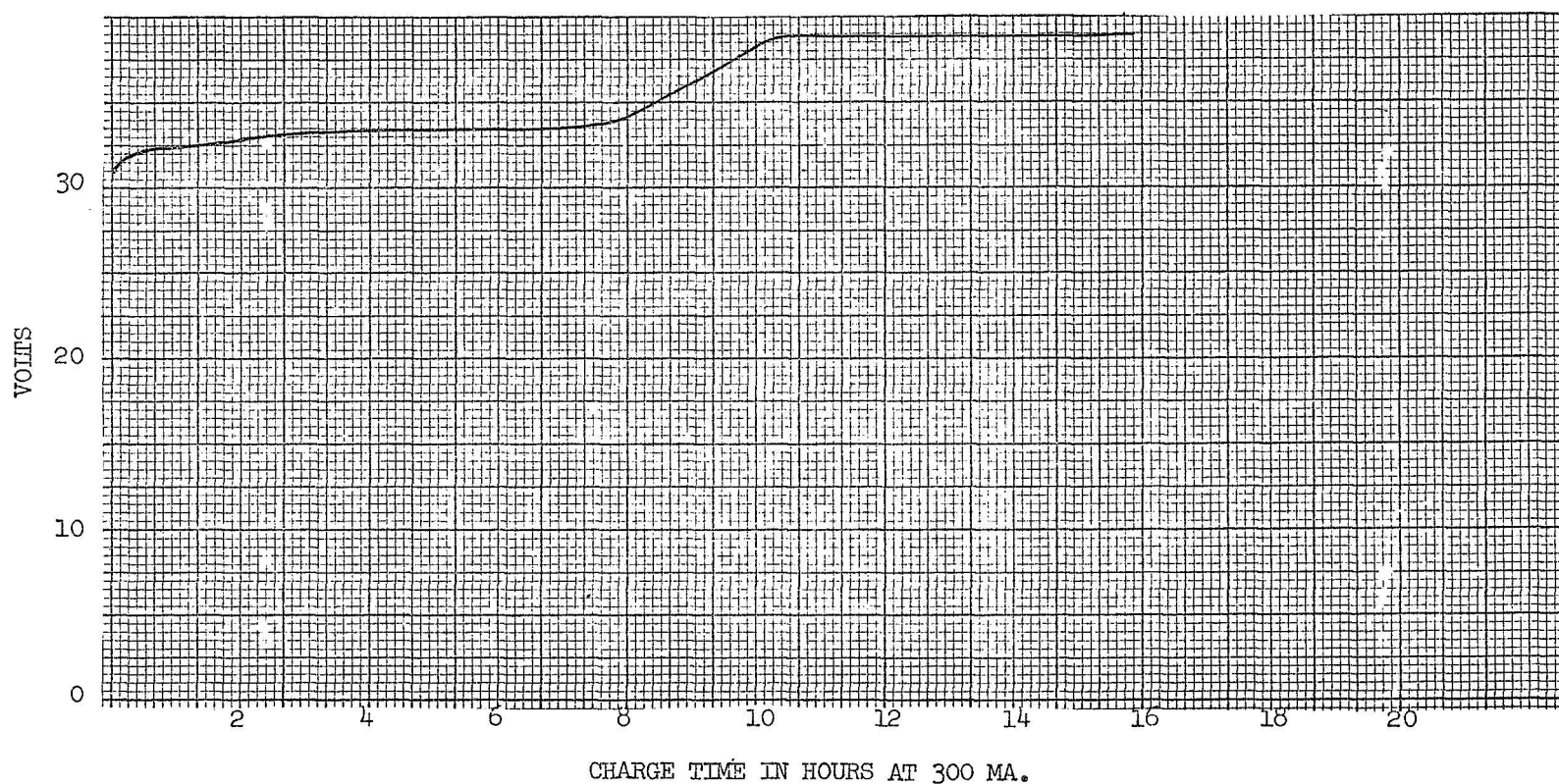
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Recharge No. 2: 4.77 ah at 300 milliamperes

Date of Recharge: 12-10-69

Charge Time to 39.00 Volts: 15 Hr. 53 Min.

Battery Serial No.: 626



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 21

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

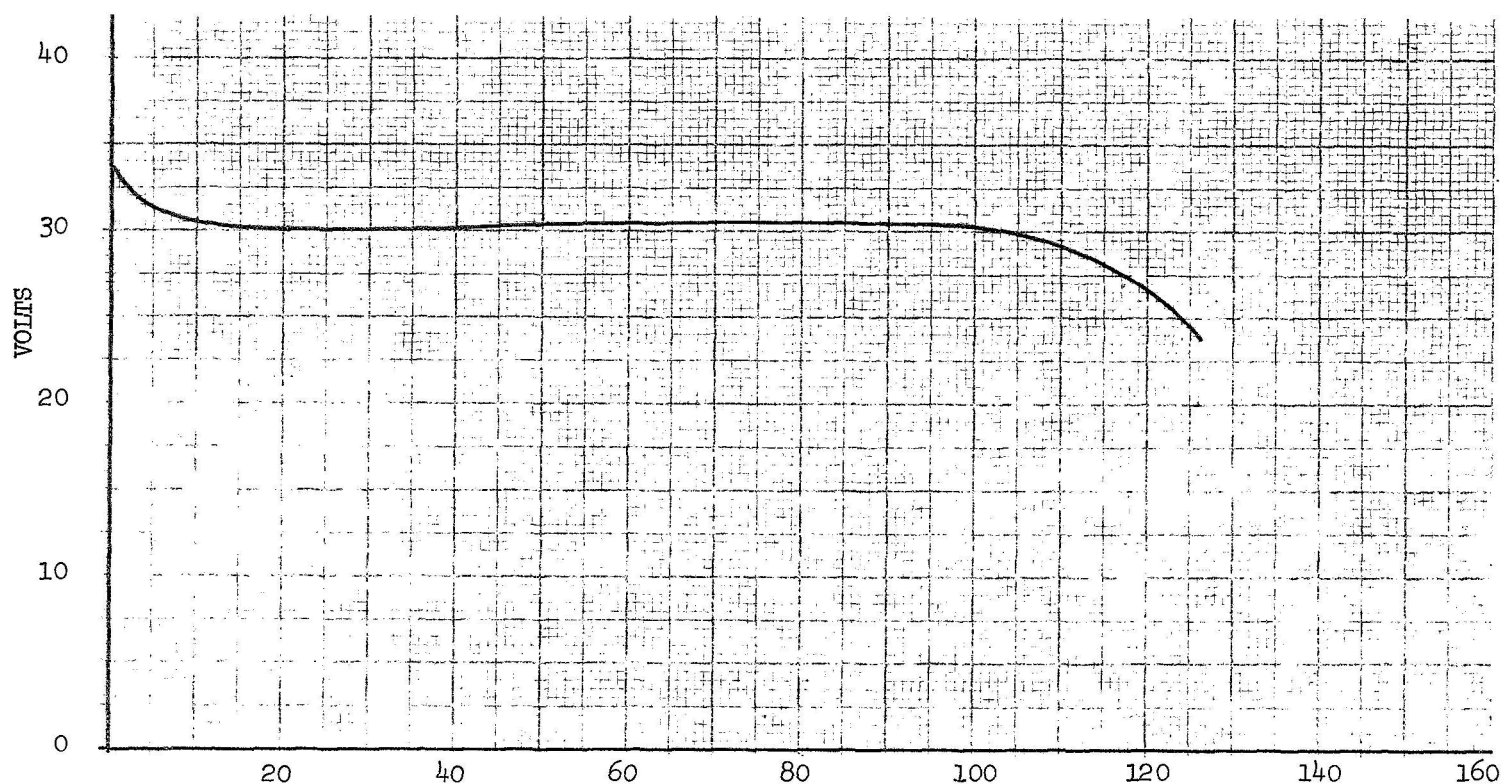
Discharge No. 2: 4.20 ah at 2.0 amps

Date of Discharge: 12-10-69

Time of Previous Charge: 15 Hr. 53 Min.

Battery Serial No: 626

Discharge Time to 24.00 Volts: 2 Hr. 19 Min.



DISCHARGE TIME IN MINUTES AT 2.0 AMPERES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 22

QE/C 70-807

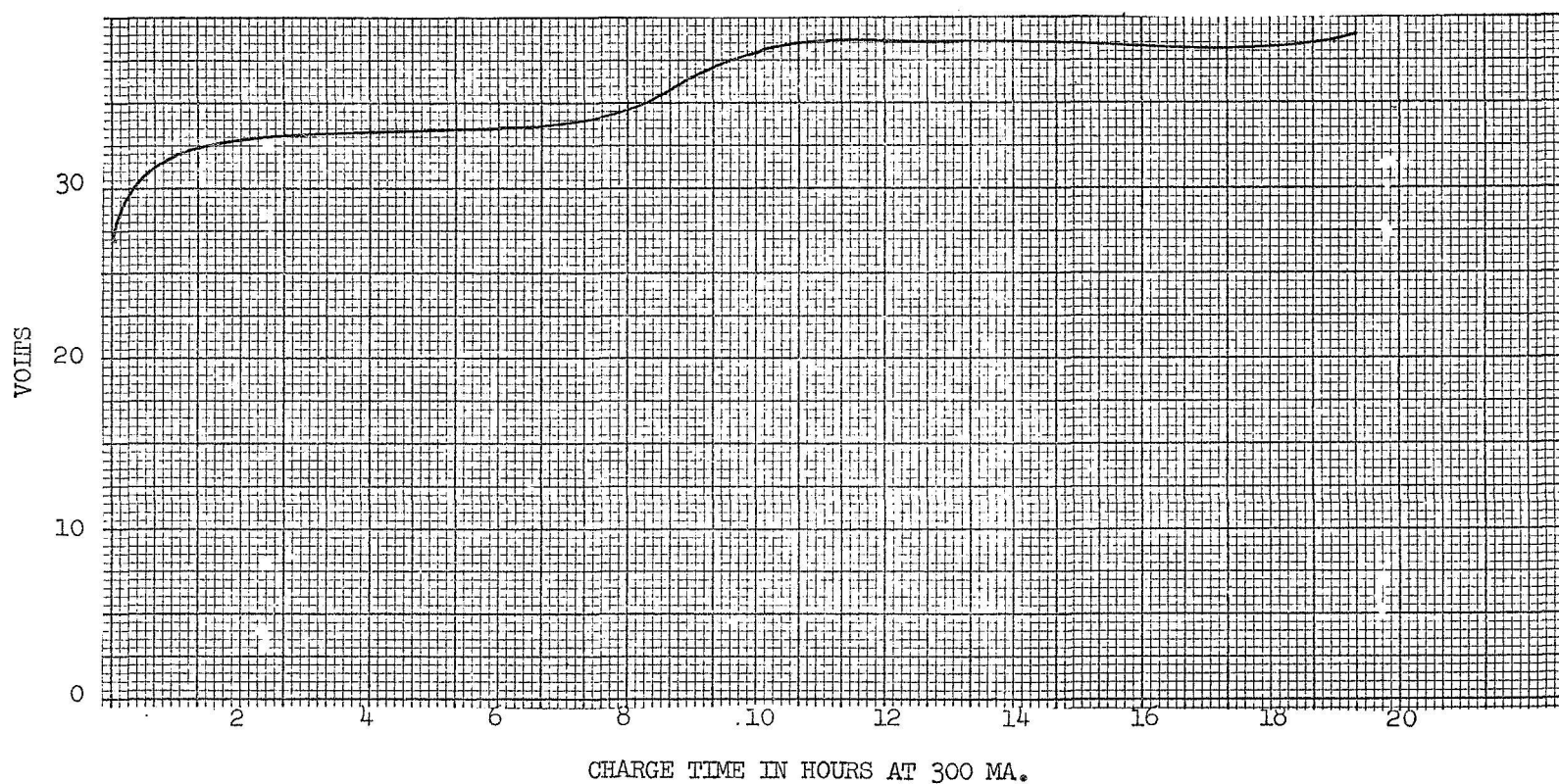
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Recharge No. 3: 5.81 ah at 300 milliamperes

Date of Recharge: 12-10-69

Charge Time to 39.00 Volts: 19 Hr. 22 Min.

Battery Serial No.: 626



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 23

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

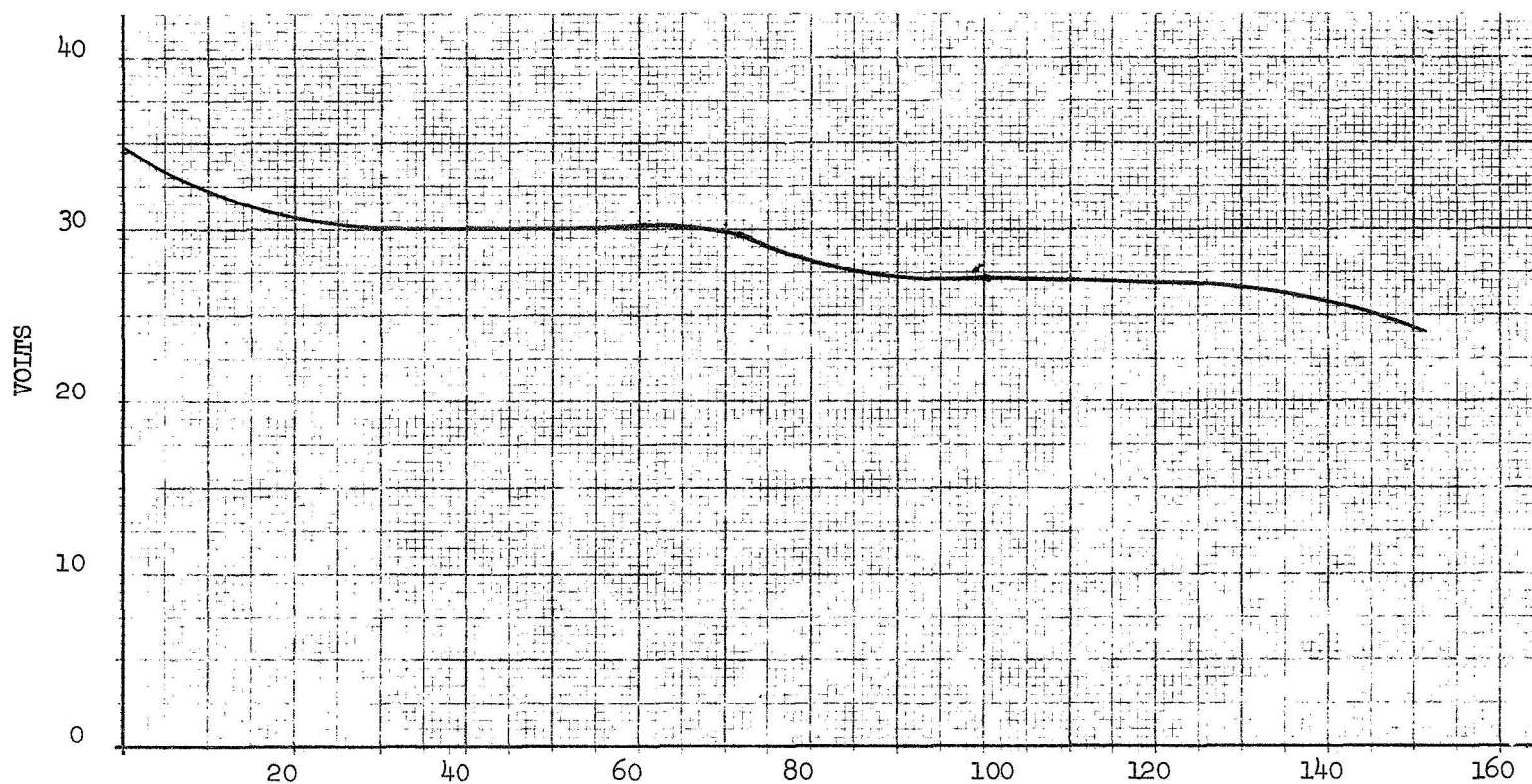
Discharge No. 3: 5.07 ah at 2.0 amps

Date of Discharge: 12-11-69

Time of Previous Charge: 19 Hr. 22 Min.

Battery Serial No: 626

Discharge Time to 24.00 Volts: 2 Hr. 32 Min.



DISCHARGE TIME IN MINUTES AT 2.0 AMPERES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 24

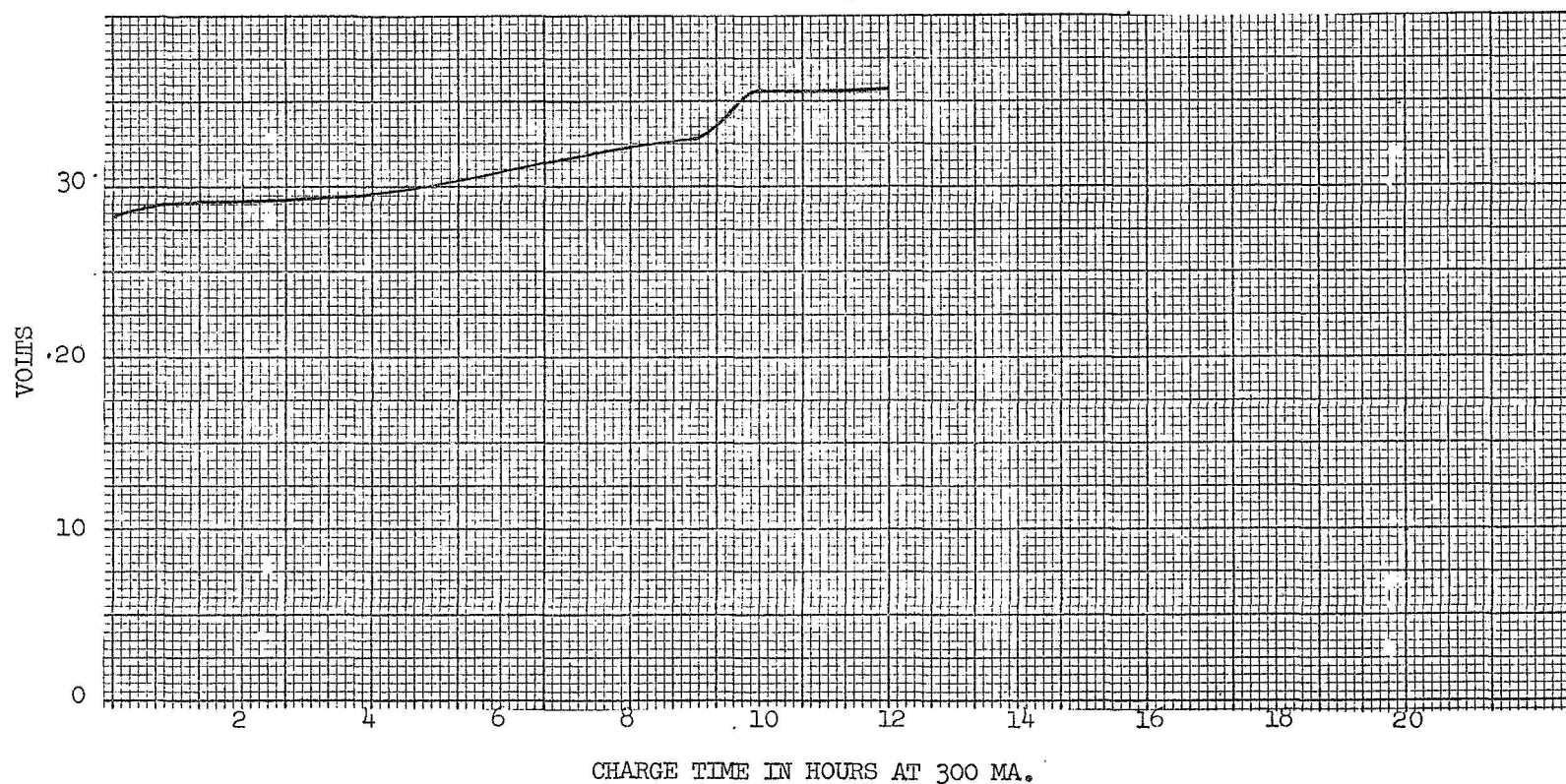
QE/C 70-807

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Recharge No. 4: Battery did not reach 39.00
volt at 300 ma. charge rate.

Date of Recharge: 12-10-69

Battery Serial No.: 626



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 25

QE/C 70-807

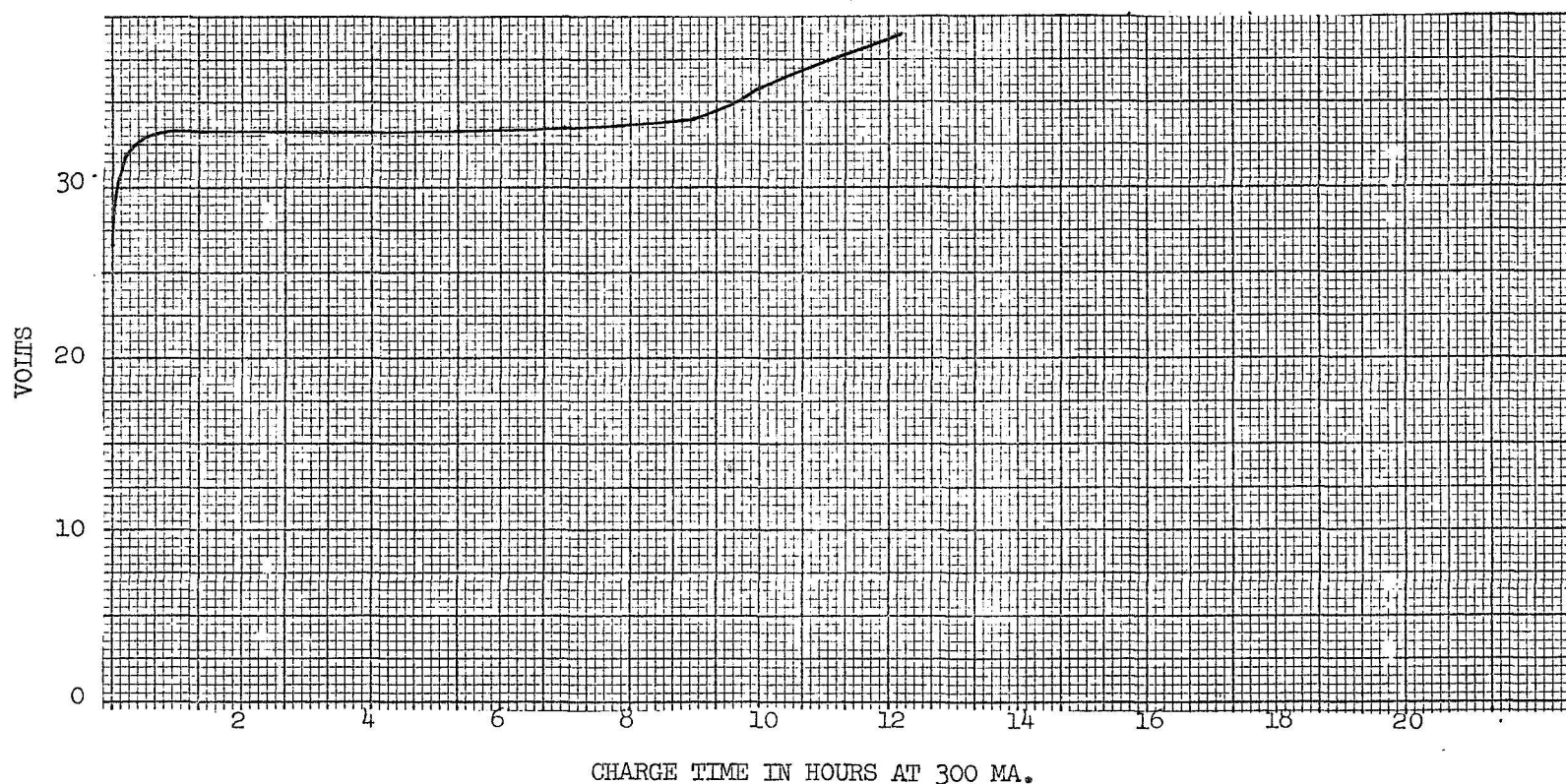
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Recharge No. 1: 3.67 ah at 300 milliamperes

Date of Recharge: 12-4-69

Charge time to 39.00 Volts: 12 Hr. 11 Min.

Battery Serial No.: 483



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 26

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

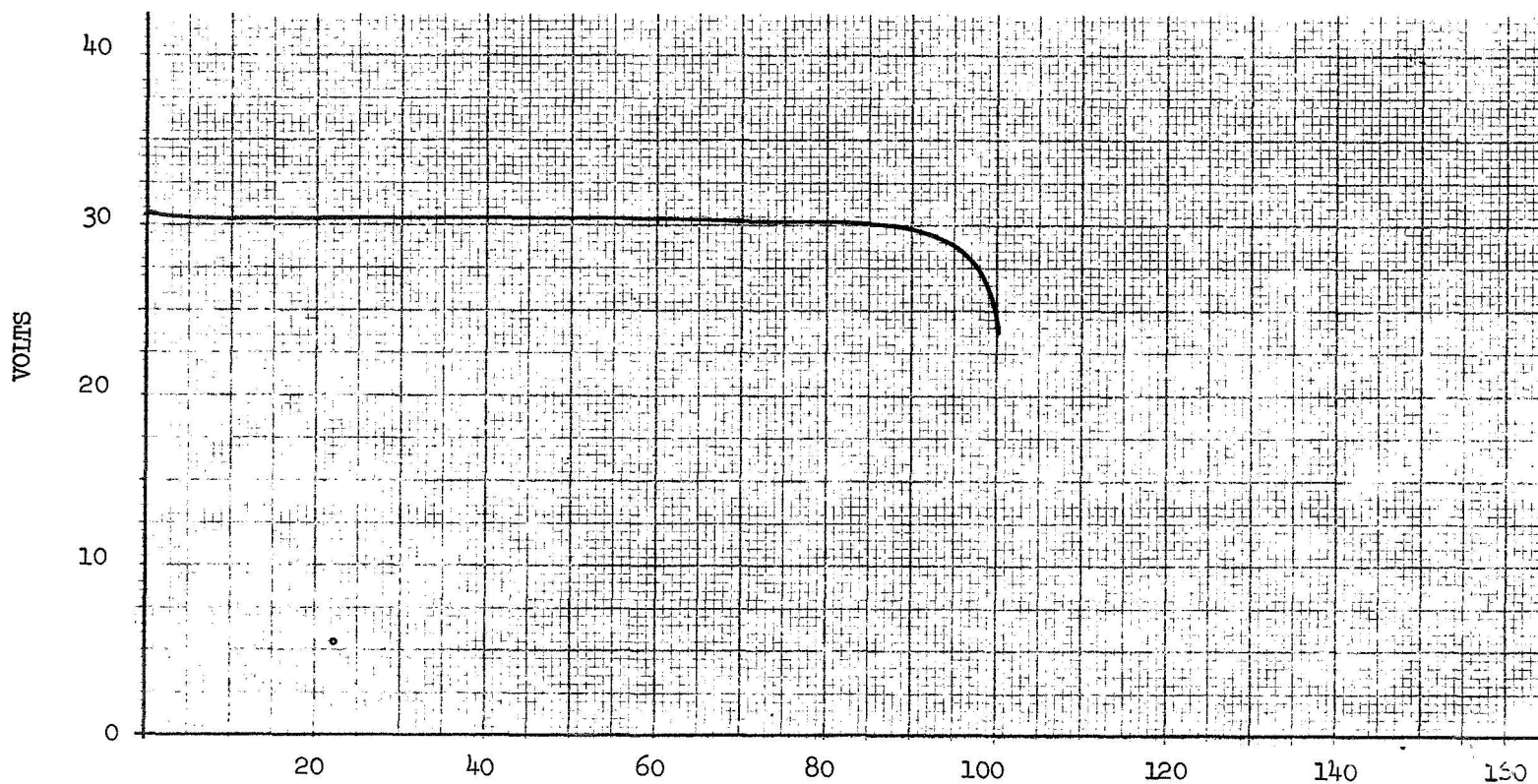
Discharge No. 1: 3.33 ah at 2.0 amps

Date of Discharge: 12-4-69

Time of Previous Charge: 12 Hr. 33 Min.

Battery Serial No: 483.

Discharge Time to 24.00 Volts: 1 Hr. 40 Min.



DISCHARGE TIME IN MINUTES AT 2.0 AMPERES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 27

QE/C 70-807

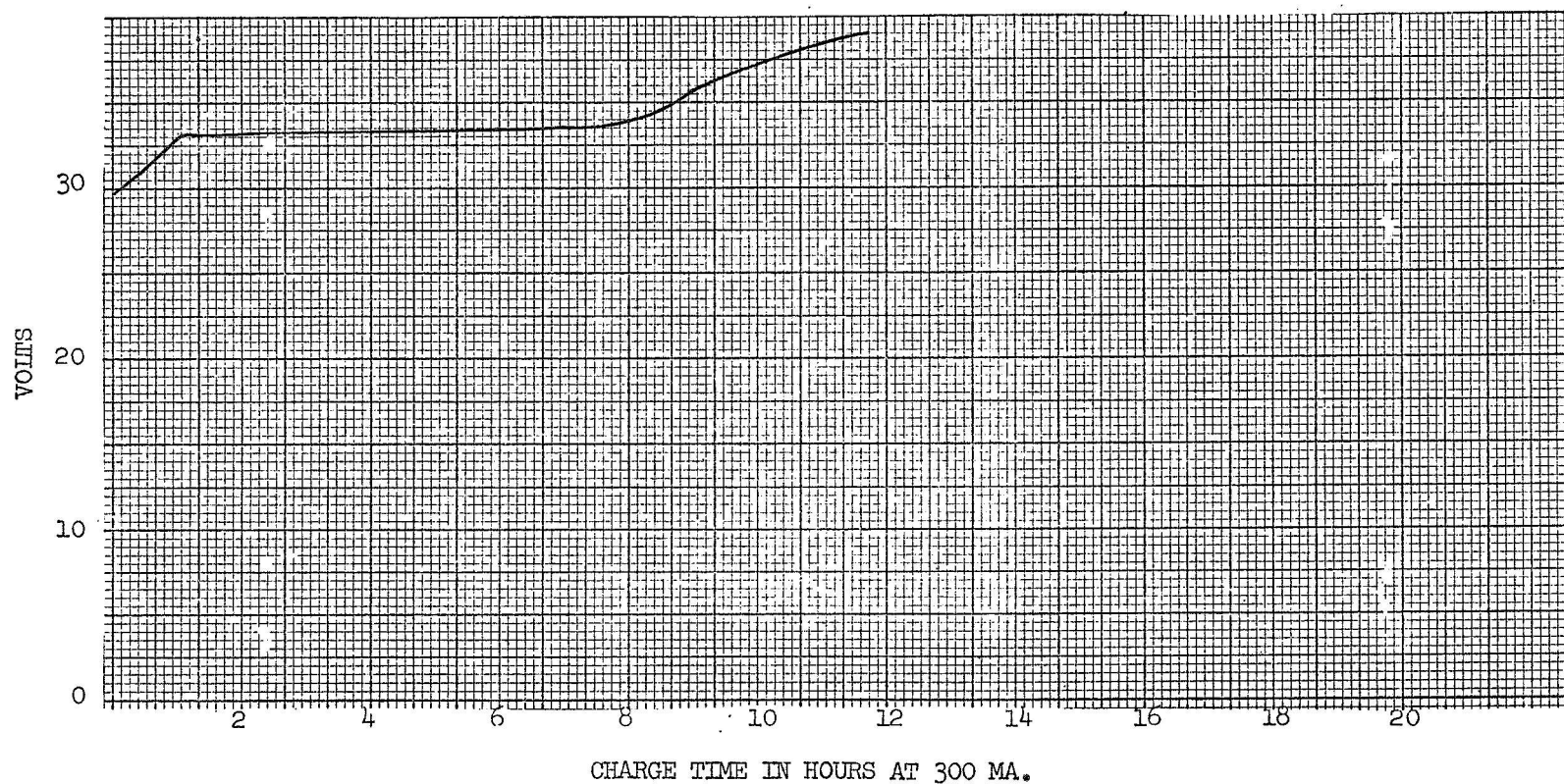
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Discharge No. 2: 3.52 ah at 300 milliamperes

Date of Recharge: 12-4-69

Charge Time to 39.00 Volts: 11 Hr. 43 Min.

Battery Serial No.: 483



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 28

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

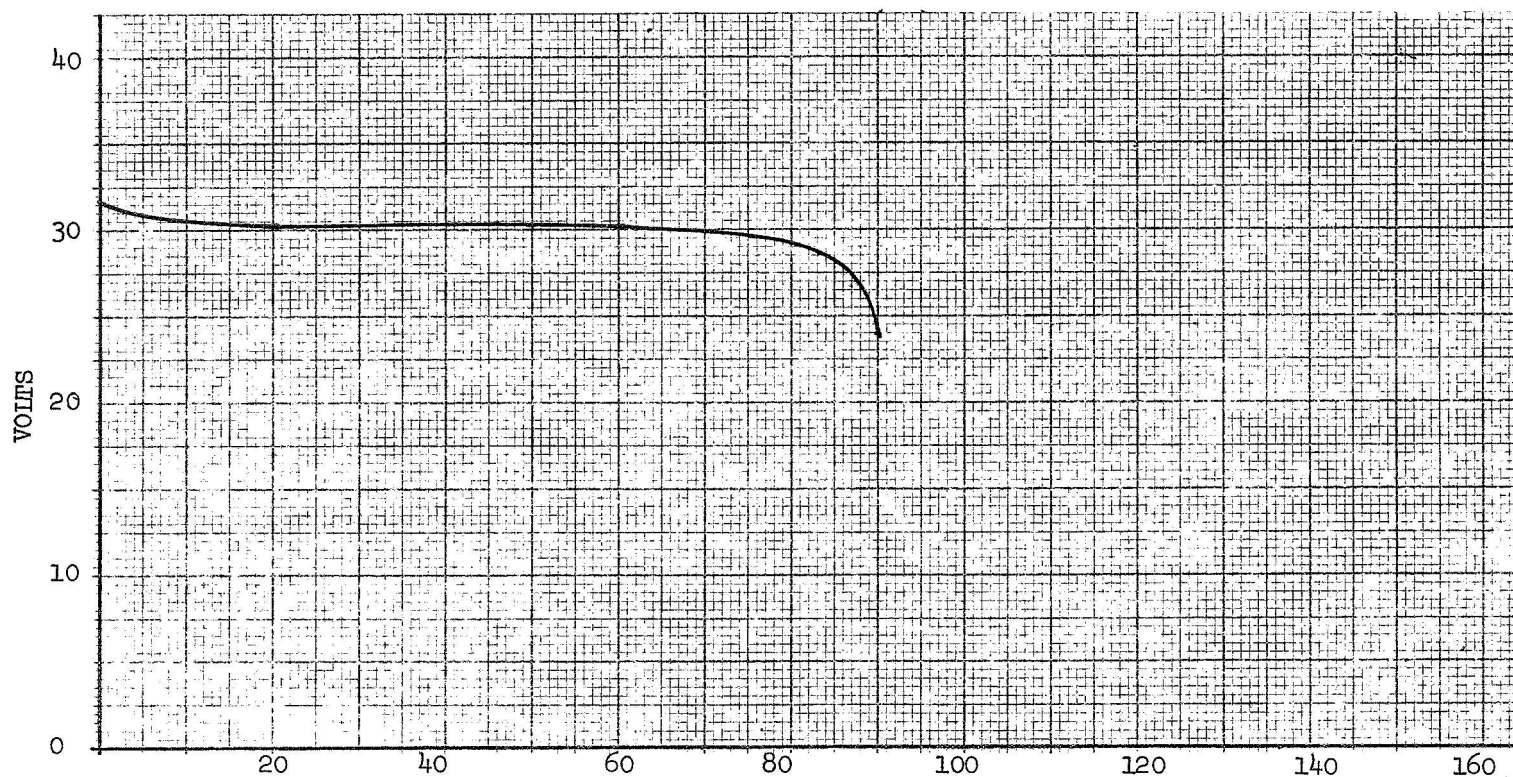
Discharge No. 2: 3.00 ah at 2.0 amps

Date of Discharge: 12-4-69

Time of Previous Charge: 11 Hr. 43 Min.

Battery Serial No: 483

Discharge Time to 24.00 Volts: 1 Hr. 30 Min.



DISCHARGE TIME IN MINUTES AT 2.0 AMPERES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 29

QE/C 70-807

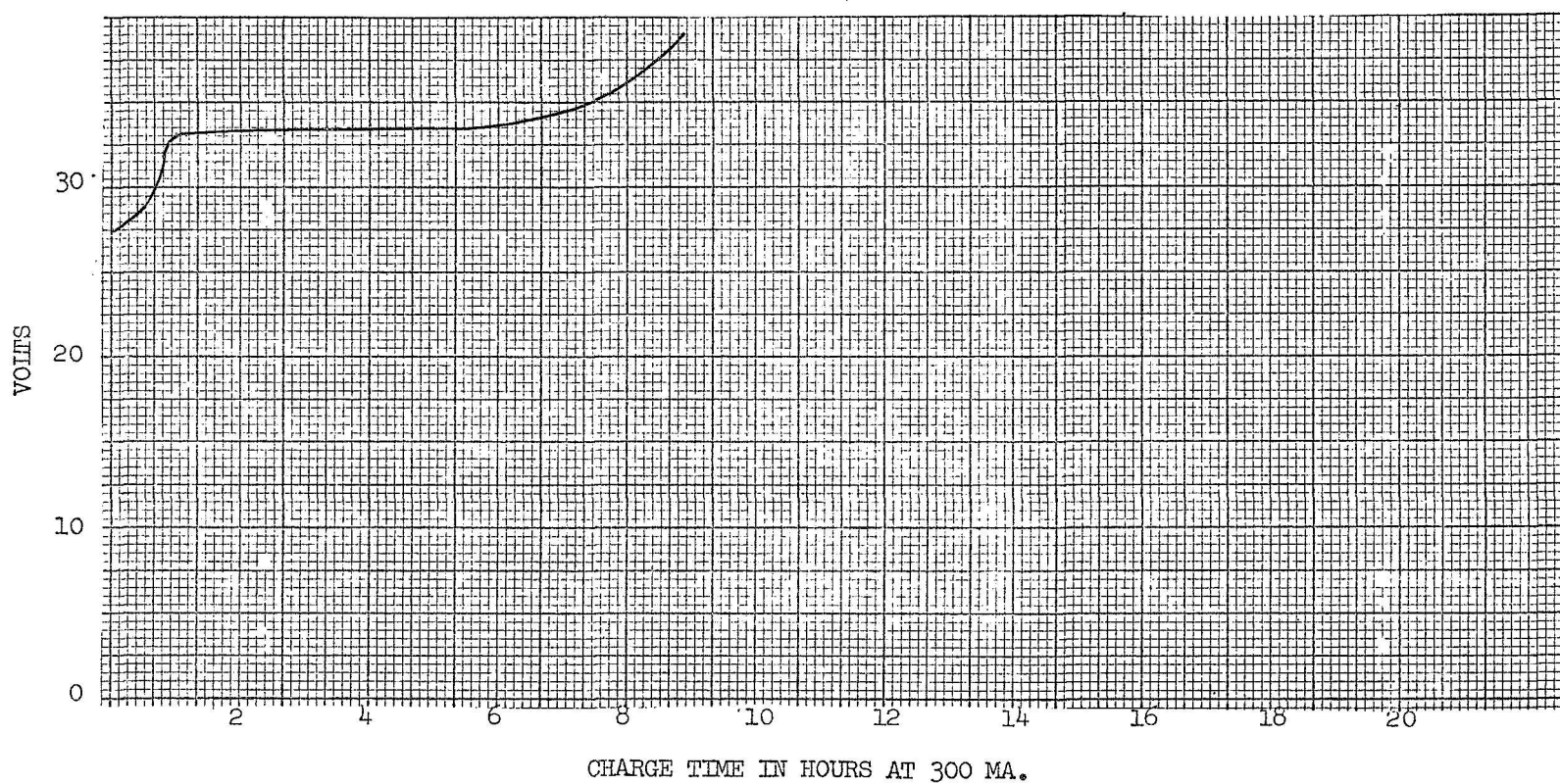
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Recharge No. 3: 2.67 ah at 300 milliamperes

Date of Recharge: 12-4-69

Charge Time to 39.00 Volts: 8 Hr: 51 Min.

Battery Serial No.: 483



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 30

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

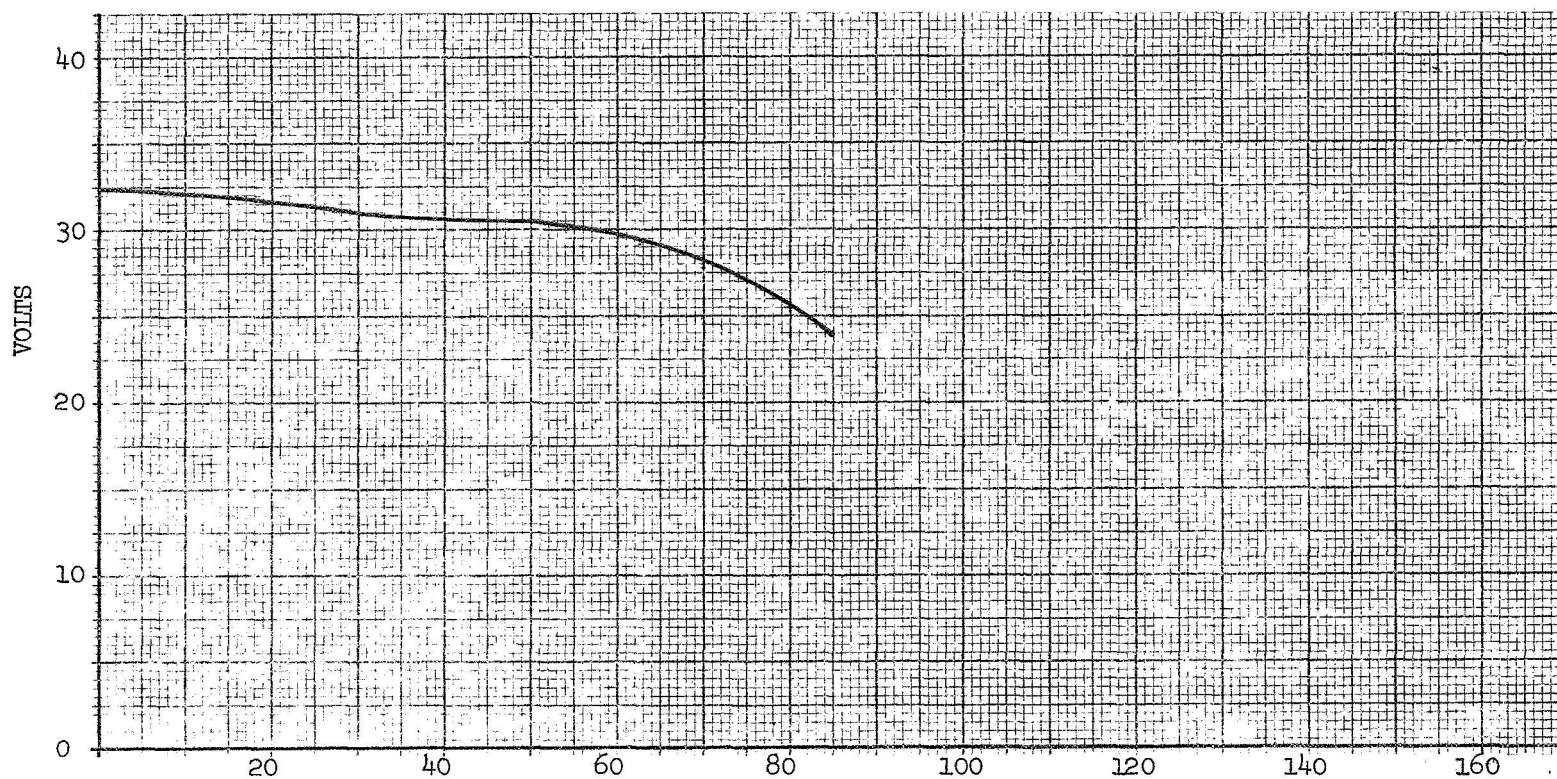
Discharge No. 3: 2.50 ah at 2.0 amps

Date of Discharge: 12-4-69

Time of Previous Charge: 8 Hr. 51 Min.

Battery Serial No: 483

Discharge Time to 24.00 Volts: 1 Hr. 15 Min.



DISCHARGE TIME IN MINUTES AT 2.0 AMPERES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 31

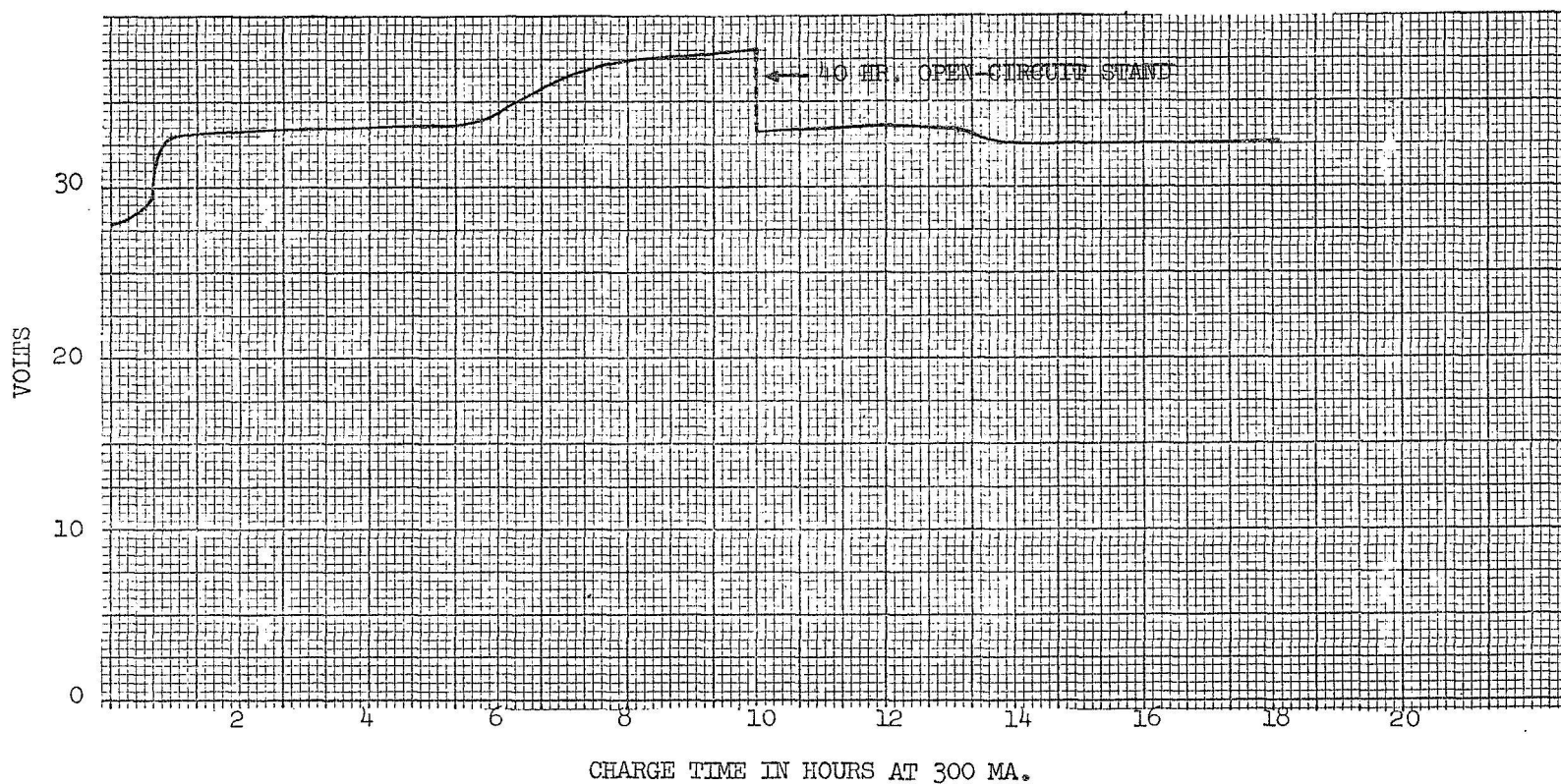
QE/C 70-807

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Recharge No. 4: Battery did not reach 39.00
volt at 300 ma. charge rate.

Date of Recharge: 12-4-69

Battery Serial No.: 483



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 32

QE/C 70-807

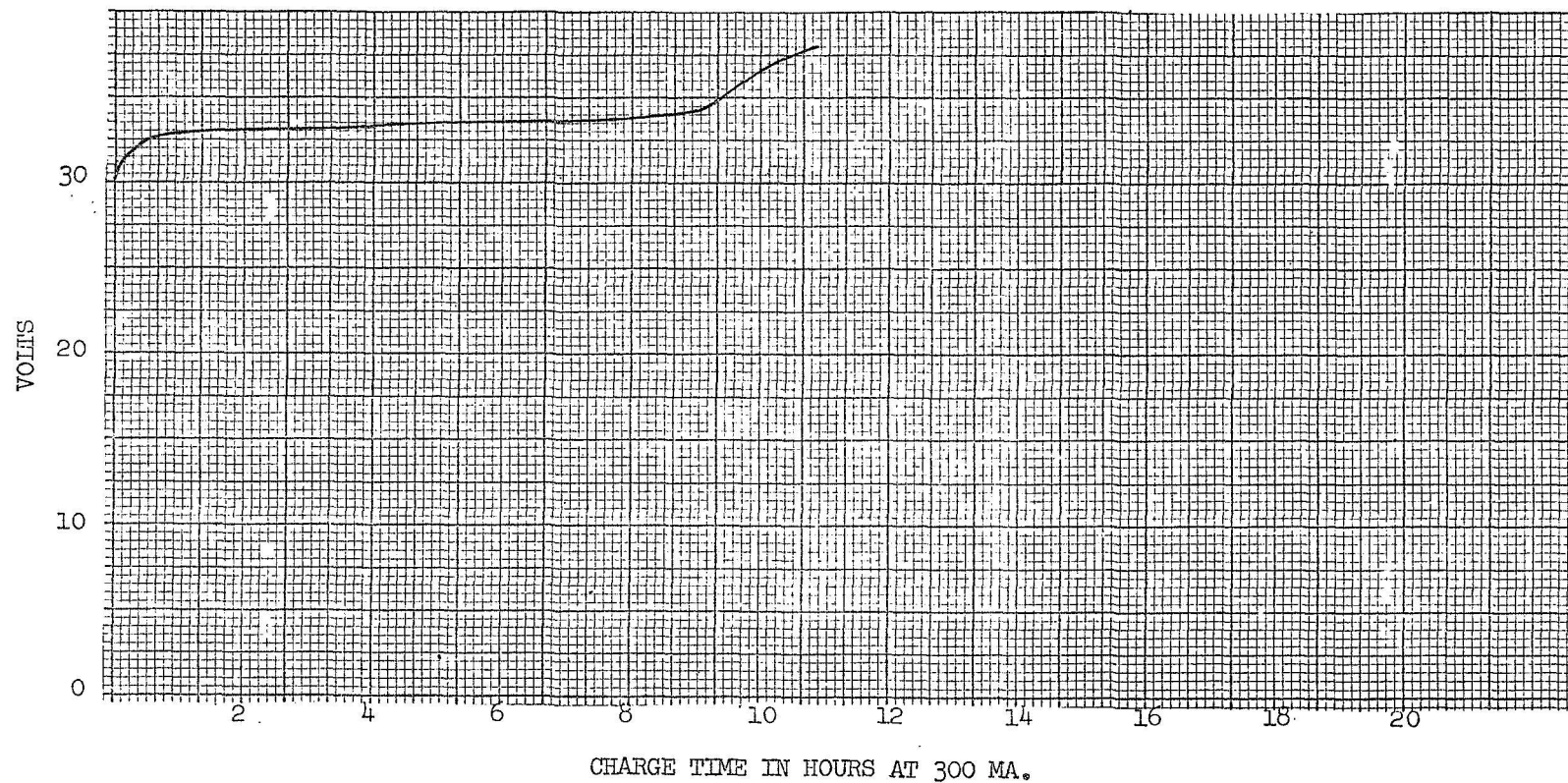
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Recharge No. 1: 3.30 ah at 300 milliamperes

Date of Recharge: 6-8-70

Charge Time to 38.00 Volts: 11 Hr. 0 Min.

Battery Serial No.: 692



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 33

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

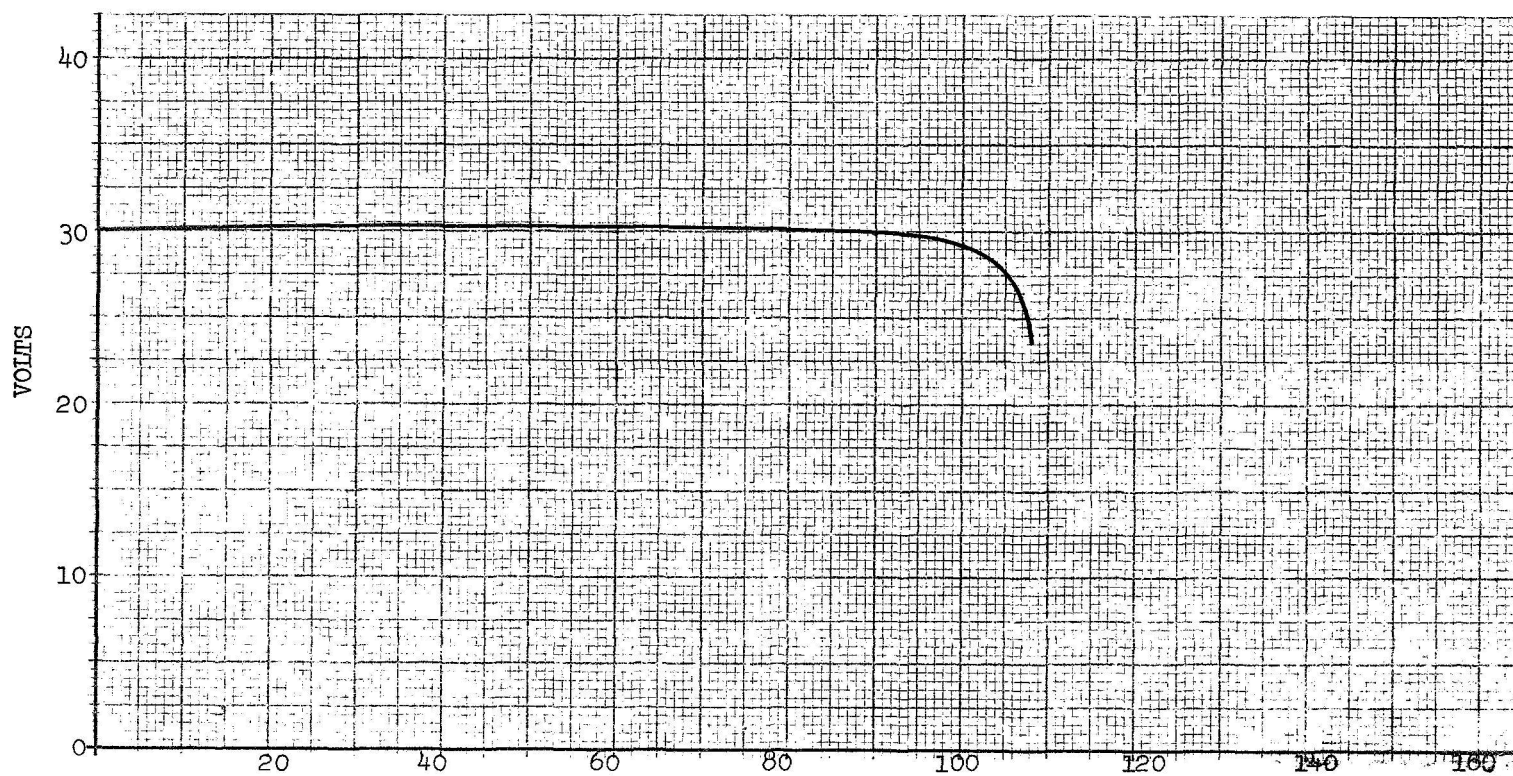
Discharge No. 1: 3.60 ah at 2.0 amps

Date of Discharge: 6-8-70

Time of Previous Charge: 11 Hr. 0 Min.

Battery Serial No: 692

Discharge Time to 24.00 Volts: 1 Hr. 48 Min.



DISCHARGE TIME IN MINUTES AT 2.0 AMPERES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 34

QE/C 70-807

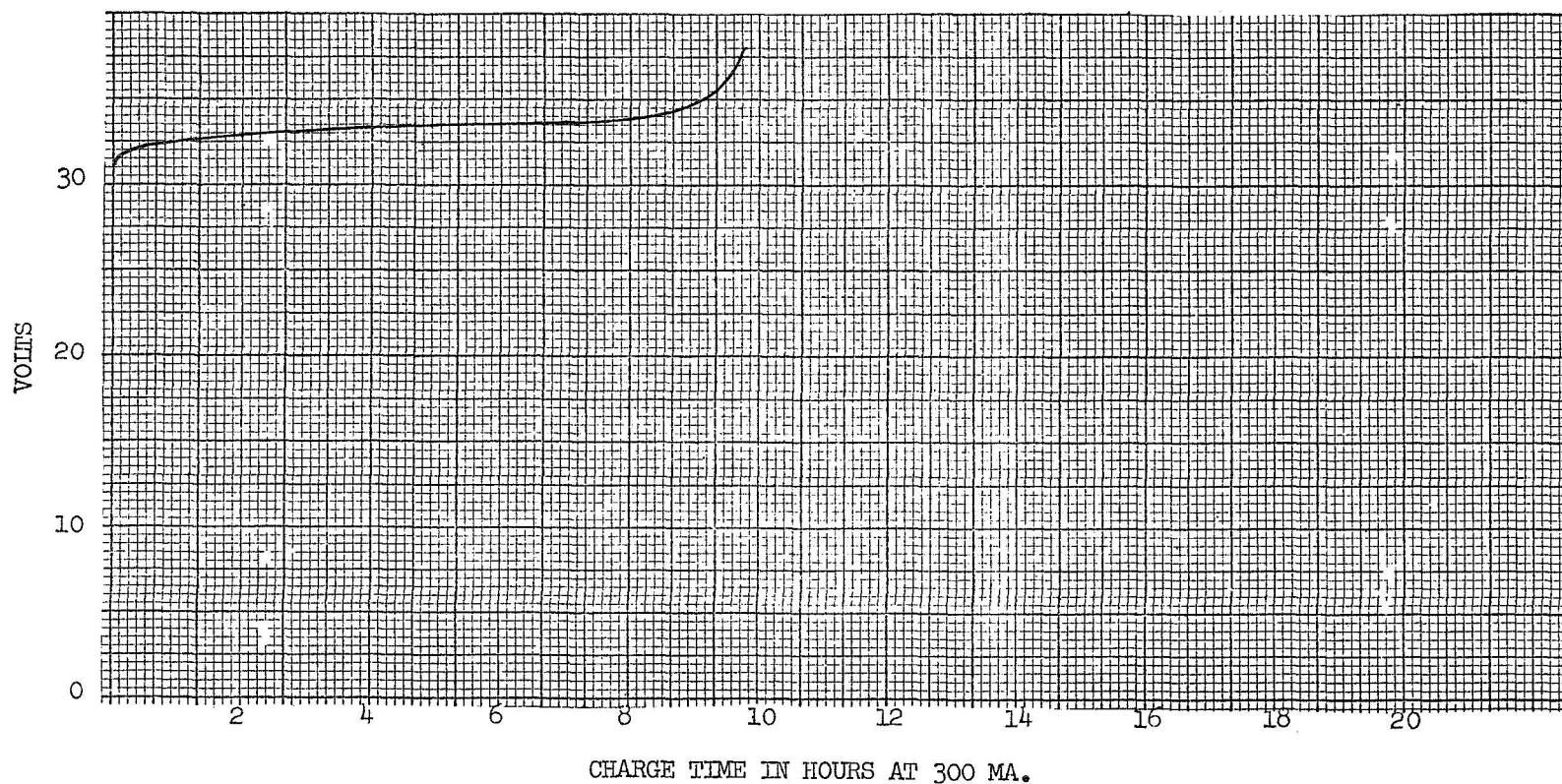
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Recharge No. 2: 2.94 ah at 300 milliamperes

Date of Recharge: 6-8-70

Charge Time to 38.00 Volts: 9 Hr. 48 Min.

Battery Serial No.: 692



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 35

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

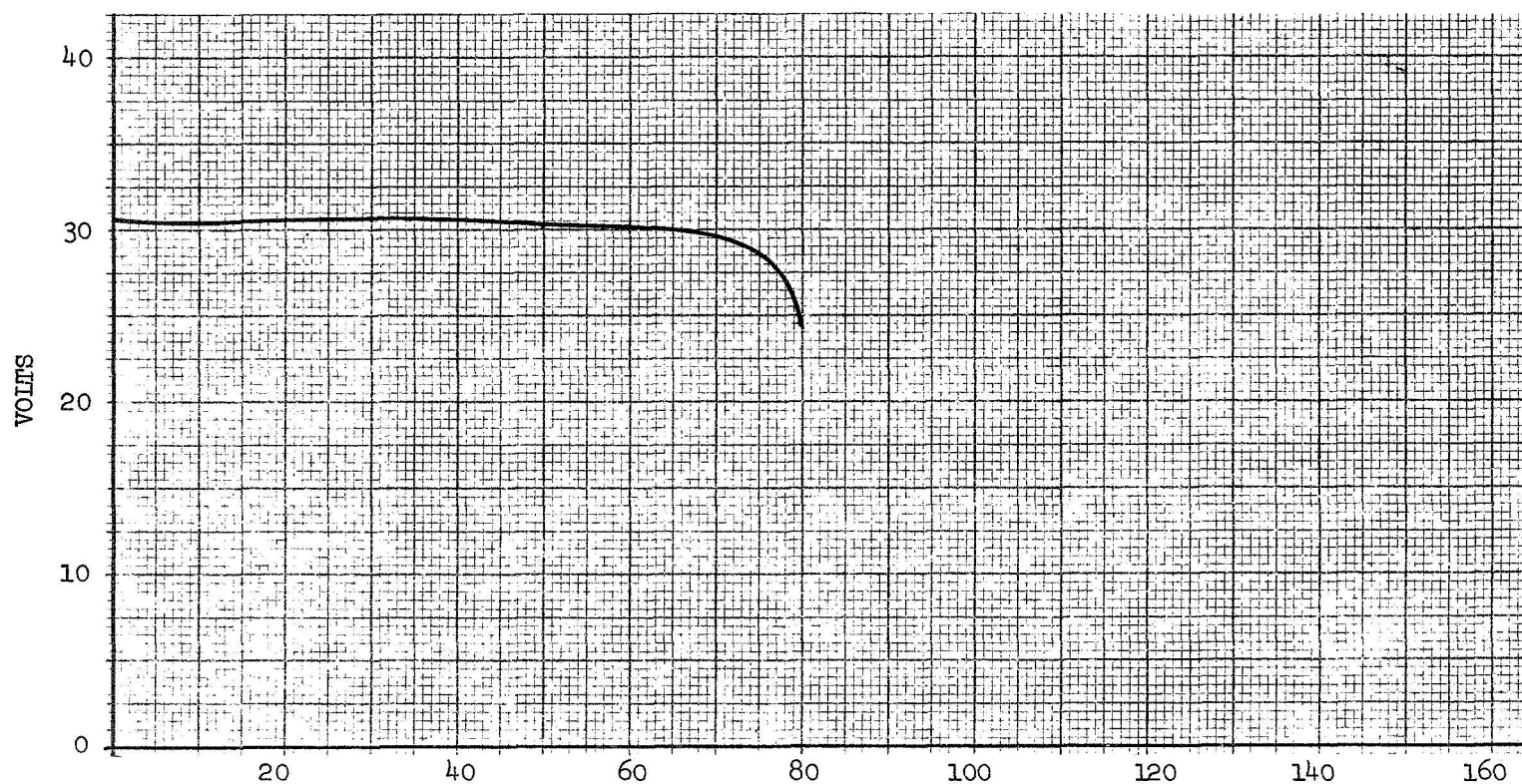
Discharge No. 2: 2.70 ah at 2.0 amps

Date of Discharge: 6-9-70

Time of Previous Charge: 9 Hr. 48 Min.

Battery Serial No: 692

Discharge Time to 24.00 Volts: 1 Hr. 21 Min.



DISCHARGE TIME IN MINUTES AT 2.0 AMPERES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 36

QE/C 70-807

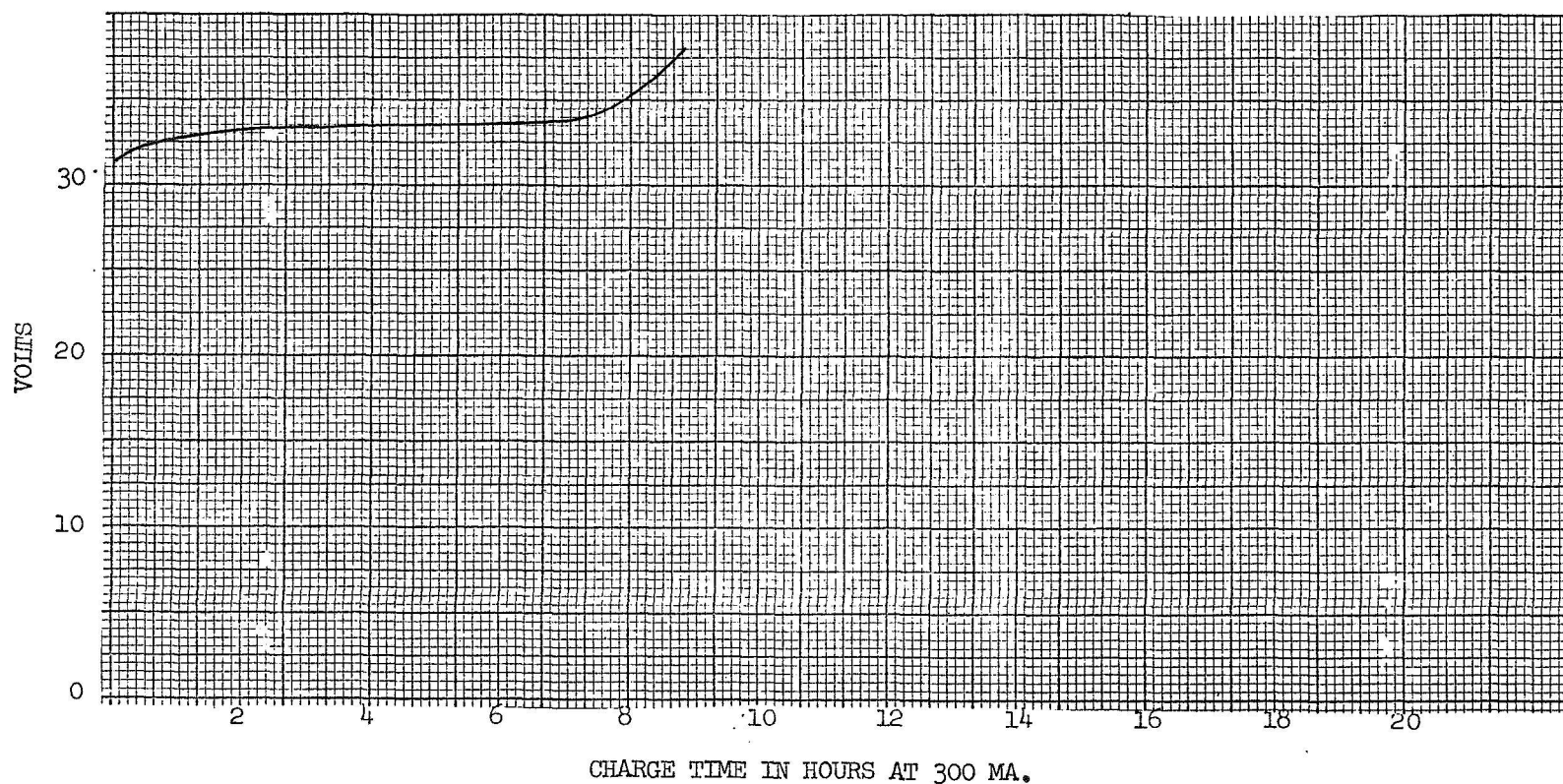
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Recharge No. 3: 2.66 ah at 300 milliamperes

Date of Recharge: 6-8-70

Charge Time to 38.00 Volts: 8 Hr. 52 Min.

Battery Serial No.: 692



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 37

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

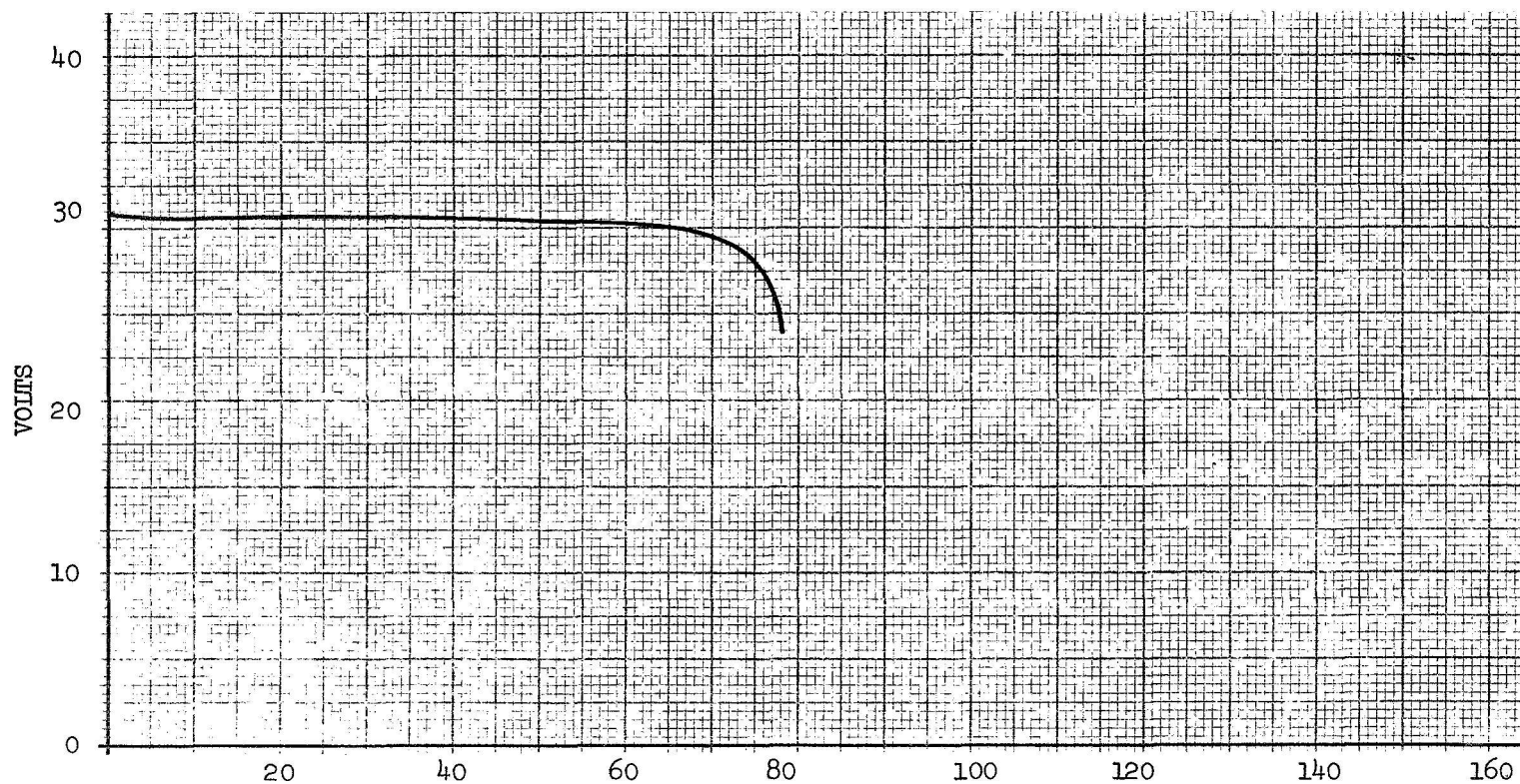
Discharge No. 3: 2.60 ah at 2.0 amps

Date of Discharge: 6-9-70

Time of Previous Charge: 8 Hr. 52 Min.

Battery Serial No: 692

Discharge Time to 24.00 Volts: 1 Hr. 18 Min.



DISCHARGE TIME IN MINUTES AT 2.0 AMPERES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 38

QE/C 70-807

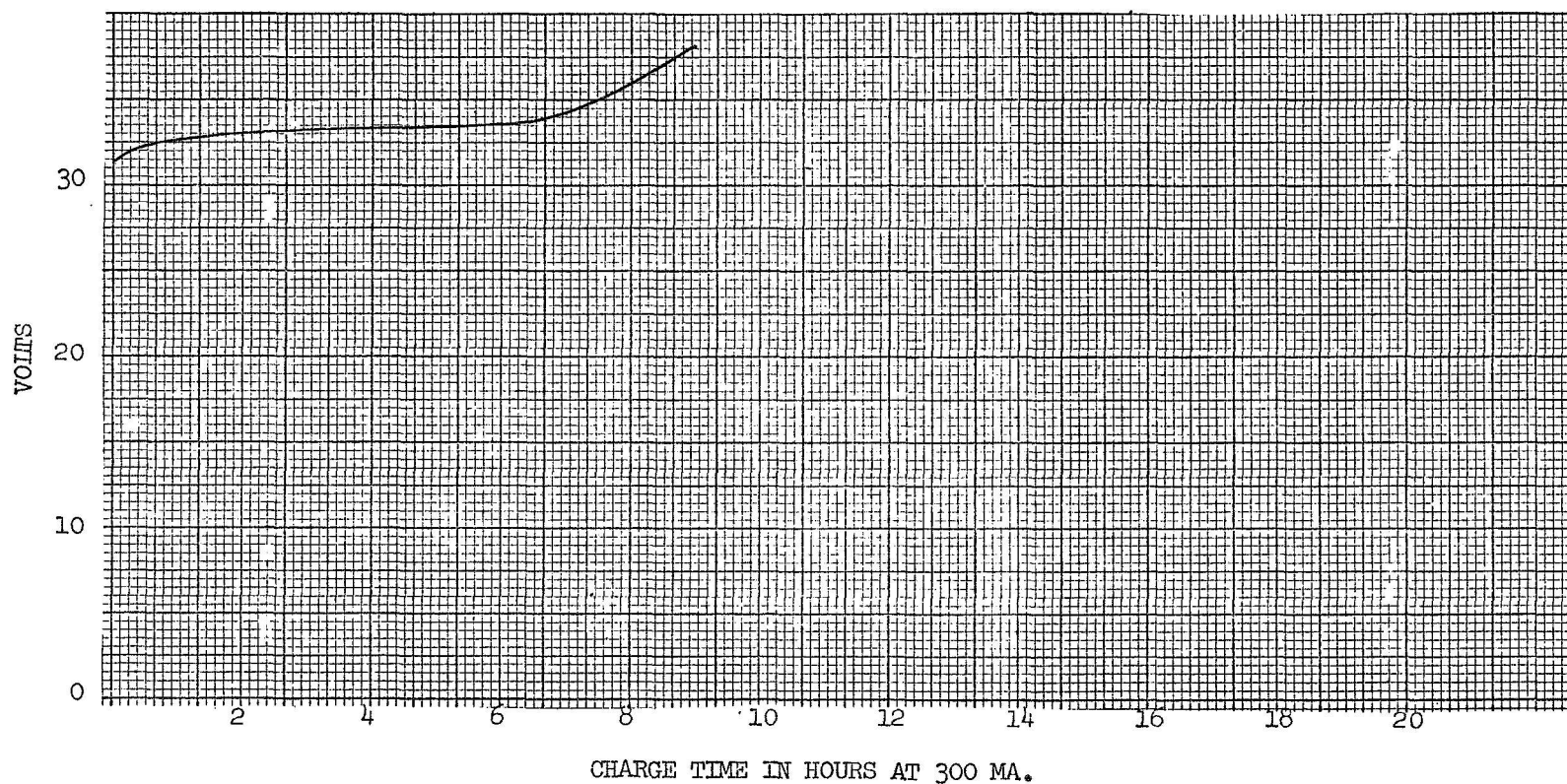
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Recharge No. 4: 2.70 ah at 300 milliamperes

Date of Recharge: 6-8-70

Charge Time to 38.00 Volts: 9 Hr. 0 Min.

Battery Serial No.: 692



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 39

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

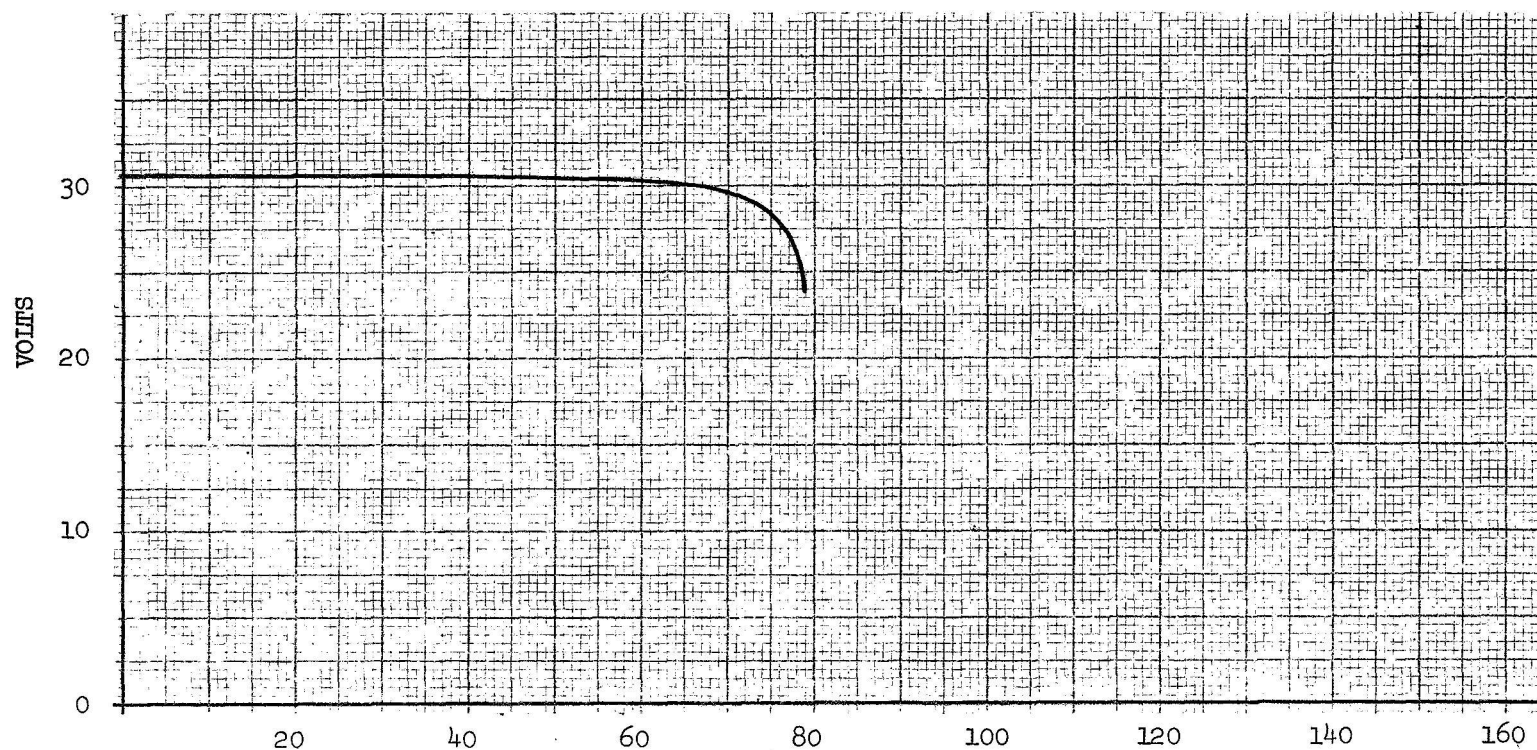
Discharge No. 4: 2.63 ah at 2.0 amps

Date of Discharge: 6-10-70

Time of Previous Charge: 9 Hr. 0 Min.

Battery Serial No: 692

Discharge Time to 24.00 Volts: 1 Hr. 19 Min.



DISCHARGE TIME IN MINUTES AT 2.0 AMPERES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 40

QE/C 70-807

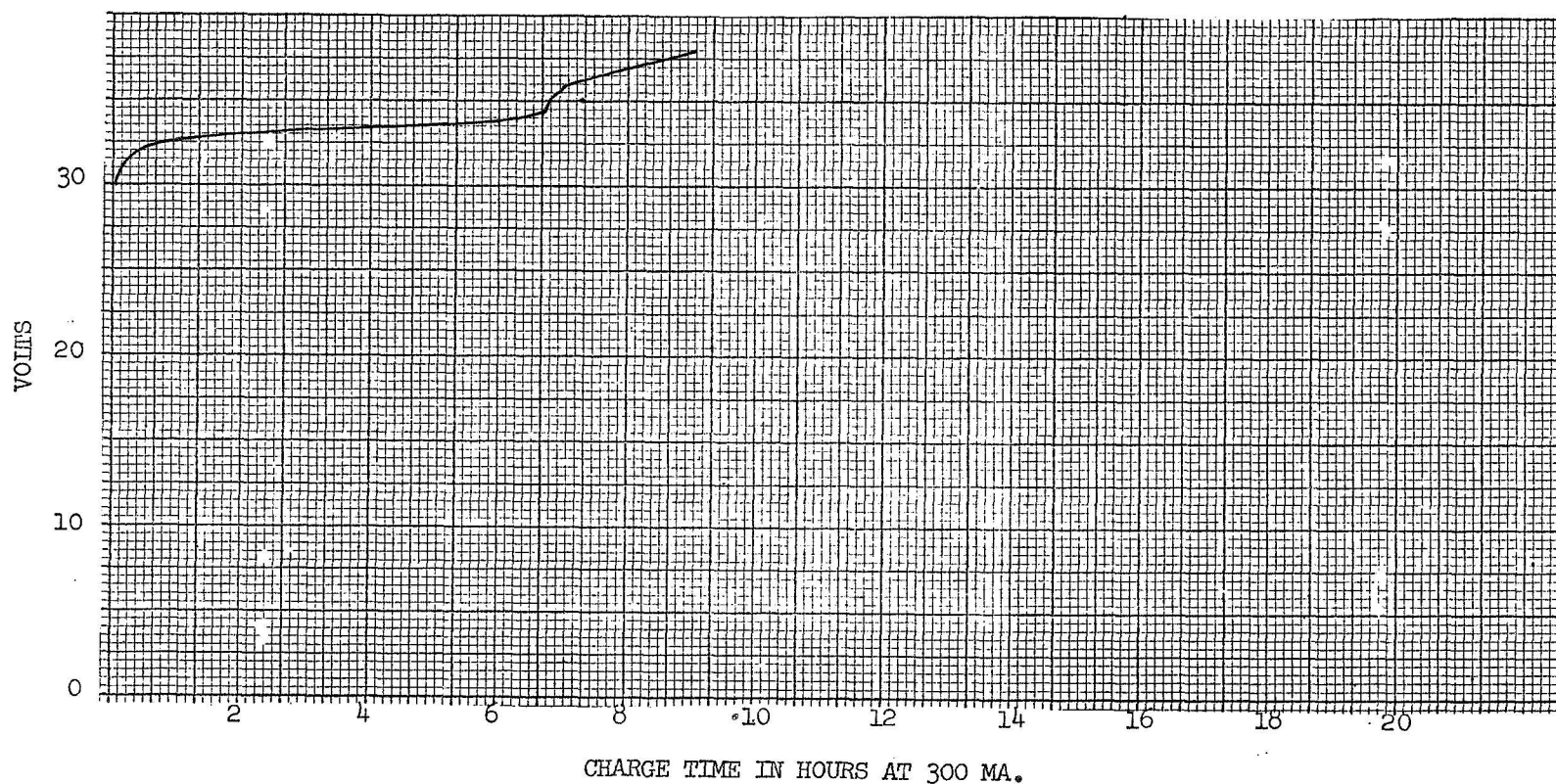
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Recharge No. 5: 2.76 ah at 300 milliamperes

Date of Recharge: 6-8-70

Charge Time to 38.00 Volts: 9 Hr. 11 Min.

Battery Serial No.: 692



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 41

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

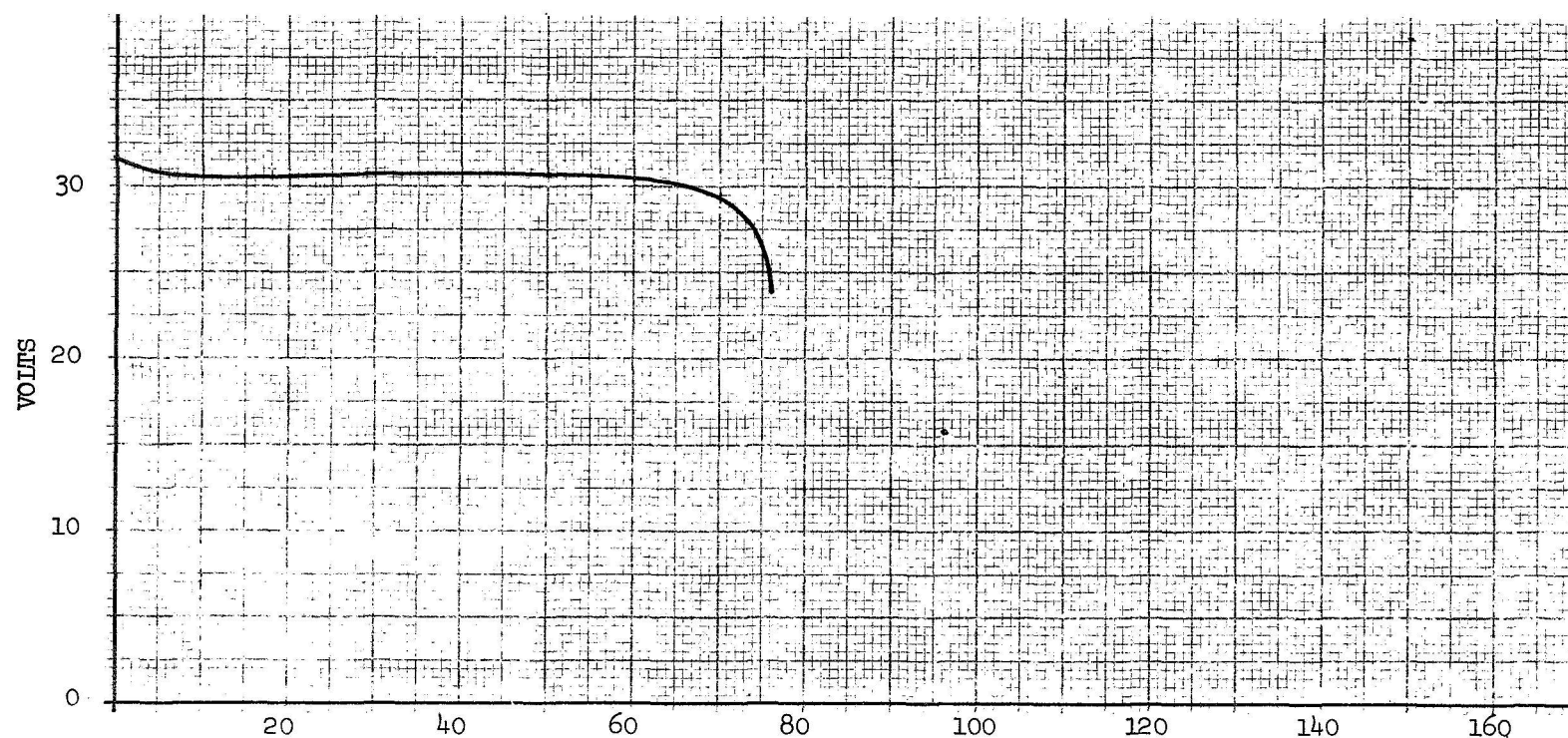
Discharge No. 5: 2.53 ah at 2.0 amps

Date of Discharge: 6-10-70

Time of Previous Charge: 9 Hr. 11 Min.

Battery Serial No: 692

Discharge Time to 24.00 Volts: 1 Hr. 16 Min.



DISCHARGE TIME IN MINUTES AT 2.0 AMPERES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 42

QE/C 70-807

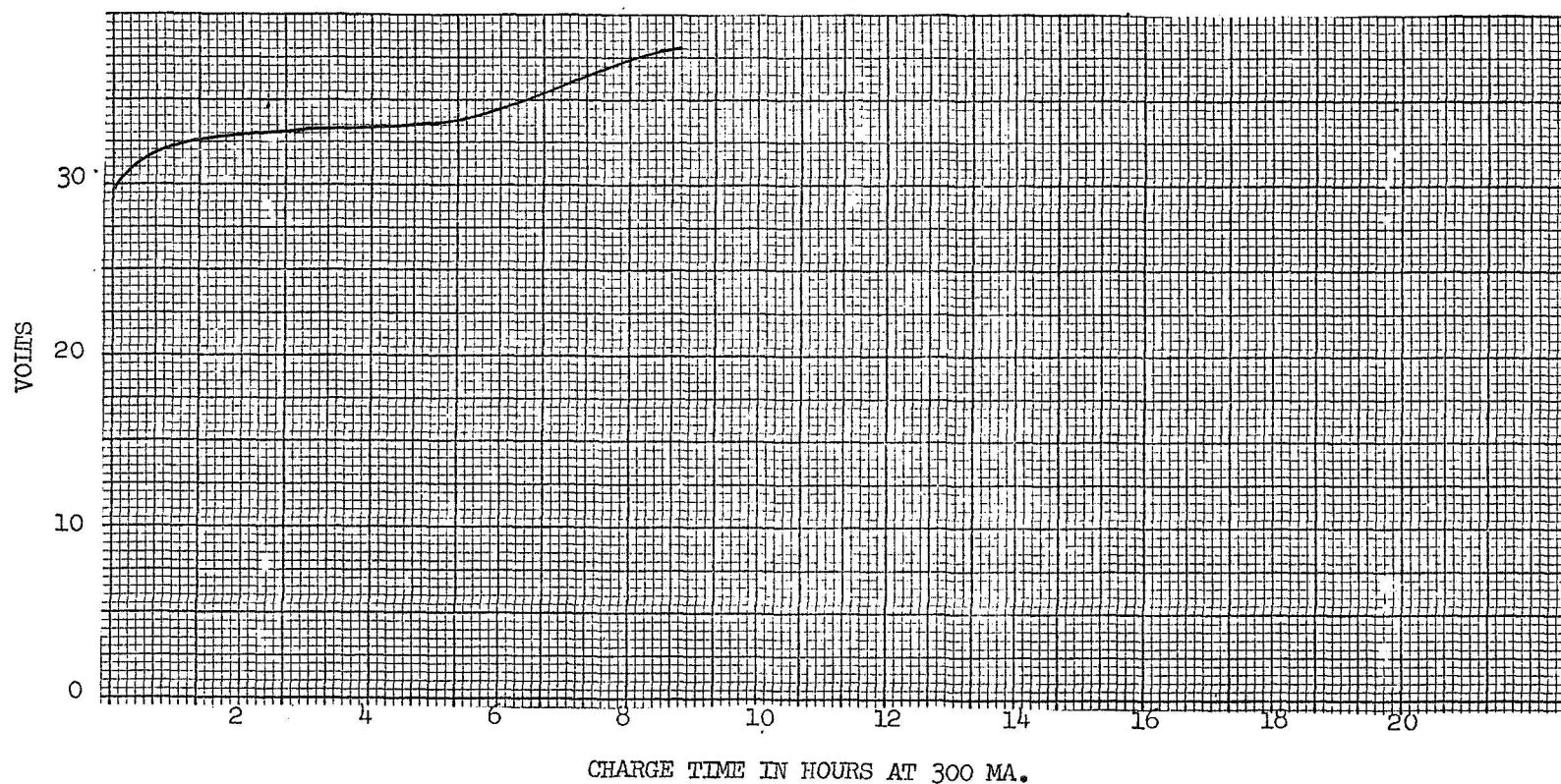
JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Recharge No. 6: 2.64 ah at 300 milliamperes

Date of Recharge: 6-8-70

Charge Time to 38.00 Volts: 8 Hr. 48 Min.

Battery Serial No.: 692



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 43

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

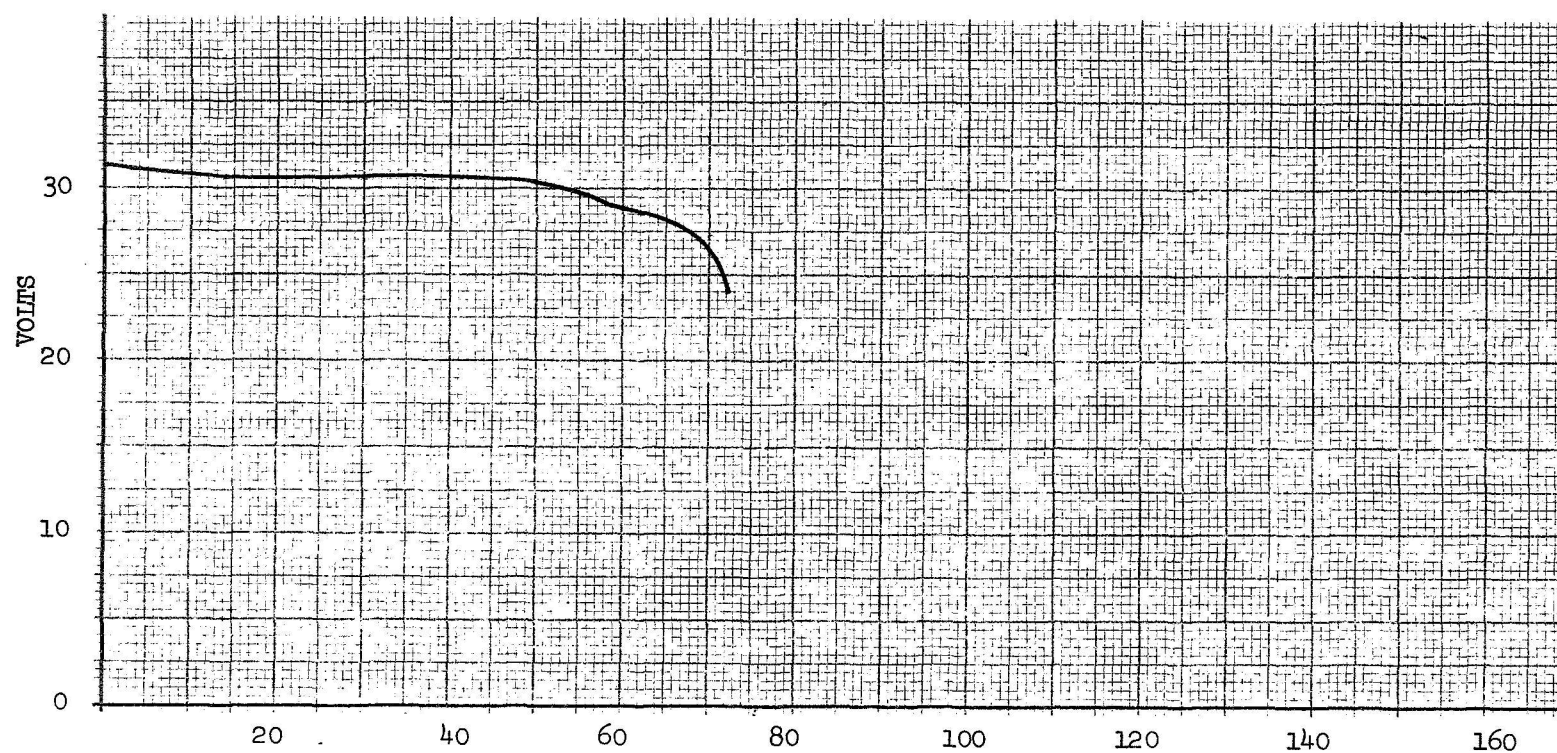
Discharge No. 6: 2.40 ah at 2.0 amps

Date of Discharge: 6-11-70

Time of Previous Charge: 8 Hr. 48 Min.

Battery Serial No: 692

Discharge Time to 24.00 Volts: 1 Hr. 12 Min.



DISCHARGE TIME IN MINUTES AT 2.0 AMPERES
DISCHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 44

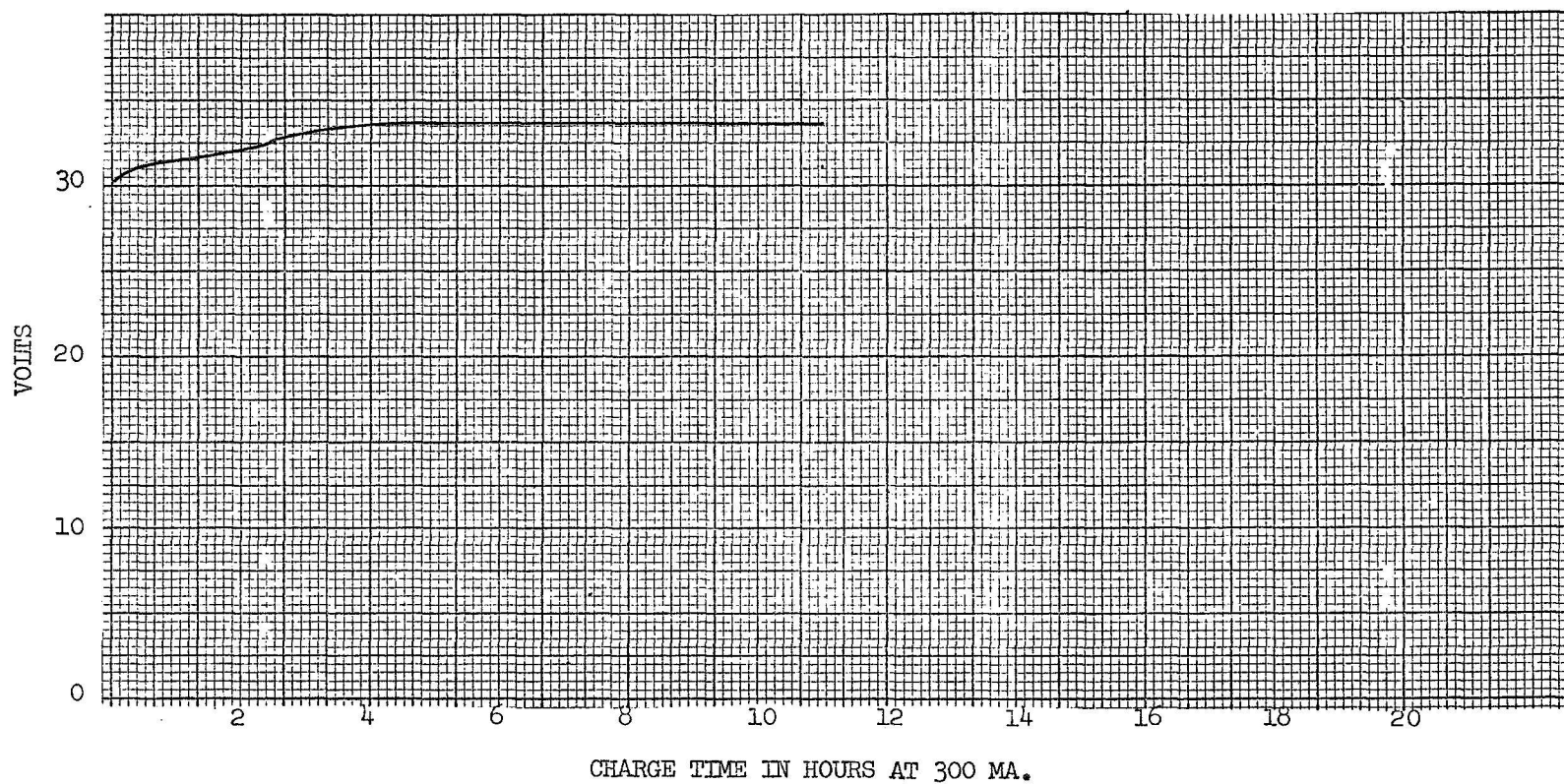
QE/C 70-807

JPL PRIMARY BATTERY TEMPERATURE STORAGE TEST

Recharge No. 7: Battery did not reach 38.00
volt at 300 ma. charge rate.

Date of Recharge: 6-8-70

Battery Serial No.: 692



RECHARGE CURVE OF EAGLE-PICHER GAP-4184 PRIMARY BATTERY

FIGURE 45

V. DISCUSSION OF RESULTS

A. Capacities versus Wet-Stand Periods (No Scheduled Storage Conditions):

1. The capacities of the five batteries following the respective wet-stand periods up to 96 hours after activation show no definite relationship between wet-stand time and discharge time. The variation in capacities appears to be due more to the range of "built-in" capacities than to length of wet-stand time; thereby nullifying any attempt to determine a direct relationship between capacity and the wet-stand periods evaluated. The fact that the batteries are capable of being cycled indicates they have an activated stand capability of several days.

a. The capacities of the batteries after wet-stand periods of 24 and 96 hours respectively were equal at 1 hour and 37 minutes (4.50 ampere-hours).

b. The capacities of the three batteries after wet stands of 5 minutes, 5 hours and 48 hours were almost equal--being 1 hour 53 minutes, 1 hour 50 minutes and 1 hour 51 minutes, equivalent to 5.03, 4.93 and 4.97 ampere-hours respectively.

B. Capacities versus Storage Temperature and Time Conditions:

1. With the exception of one battery in storage at 150° F for 1 year, the capacities of the batteries stored unactivated at 68° F to 1 year, at 105° F to 1.5 years, and at 150° F to 4 months were within or above the range of capacities established by the five batteries (without scheduled storage conditions) following wet-stand periods up to 96 hours after activation. (See Figure 46.)

a. Batteries, serial numbers 621 and 619, stored at 105° F for 3 and 6 months respectively, had residual capacities exceeding the capacities of the five batteries not subjected to scheduled storage conditions.

2. From Figure 46 it is seen that a slight trend is developing that shows a decrease of capacity with time at each of the three designated storage temperatures; however, the capacities did not decrease directly with increase of storage temperature as might be expected.

a. The residual capacity of battery, serial number 619, stored at 105° F for 6 months was 5.3 ampere-hours, about 11 percent greater than that of battery, serial number 477, stored at 68° F for 6 months.

b. The residual capacity of battery, serial number 692, stored at 105° F for 18 months was 4.60 ampere-hours, equal to that of battery, serial number 626, stored at 68° F for 12 months.

c. It appears that the variation seen in battery capacity is due more to the inherent "built-in" capacities than the effects of the storage period and temperature.

C. Sterilization of Battery, Serial Number 690:

1. Subjection of this battery to the temperature of 257° F for 24 hours was greater than the battery could withstand. The battery failed to activate due apparently to degradation, by heat, of the match mix surrounding the bridgewire of the match in each gas generator.

a. Following failure to activate in December 1969, the battery was returned to the manufacturer for replacement of the two gas generators. Upon its return to NAD Crane in June 1969, the battery again failed to activate.

(1) Preliminary electrical tests indicated no discrepancies.

2. Postmortem:

a. No visual damage was noted before removal of the case.

b. The plastic monobloc was warped and deformed due to the temperature cycle as evidence by Figures 48 and 49.

c. The diaphragm at the monobloc end of the activation system had not ruptured, as evidenced by Figure 50.

d. The diaphragm at the gas generator end of the activation system was ruptured as shown in Figure 51. Since the replacement gas generators did not activate the battery and since their wire leads were wet with electrolyte, indications are that this diaphragm was ruptured by the effect of one or both of the original gas generators degraded by the 24-hour storage period at 257° F. Electrolyte may have deteriorated the replacement generators.

D. Cycling Results:

1. Three batteries, serial numbers 692, 626 and 483, have been recycled following the profile discharge. Each battery was

charged 300 milliamperes and discharged at 2 amperes. The batteries were discharged to 24 volts; numbers 626 and 483 recharged to 39.0 volts and number 692 was recharged to 38.00 volts. During the fourth recharge, numbers 626 and 483 failed to reach the upper charge limit of 39.00 volts; number 692 did not recharge on cycle number 7.

a. Battery 692 completed three discharges with a charge efficiency from 93 to 85 percent, but after the battery was subjected to a 40-hour open-circuit rest the pack voltage began to decrease with an increase of charge time.

b. Battery 626 completed three discharges with a charge efficiency from 99 to 87 percent; during the third discharge the voltage fell from 30 volts at 70 minutes to 27 volts at 85 minutes. On the fourth recharge the voltage was approximately 4 volts low at 2 hours. The voltage drops could be the result of separator breakdown on two or three cells in the pack.

c. Battery 483 completed six discharges with a charge efficiency from 109 to 90 percent. During the sixth discharge the pack voltage dropped 2 volts in 5 minutes but continued to discharge for 12 minutes; the recharge was also 2 volts low. The loss of voltage indicates the loss of two cells during discharge; possibly by separator breakdown.

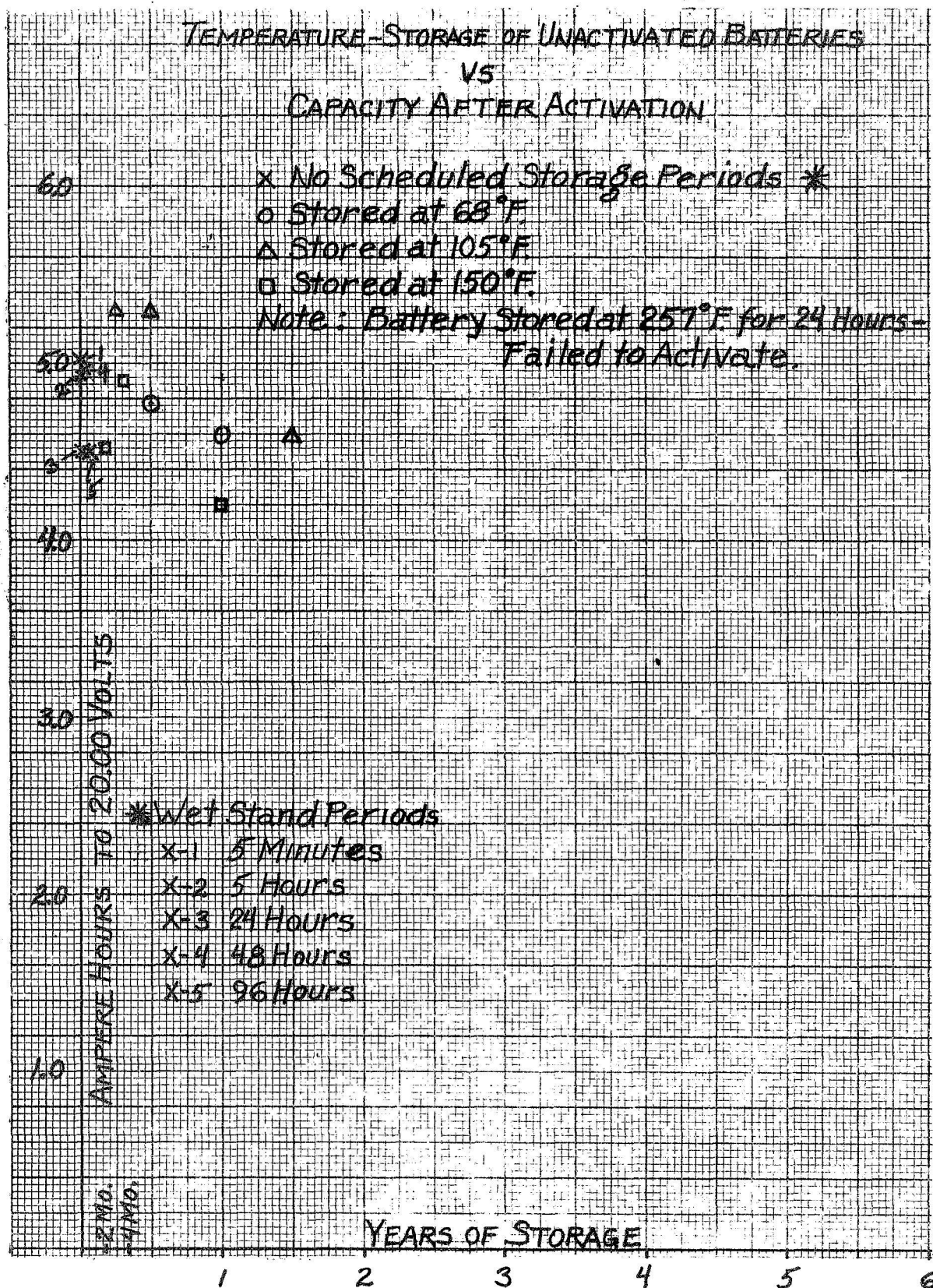
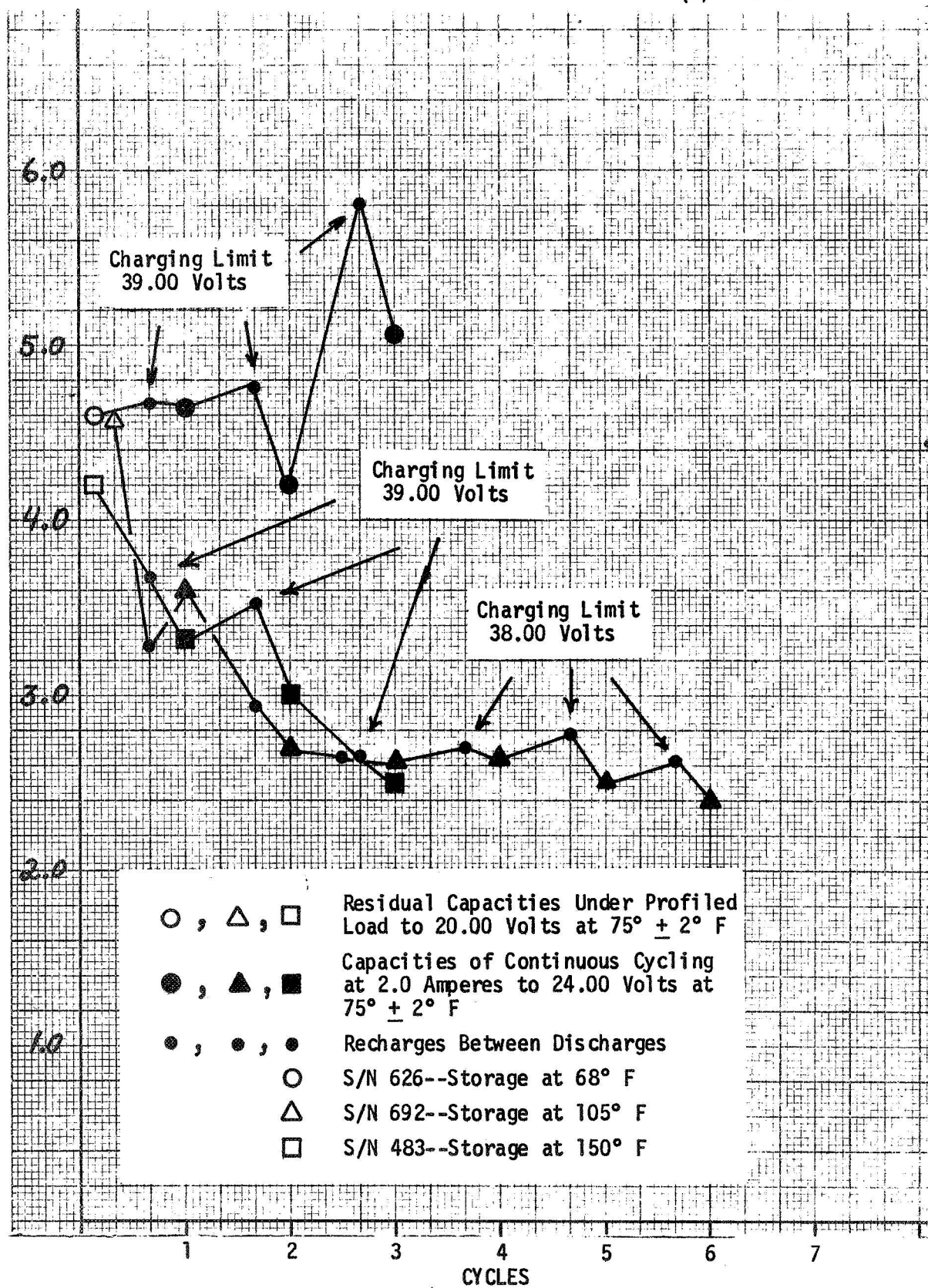


FIGURE 46



RESIDUAL AND CYCLING CAPACITIES AFTER ACTIVATION

FIGURE 47

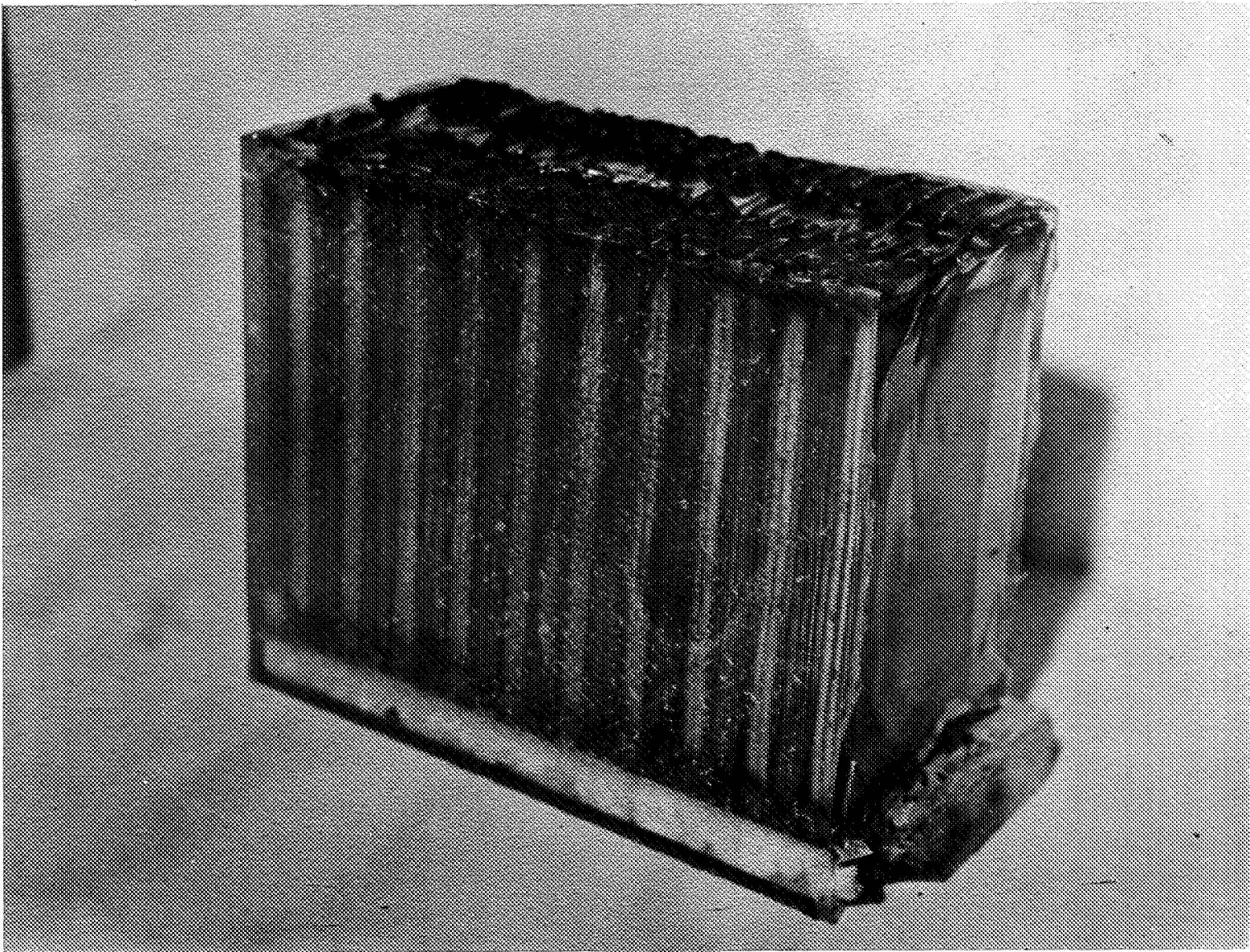


FIGURE 48

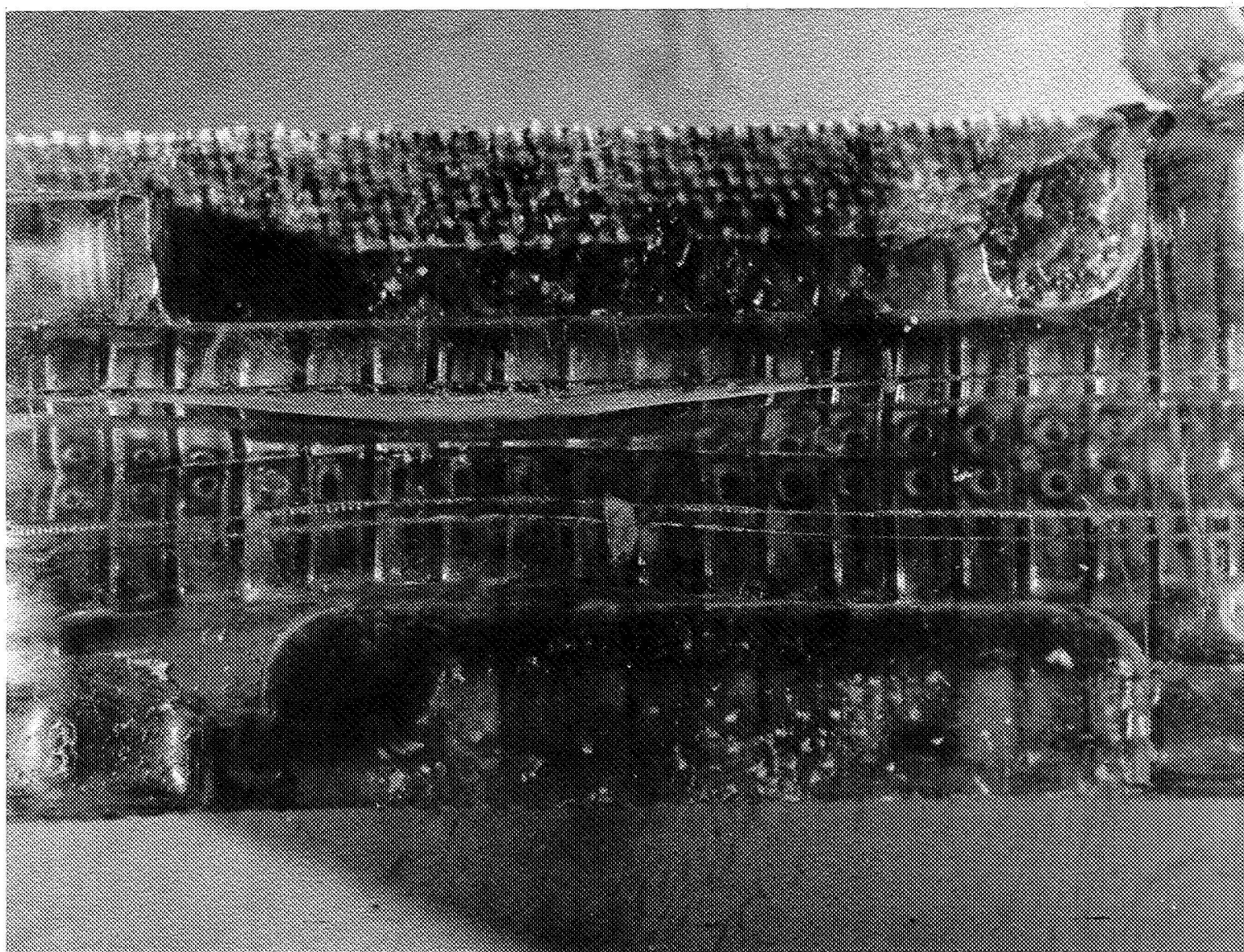


FIGURE 49

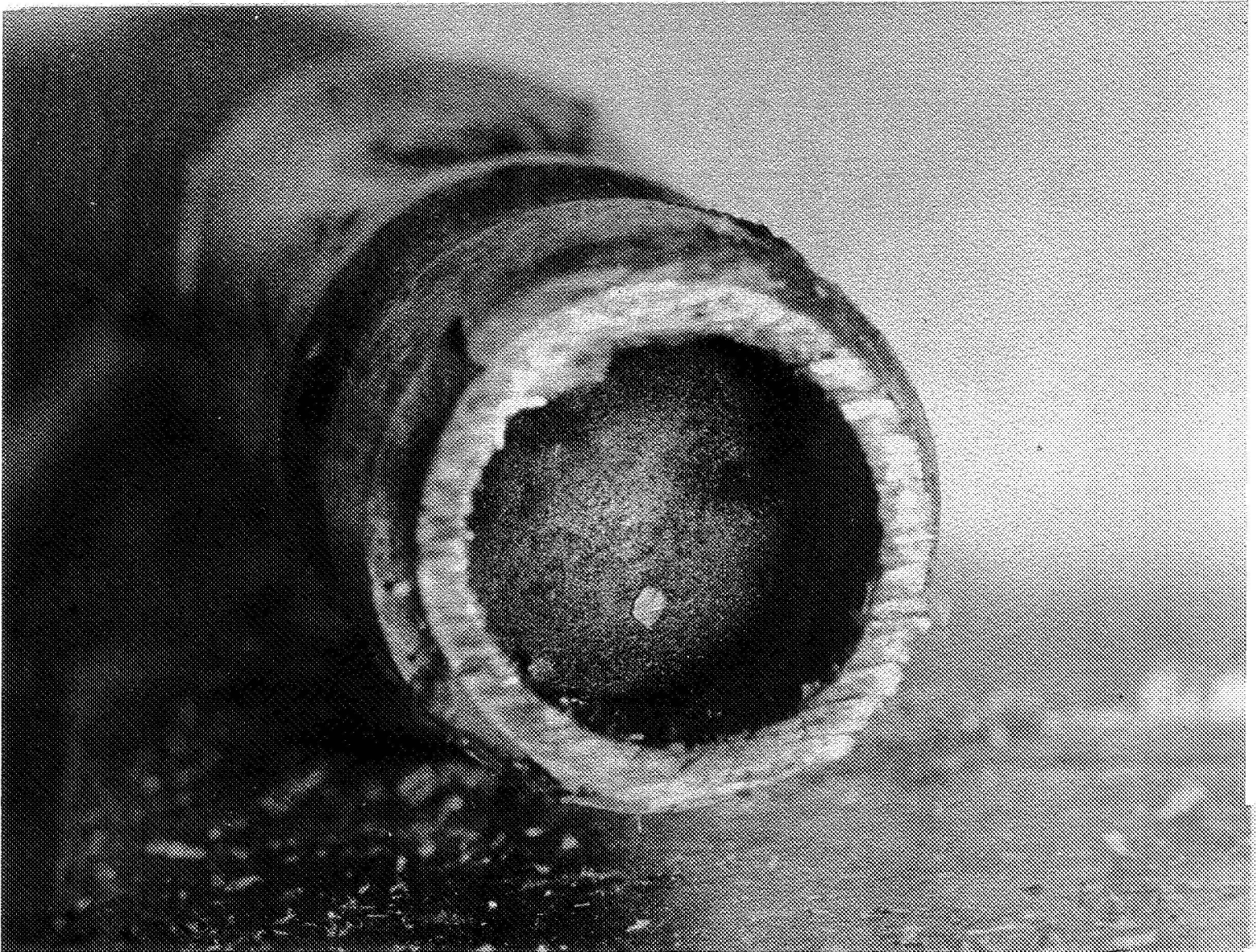


FIGURE 50.

QE/C 70-807

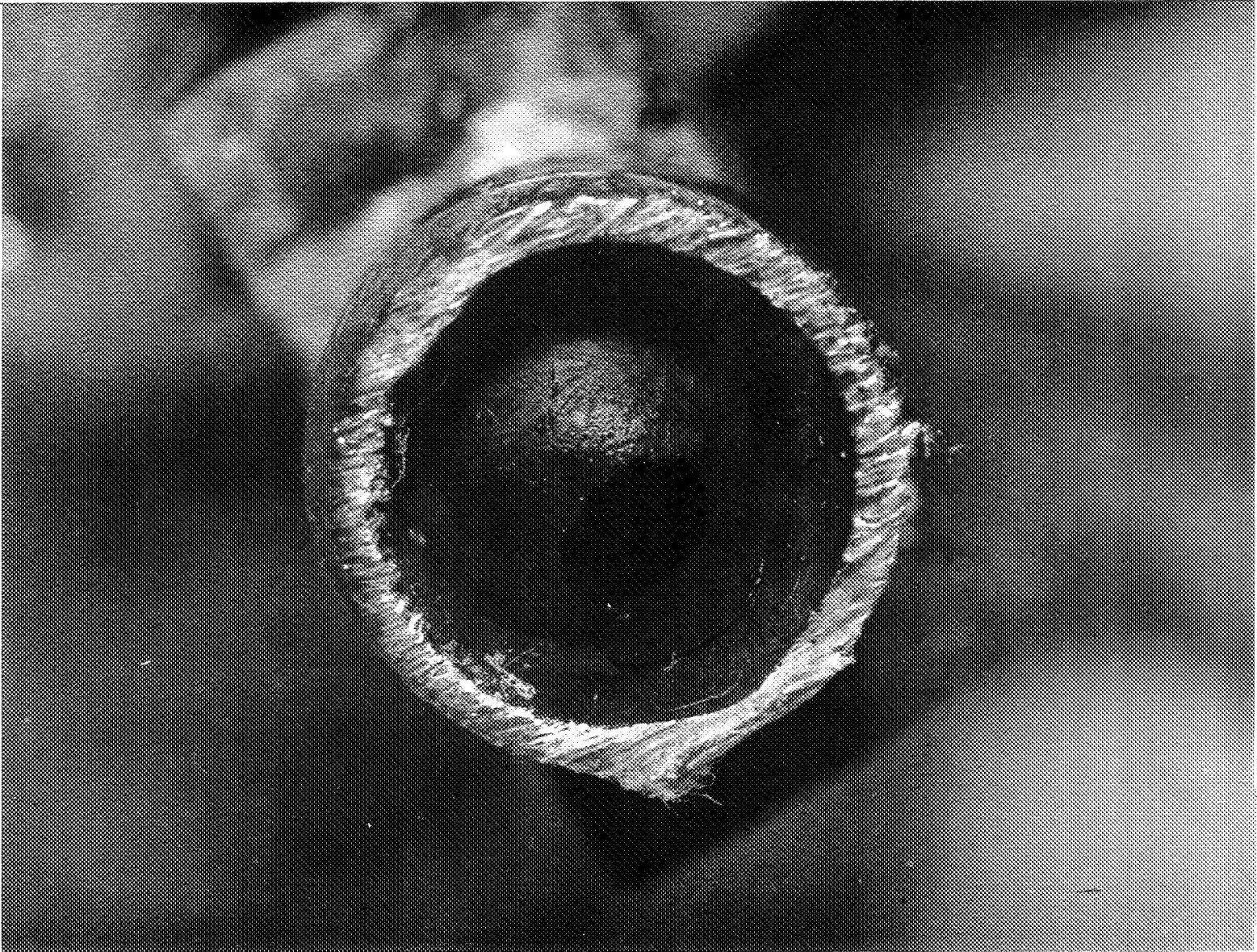


FIGURE 51

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