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NICAD

NICAD DIVISION GOULD-NATIONAL BATTERIES, INC.

Vented Nickel-Cadmium E-41 Alarm Battery (Development Models)

Supplementary Report
August 1, 1960 to March 31, 1961
Signal Corps Contract No. DA 36-039 SC-85273
DA Project No. 3G18-03-001
Signal Corps Technical Requirement
SCL-6837, 5 October 1959
U.S. Army Signal Research and
Development Laboratory
Fort Monmouth, New Jersey
Gould-National Batteries, Inc.
NICAD Division
Easthampton, Mass.

Supplementary Report

Vented Nickel-Cadmium E-41 Alarm Battery (Development Models)

Signal Corps Contract No. DA 36-039-SC-85273

Signal Corps Technical Requirement SCL-6837

DA Project No. 3618-03-001

August 1, 1960 to March 31, 1961

The life cycle testing of vented nickel-cadmium batteries for the E-41 Alarm

Prepared by _____
Stanley Januszkiewicz, Project Engineer

NICAD DIVISION
GOULD-NATIONAL BATTERIES, INC.
EASTHAMPTON, MASS.

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1. PURPOSE

The purpose of the test was to determine whether the vented nickel-cadmium battery for the E-41 Alarm would withstand two hundred (200) cycles as specified in Amendment No. 1, SCL-6837.

2. ABSTRACT

a. A cycling unit was designed and built to perform the life cycle tests on the E-41 alarm battery. Considerable electrical trouble was experienced with the motor generator charging source.

b. The initial battery capacities were lower than expected from our previous acceptance test data. This was traced to insufficient overcharge of the positive plate.

c. In view of the fact that the attainment of complete charge of the positive plates after the capacity cycle could not be readily accomplished by extending the constant potential charge to four (4) hours, this charge was changed to constant current.

d. The batteries successfully passed the two hundred (200) charge - discharge cycles.

3. CONFERENCES

(1) At Gould-National Batteries, Inc., Easthampton, Mass., Mr. S. Januszkiewicz of Gould-National Batteries, Inc., Messrs. T. Strozyk and M. Pookop of Chemical Warfare, and Mrs. S. Duze of U. S. Army Research and Development Laboratories - February 16, 1961.

Concurrent cycling tests by the Chemical Corps that had exceeded two hundred (200) cycles were discussed. These were carried out manually with each discharge proceeding to 20.00 volts. It had been found necessary to introduce occasional constant potential charges of four (4) hours in order to recover small capacity losses on cycling.

4. FACTUAL DATA

a. Introduction

The original contract proposal (SCL-6837; 5 October 1959) stipulated that the battery undergo 200 cycles of charge and discharge at 80°F. This battery for the E-41 alarm consists of 20 NICAD - CCK5XMN cells, having a nominal 6 A.H. of capacity. The schedule called for one (1) cycle to be performed every twenty-four (24) hours according to the following sequences:

"a. Charge at the five (5) hour rate for 7 hours.

b. Battery on open circuit shall stand for 2½ hours.

c. Discharge at 0.500 ampere for 12 hours.

d. Battery on open circuit stand for 2½ hours.

e. On every 14th cycle, the battery shall be discharged at 0.500 ampere to 20 volts, and on the succeeding cycle recharged at the five (5) hour rate to 140% of the capacity removed.

f. The total elapsed time for steps (a) to (d) shall be 24 hours. For step (e) the open circuit time may be adjusted so that each cycle lasts 24 hours."

This schedule was modified as follows by SCL-6837 - Amendment No. 1, 29 January 1960

"a. Charge at a constant potential of 31.0 ± 1% volts (1.55 volts per cell) for two (2) hours.

b. Battery on open circuit stand for five (5) hours.

c. Discharge at 0.500 ampere for twelve (12) hours.

d. Battery on open circuit stand for five (5) hours.

e. On every 14th cycle, the battery shall be discharged at 0.500 ampere to 20.0 volts and on the succeeding cycle recharged at 31.0 ± 1% volts (1.55 volts per cell) for four (4) hours.

f. The total elapsed time for steps (a) to (d) shall be twenty-four (24) hours. For step (e) the open circuit time may be adjusted so that each cycle lasts twenty-four (24) hours."

In addition to the change in the cycling schedule, the amendment provided for the method of selection of the batteries. This was based upon the lot size of the batteries - if under 66, one (1) per lot; if 66-200, two (2) per lot. Also provided for was an adjustment schedule in the contract if the batteries failed the required life tests.

b. Apparatus

The cycling apparatus to fulfill the requirements of the cycling schedule was custom designed and built at NICAD. A detailed description of the panel is presented in the attached NICAD Drawings - CPA-3805-1, -8.

The cycling board consists of two (2) identical units in parallel. Each board operates independently of the other except for their common charging source and timer on which independent cams are driven by the same motor unit. The operation of the board can be made either automatic or manual by merely changing the switches located on the panel board.

The charging source was a General Electric Aircraft Energizer Model 5BY203AL: 14-35 Volts Direct Current; 265 Amperes Continuous; 500 Amperes Intermittent. The voltage controls were rewired to allow adjustment at the front of the cycling panel. Although this unit was purchased as a reconditioned item it gave considerable mechanical trouble. During the course of the cycling, it was necessary to replace the voltage regulator and brushes, resurface the rotor due to poor contact of the voltage regulation brush, and replace the field coils due to an internal short. As can be intimated from the above, the greatest difficulty during the cycling test was the most critical unit, the charging source.

The cycling timer was Model MC-12 made by Industrial Timer Corp.,

Newark, New Jersey. This timer makes one (1) revolution every 24 hours. The operation of each battery is controlled by two (2) cams, one for charging and the other for discharging. The operation of charge, discharge and open circuit is controlled by energizing mercury relay switches on the panel. Although this timer is satisfactory for the required cycling schedule, the use of a more elaborate timer would be justified to allow the easy changeover to other cycling schedules, as for example (after every fourteenth (14th) cycle,).

The layout of the charge and discharge circuits is readily understood. The charge circuit from busbar to busbar as in Figure I consists of the battery, a Beede Model 16 (0-50) ammeter; a Weston 50 ampere-shunt; a Struthers - Dunn Inc. mercury relay, type 48AXX3, contact rating 45 ampere - 115 volts A.C.; a S.P.S.T. 60 ampere manual switch; and a 50 ampere fuse. The wiring was made as large as practical to decrease the ohmic resistance losses between the busbar voltage and the battery terminals. The discharge circuit as in Figure I consists of the battery, a Beede Model 16 (0-1) ammeter; a Weston 1 ampere shunt; a Ebert Electronic Inc., mercury relay, Type HD-1, contact rating 12 amperes 115 volt D.C.; a S.P.S.T. 12 ampere manual switch; a 1 ampere fuse; and two (2) Jagabi resistors in series, one 88 ohms - 1.2 amperes and the other 11 ohms - 5.0 amperes.

c. Cycling Test

The batteries for the cycling test selected by the Signal Corps were Nos. 28 and 83 from Lot Nos. 2 and 3 respectively. They were subjected to cycling as per the amended schedule. As a matter of practice, the discharge was started at 8:00 A.M. In several instances where it was desired to check time variations on battery capacity, the discharge rate was doubled so that the discharge could be completed within the normal work day. A complete summary of capacity cycles is presented in Table No. 1.

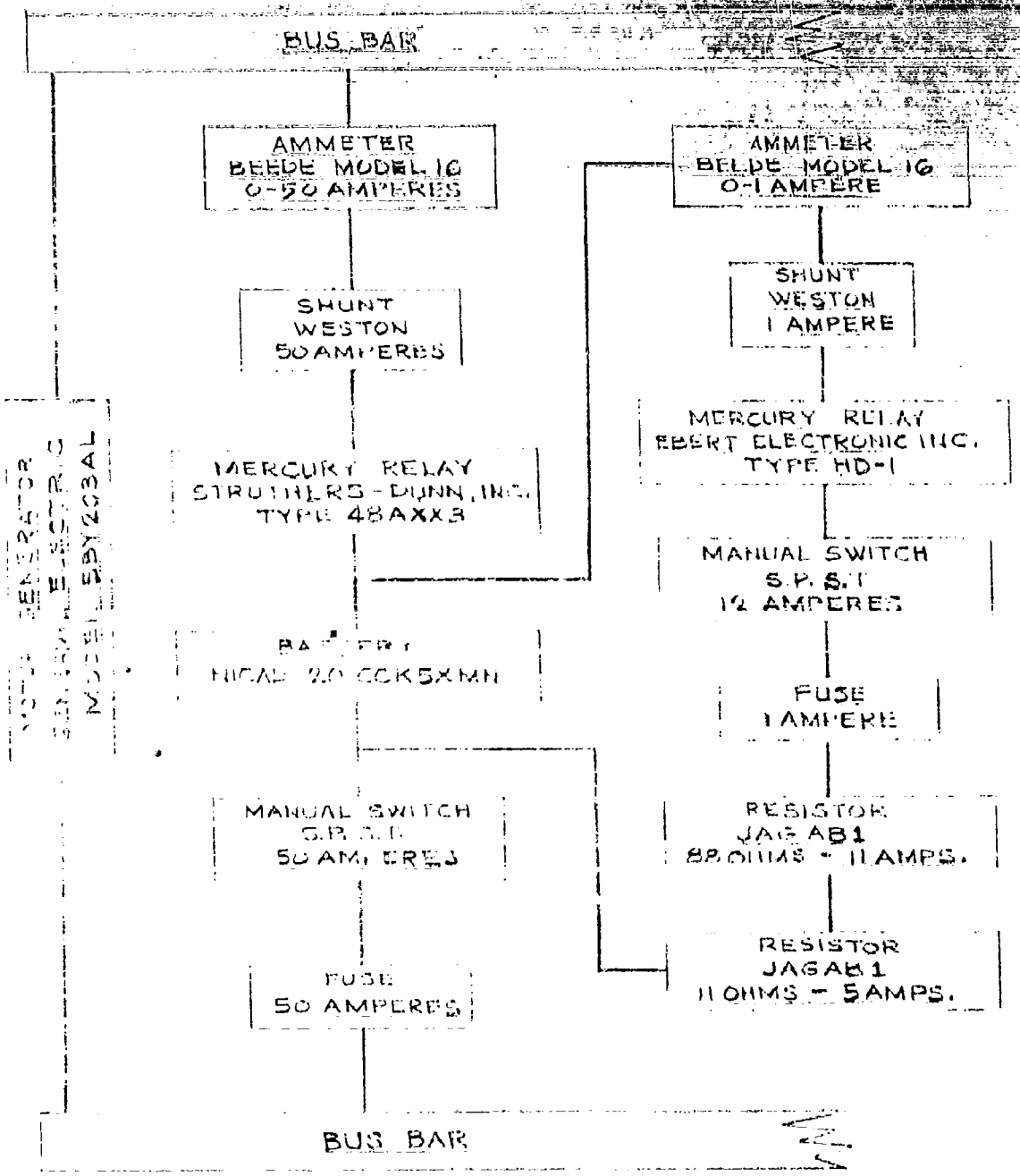

Figure 1

CHARGE-DISCHARGE CIRCUITS-DIAGRAM

Table No. 1

Cycling Test Results

Cycle No.	Charge	Discharge Current Amperes	Discharge Capacity A.H. to 1.00 Volt/Cell #28	#83
1	1.55 V/Cell - 4 hours	1.0	6.84	6.61
14	1.55 V/Cell - 2 hours	0.5	6.52	6.31
19	1.55 V/Cell - 2 hours	1.0	6.50	6.25 (1)
20	1.55 V/Cell - 2 hours	1.0	7.32	7.11
28	1.55 V/Cell - 2 hours	0.5	6.37	6.29 (2)
42	1.55 V/Cell - 2 hours	0.5	6.53	6.40
53	1.55 V/Cell - 2 hours	1.0	6.28	6.09
54	0.8 ampere - 16 hours	1.0	7.41	7.10
56	1.55 V/Cell - 2 hours	0.5	7.60	7.35 (3)
70	1.55 V/Cell - 2 hours	0.5	7.39	7.24
84	1.55 V/Cell - 2 hours	0.5	7.02	6.88
98	1.55 V/Cell - 2 hours	0.5	6.98	6.73
112	1.55 V/Cell - 2 hours	0.5	6.73	6.54
126	1.55 V/Cell - 2 hours	0.5	7.10	6.95
140	1.55 V/Cell - 2 hours	0.5	6.35	6.61
154	1.55 V/Cell - 2 hours	0.5	6.25	6.43
168	1.55 V/Cell - 2 hours	0.5	6.83	6.94

Table No. II (con'd)

Cycle No.	Charge	Discharge Current Amperes	Discharge Capacity A.H. to 1.00 Volt/cell #28	#83
182	1.55 V/Cell - 2 hours	0.5	6.03	6.19 (4)
196	1.55 V/Cell - 2 hours	0.5	6.31	6.58 (5)
201	1.55 V/Cell - 2 hours	0.5	6.08	6.35

Notes:

(1) Discharge continued for a total of eight hours. Adjustment made in time cycle to insure full two (2) hours of charge.

(2) After 35 cycles, voltage of generator would not exceed 28 volts. The difficulty was located in voltage regulator. This is believed cause of low voltage on charge. When set in P.M. voltage was at specified 31.0 volts. In A.M. of next day voltage down to 30.0 - 30.2 volts.

(3) After this cycle, batteries were charged at one (1) ampere for approximately 10 hours. This procedure repeated on cycle following succeeding capacity cycles.

(4) Power shut off over week-end.

(5) Generator trouble due to short in field windings.

The cells were subjected to an initial cycle capacity test after a four (4) hour charge at 1.55 volts/cell. The battery capacities were on the low side both with respect to the desired initial capacity and that previously found during the acceptance tests. Previous experience had indicated that with continued overcharge on cycling the capacity of the cells would improve.

The fourteenth cycle capacity discharge did not show any improvement so a check was made of the time cycle which was recorded with an Esterline-Angus Model AW Recording Ammeter modified for use as a voltmeter. It was found that several time adjustments were required. Table No. II indicates the actual time cycles before and after adjustment. In addition there are presented the times at the end of cycling. It can be seen that the cycling times fulfill the specification requirement within the limits of the adjustment that can be made on the small cams. It had also been observed that although the voltage was properly set at 31.0 volts before leaving at night, in the morning it would be between 30.0 and 30.2 volts.

A recheck of the capacity on the nineteenth (19th) cycle indicated that there had not been a capacity improvement with the adjusted charge time. The batteries were discharged for a total of eight hours using an external voltage to equalize the cells. This resulted in a substantial increase in capacity on the next cycle as shown in Table No. 1. On the twenty-eighth (28th) cycle, the cell capacities were again low since considerable trouble was experienced with the charging voltage.

After the thirty-fifth (35th) cycle, the voltage regulator broke down in a way that did not allow the charge voltage to exceed 28 volts. Inasmuch as this occurred during the weekend, these three cycles were discarded. The batteries were left in the discharged state while the generator was being repaired.

Table No. II

Automatic Cycling Times

Battery		No. 28			No. 83		
	Specification	Before Adjustment	After Adjustment	End of Cycling	Before Adjustment	After Adjustment	End of Cycling
Charge	2-0 (1)	1-56	2-7	2-22	1-53	2-6	2-6
Open Circuit	5-0	5-2	4-49	4-44	5-27	5-16	5-2
Discharge	12-0	12-19	12-20	12-3	12-12	12-11	11-59
Open Circuit	5-0	4-42	4-44	4-44	4-26	4-26	4-53

(1) Time is referred to as 2 hours - 0 minutes

The cycling was then resumed using only the regular two hour charge at 1.55 volts/cell. A recheck of capacity was made on the fifty-third (53rd) cycle to determine if the capacity had improved with the repair of the generator. In view of the fact that the capacity was marginal, the cells were given a constant current charge to fully charge both plate groups. This procedure led to an immediate capacity improvement.

It has been found in other work that in constant potential cycling there will be a very gradual decrease in capacity if the charge conditions are not ideal. One of the most important is the necessity of the high initial in-rush current. This high in-rush and the efficiency of the conversion of nickelous to nickelic hydroxide are related. As has been found in other instances, the higher current density increases the efficiency of the reaction. In our apparatus it was not possible to adjust the voltage at the battery terminals and as a result the in-rush current was limited to a certain extent by the ohmic resistance of the lead wires and instruments. In constant potential charging the overcharge of the positive plate is of course limited by the full charge of the negative plates. It is most probable that the effect of the decreased positive plate charge efficiency which is an undercharged positive electrode, could have been overcome if the constant potential charge were extended from two to four hours. This point has been substantiated in tests on these batteries by the Chemical Corps. (Ref. 3(1)).

Inasmuch as the cycling apparatus was not designed to readily go from two to four hours of constant potential charge, it was decided to use a constant current charge to equalize the plate capacity after every fourteenth cycle. A four hour charge would have required manual control of the cycle. To fulfill other requirements, this would have meant that a Technician would have been needed for a 1:00 A.M. to 5:00 A.M. shift in addition to the long discharge. Since funds were not available and

nothing would have been learned, a constant current charge appeared reasonable. The charge following the discharge to 20.00 volts was done at one ampere overnight.

As an afterthought, the same effect could have been accomplished by carrying the discharge beyond zero (0) volts using an external potential and recharging at constant potential for two (2) hours as was done on cycles 19 and 20.

The battery cycling from this point to the 177th cycle was routine. Prior to the next cycle, it was necessary to shut off the electric power to the plant to allow electric crews to install new lines to an adjacent factory. After the 188th cycle, the motor generator broke down when new cells for the Chemical Corps being charged from the same source prior to acceptance testing were allowed to reverse the fields of the generator. After repairing the unit, the additional cycles were completed without difficulty.

The electrolyte levels of the cells were adjusted in the charged state after every capacity cycle.

5. CONCLUSIONS

The vented nickel-cadmium battery designed for the E-41 miniaturized point source alarm has successfully completed two hundred (200) charge - discharge cycles after which it is still capable of meeting the discharge requirement of 0.5 ampere for 12 hours to 20.00 volts. To fulfill this requirement it is necessary that the battery have occasional prolonged constant potential or regular constant current charge to more fully charge the positive and negative plates.

6. RECOMMENDATIONS

In future Contracts, provision should be made for approved procedures to be followed in case of malfunction of the circuit and equipment. For example, there was not clearly defined procedure to be followed after the breakdown of the generator or after power failure.

7. IDENTIFICATION OF PERSONNEL

Name	Title	Time, Hrs.
J. Anderson	Electrical - Chemical Technician	46
S. Januszkiewicz	Project Leader	29

AD

Gould-National Batteries, Inc. UNCLASSIFIED
NICAD Division, Easthampton, Mass. 1. Requirements
SEALED NICKEL-CADMIUM D-41 ALARM 2. Test Circuit
BATTERY S. Januszkiewicz 3. Cycling Test
Supplementary Report - 31 March 4. Contract DA-
1961 12 pp. 1 figure - 26-039-SC-
2 tables; 2 drawings 85273
(Contract DA-36-039-SC-85273)
(DA Project No. 3618-03-001)

The vented nickel-cadmium battery designed for the D-41 alarm has successfully passed 200-charge-discharge cycles. These cycles indicated a need for occasional extended constant potential or regular constant current charge to more fully charge the positive and negative plate in a cell.

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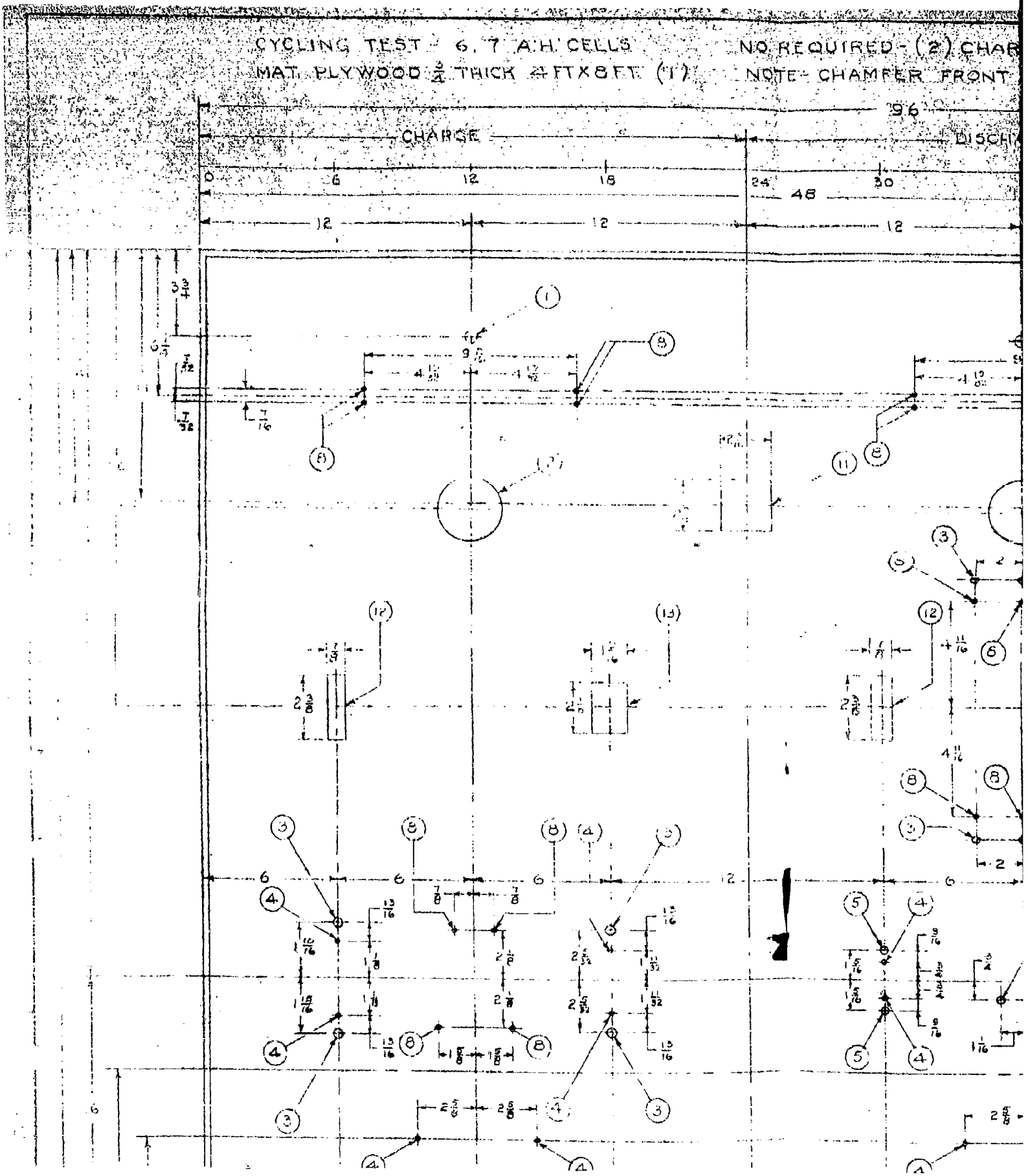
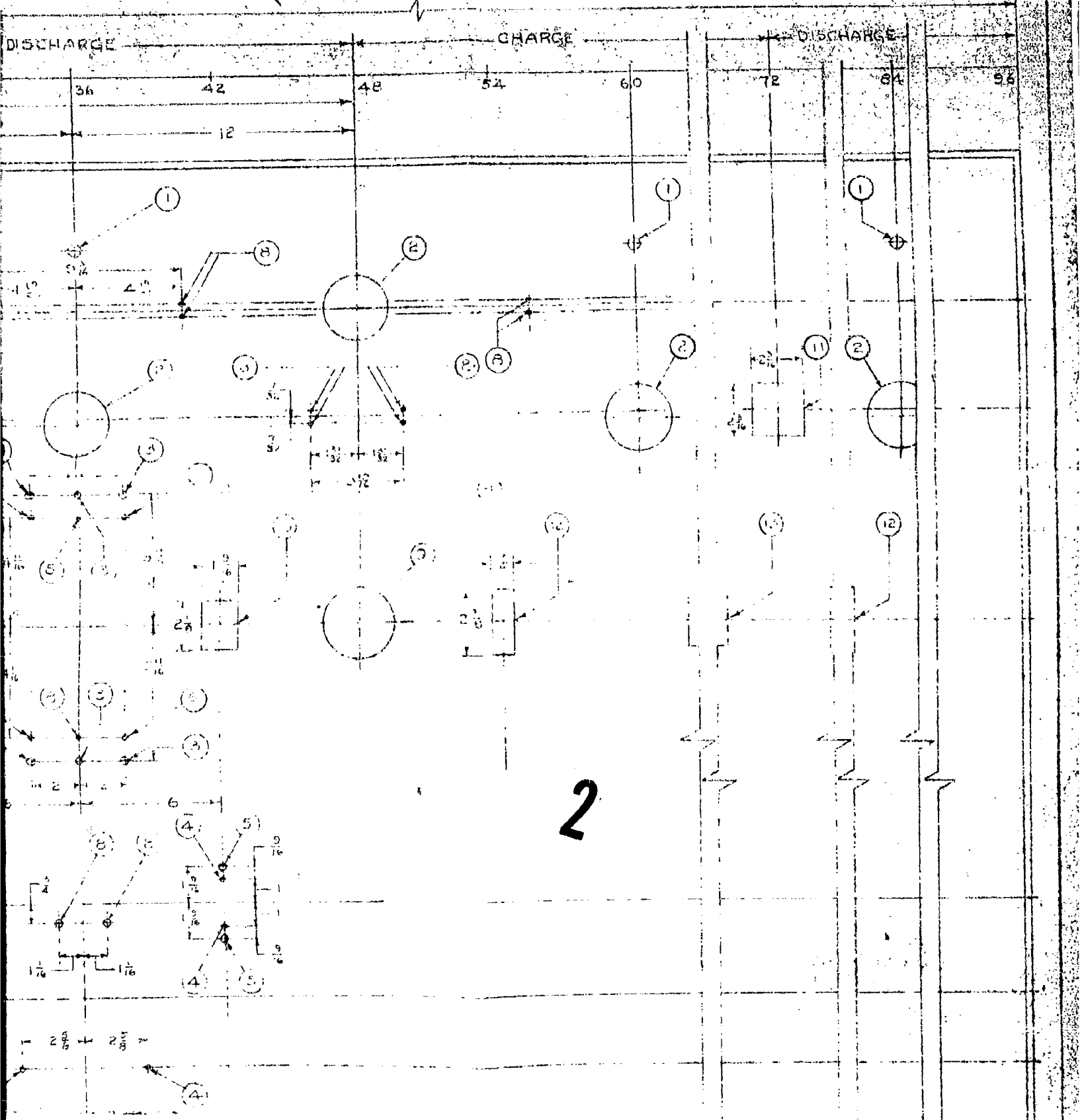
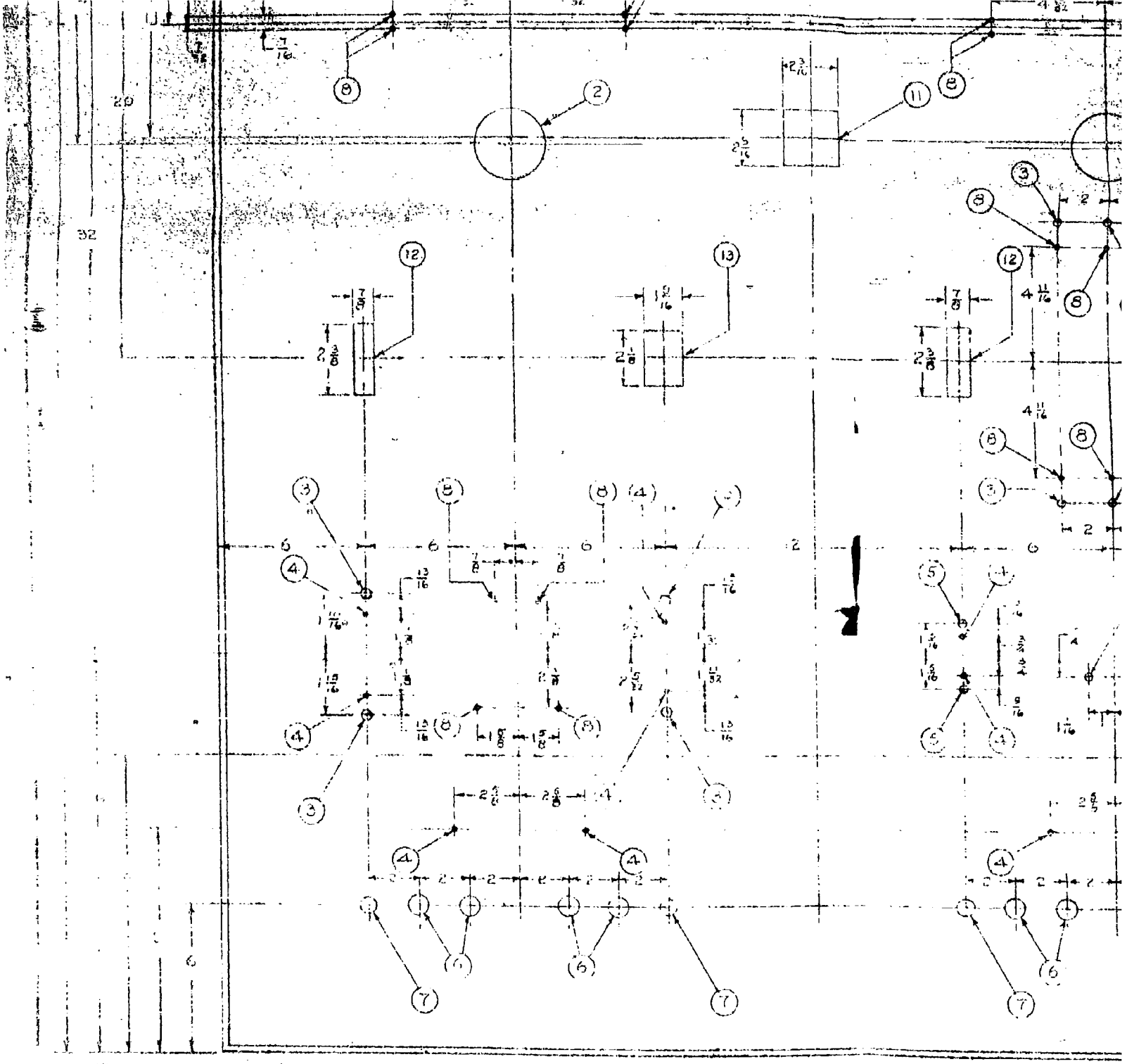

CYCLING TEST - 6, 7 A.H. CELLS
MAT. PLYWOOD 3/4 THICK 4 FT X 8 FT. (1)
NO. REQUIRED - (2) CHAR
NOTE- CHAMFER FRONT
96
CHARGE
DISCH
0
6
12
18
24
30
48
12
12
12

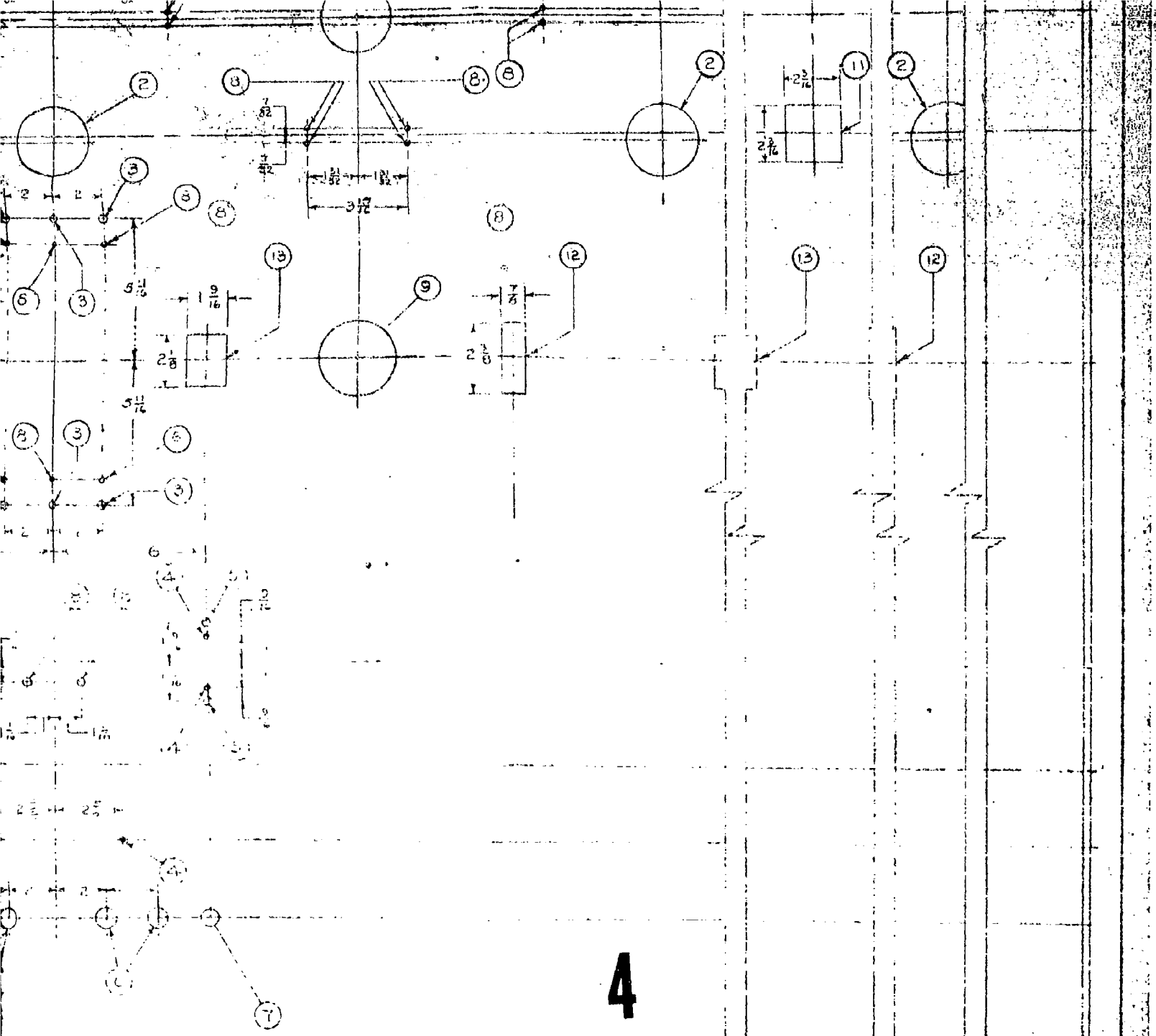
CHARGE & DISCHARGE PANELS

FRONT EDGES $\frac{1}{4} \times 45°$ (4) (DRILL ALL HOLES USE WOOD BIT ONLY) PAINT PANEL (1) BLACK FRONT





(1) $\frac{11}{16}$ DIA. HOLE (4)
(2) $2\frac{13}{16}$ DIA. HOLE (5)
(3) $\frac{5}{16}$ DIA. HOLE (18)
(4) $\frac{7}{32}$ DIA. HOLE (21)
(5) $\frac{1}{4}$ DIA. HOLE (8)
(6) $\frac{3}{4}$ DIA. HOLE (16)
(7) $\frac{1}{2}$ DIA. HOLE (2)
(8) $\frac{3}{16}$ DIA HOLE (32)
(9) 3 DIA. HOLE (1)
(10)
(11) $2\frac{3}{16} \times 2\frac{5}{16}$ OPENING (2)
(12) $\frac{7}{8} \times 2\frac{3}{8}$ OPENING (4)
(13) $1\frac{9}{16} \times 2\frac{1}{8}$ OPEN



4

OPENING (4)

DRAWN	J.E.F	1-15-60
SCALE 3:12		

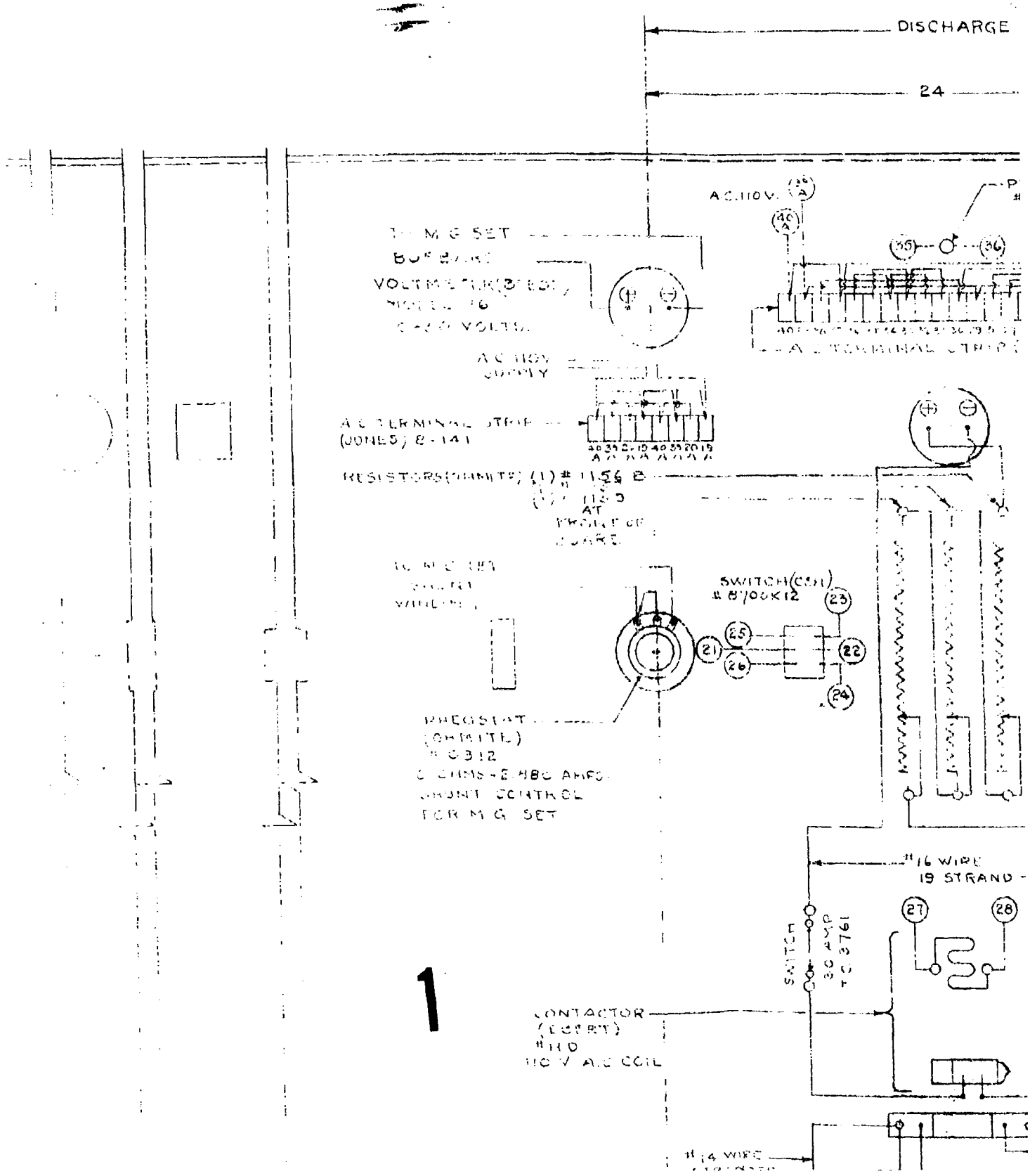
CYCLING TEST
E-41 ALARM BATTERY
20-CCK5XMN CELLS
PANEL (FRONT)

NICAD DIVISION
GOULD-NATIONAL BATTERIES
EASTHAMPTON MASS.

CPA-3805-1

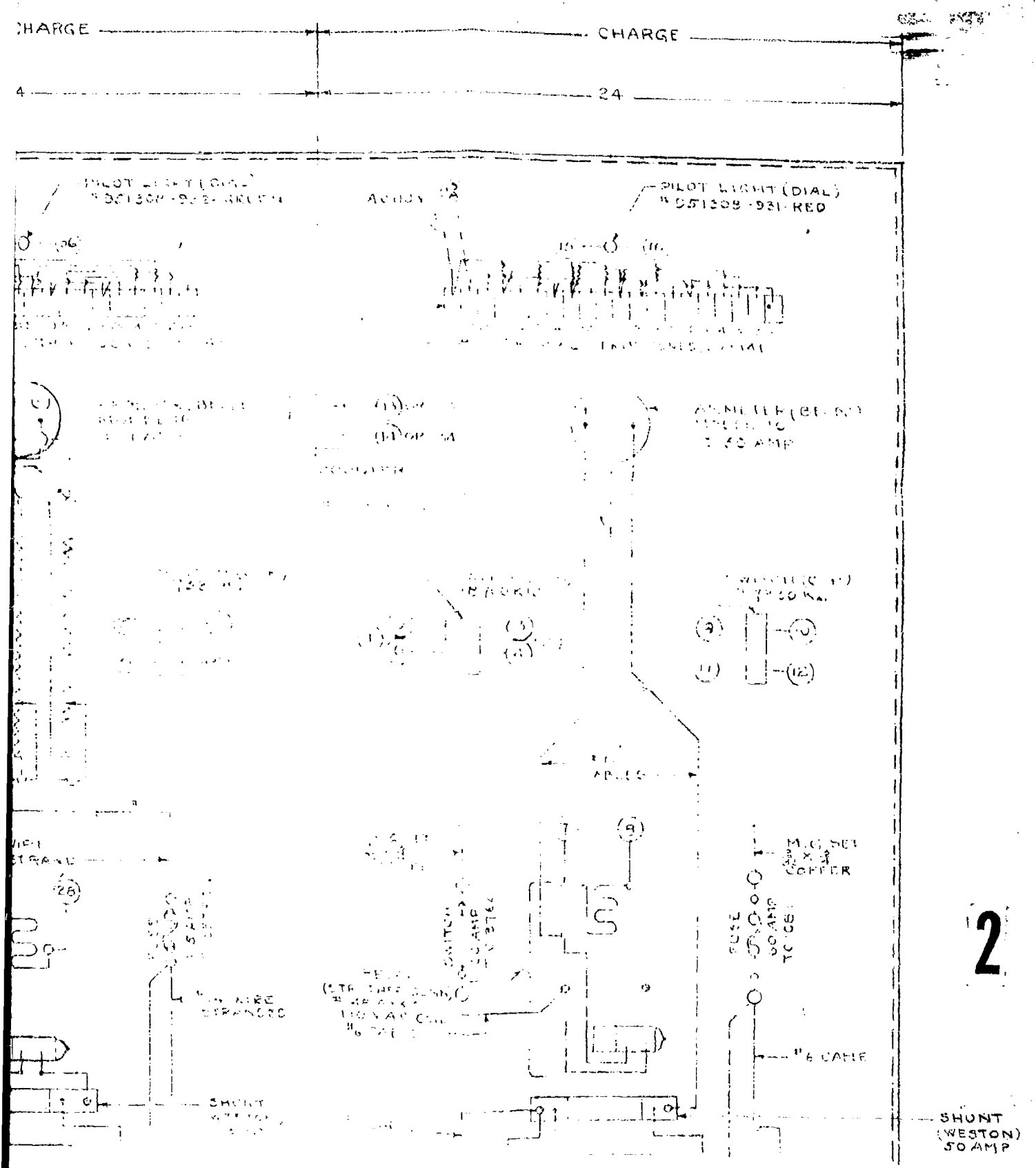
CYCLING TEST 667 A.H. CELL

WIRING - BACK OF BOARD CON



1

H. CELLS
RD CONNECTIONS (2 BOARDS)



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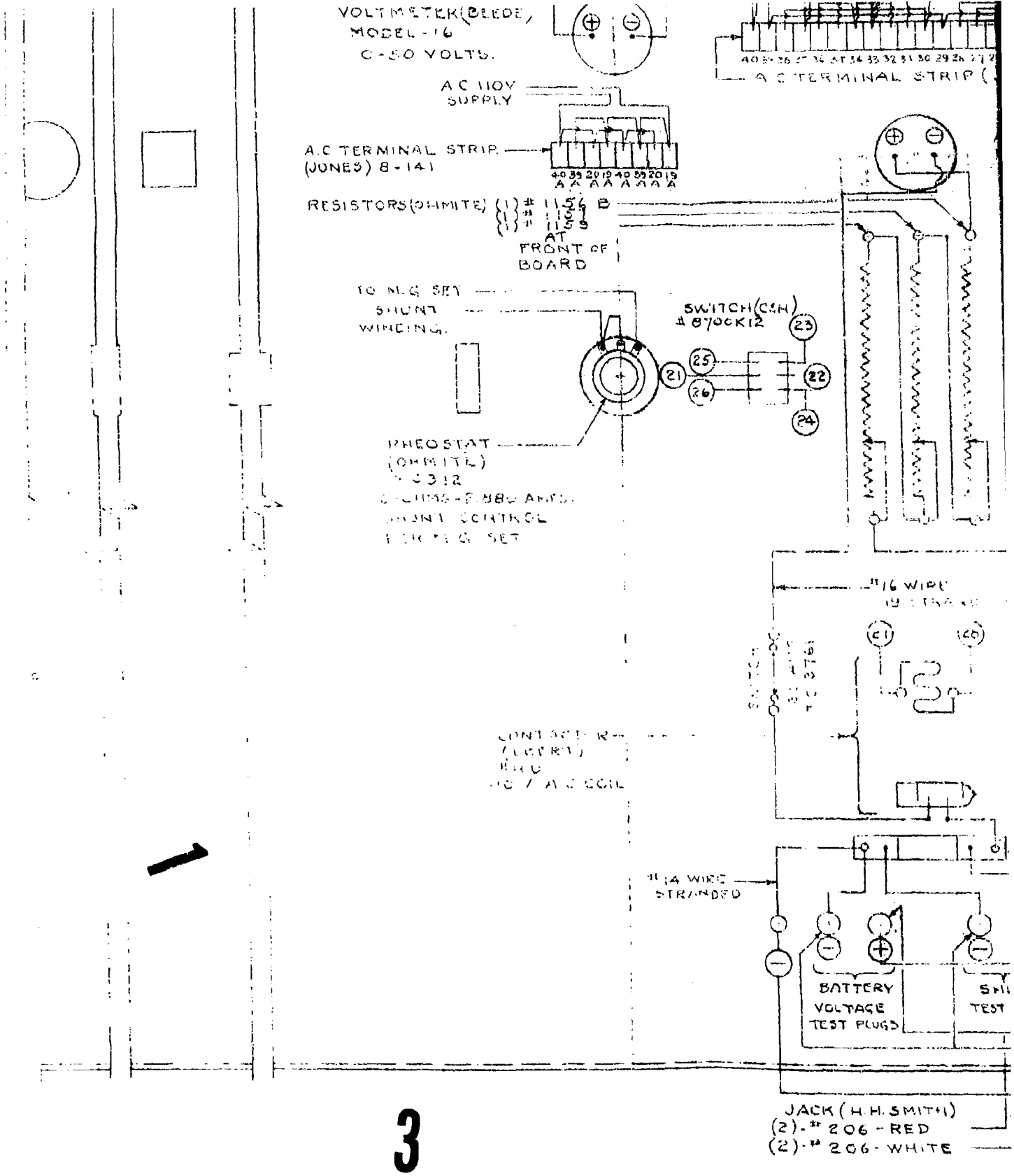
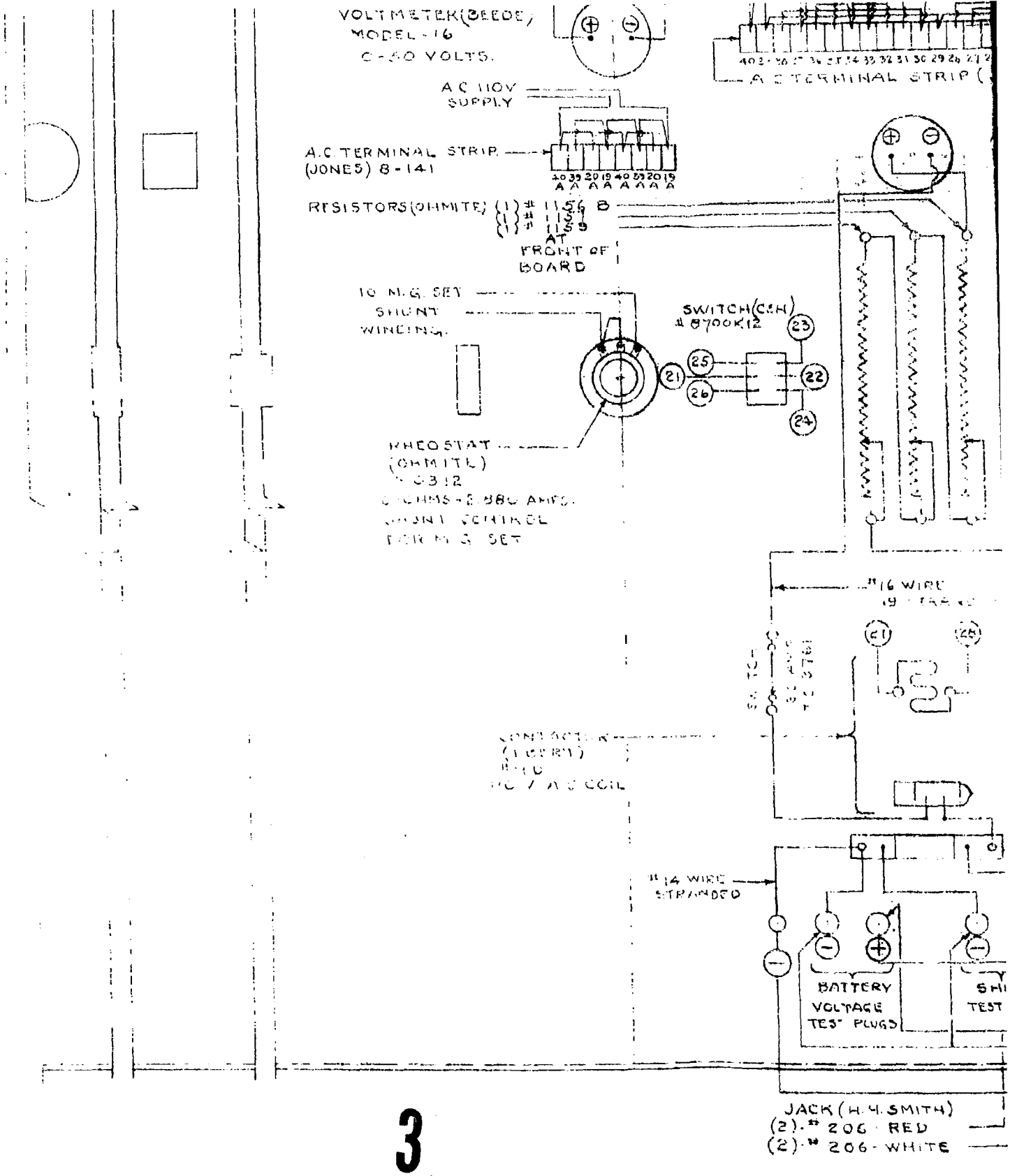
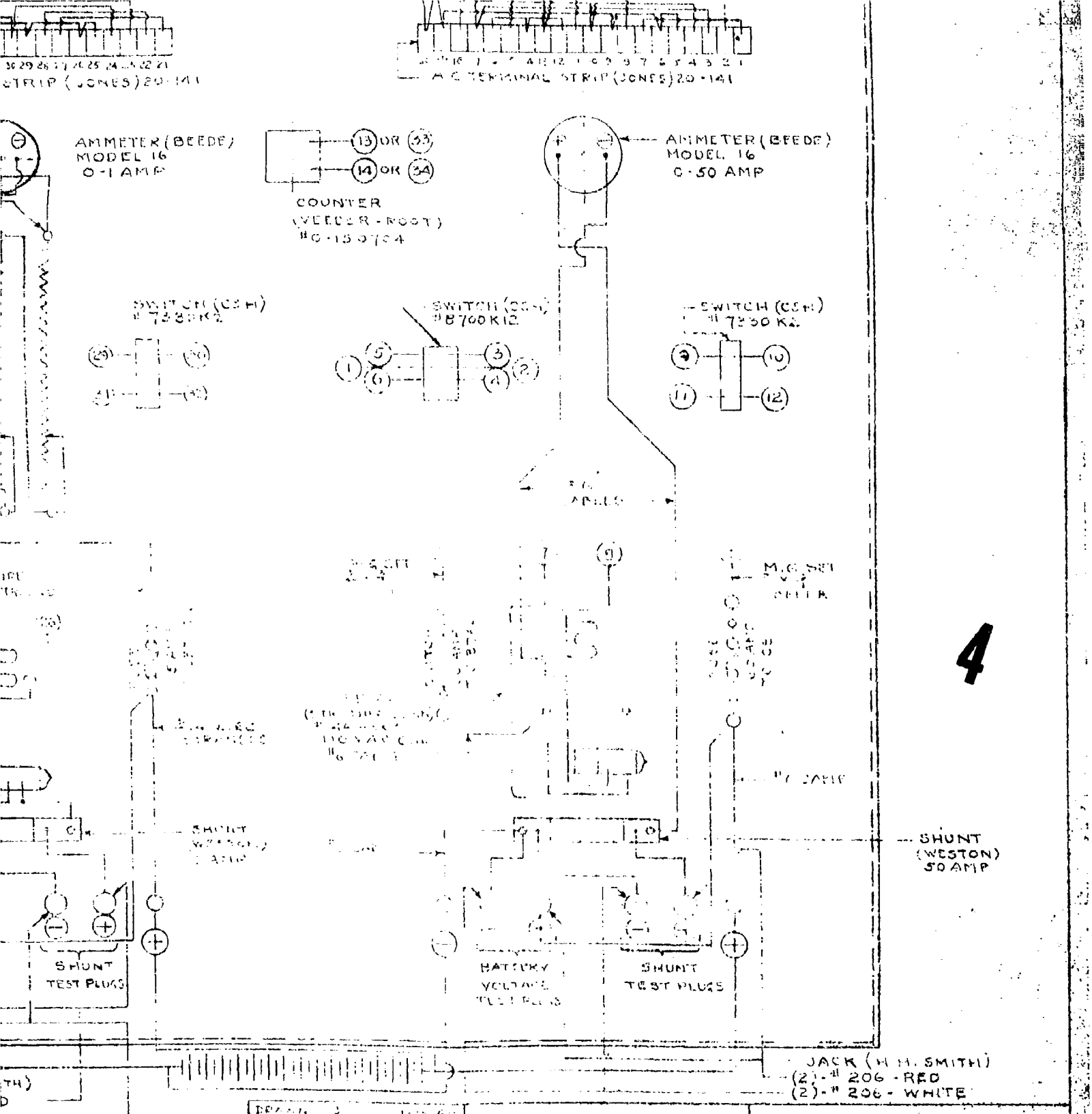

VOLTMETER (BLEDE)
MODEL - 16
0 - 50 VOLTS.
A.C 110V
SUPPLY
A.C TERMINAL STRIP
(JONES) 8 - 141
RESISTORS (OHMITE) (1) # 1156 B
(1) # 1157
(1) # 1159
AT
FRONT OF
BOARD
TO N.G. SET
SHUNT
WINDING.
SWITCH (C&N)
870CK12
RHEOSTAT
(OHMITE)
C312
SHUNT CONTROL
FOR N.G. SET
#16 WIRE
CONTACTOR
(LEECH)
110 V A.C COIL
#14 WIRE
STRANDED
BATTERY
VOLTAGE
TEST PLUGS
JACK (H.H. SMITH)
(2) - # 206 - RED
(2) - # 206 - WHITE

3


VOLTMETER (BEEDE)
MODEL - 16
0 - 30 VOLTS.
A.C. 110V SUPPLY
A.C. TERMINAL STRIP (JONES) 8 - 141
RESISTORS (OHMITE) (1) # 1156 B
(1) # 1157
(1) # 1159
AT FRONT OF BOARD
10 M.G. SET SHUNT WINDING.
SWITCH (CEH) # 8700K12
RHEOSTAT (OHMITE)
#16 WIRE
#14 WIRE STRANDED
BATTERY VOLTAGE TEST PLUGS
JACK (H.H. SMITH)
(2) # 206 RED
(2) # 206 WHITE


A C TERMINAL STRIP (JONES) 20-141
AMMETER (BEEDE)
MODEL 16
0-1 AMP
COUNTER
(VEEDER-ROOT)
#C-1557C4
AMMETER (BEEDE)
MODEL 16
0-50 AMP
SWITCH (CSH)
#7290K2
SWITCH (CSH)
#8700K12
SWITCH (CSH)
#7290K2
SHUNT
TEST PLUGS
BATTERY
VOLTAGE
TEST PLUGS
SHUNT
TEST PLUGS
SHUNT
(WESTON)
50 AMP
JACK (H.H. SMITH)
(2)-#206-RED
(2)-#206-WHITE
4
CYCLING TEST
E-41 ALARM BATTERY
20-5AH CELLS
WIRING
BACK OF PANELS
NICAD DIVISION
GOULD NATIONAL BATTERIES INC.
EASTHAMPTON MASS.
CPA-3505-8

Gould-National Batteries, Inc.
NICAD DIVISION
Easthampton, Massachusetts

11 September 1961

References: U.S. Army Signal Research & Development Laboratory
Contract No. DA-36-039 SC-85471
DA Project No. 3 G 28-05 003
Supplementary Report

Gentlemen:

We are submitting the Supplementary Report giving the results of the Life Cycling Tests. This is in accordance with the requirements of Item 1 of referenced contract, and modification No. 2 thereto.

Very truly yours,

NICAD DIVISION
Gould-National Batteries, Inc.

F. C. Anderson
Chief Engineer

FCA/bes

Enclosure

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DA-36-039 SC-85273

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