X-716-65-405

NASA TM X-55383

SILVER ZINC BATTERIES POWER SUPPLY FOR THE ATMOSPHERE EXPLORER-B SPACECRAFT (AE-B)

BY

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OCTOBER 1965

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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FOREWORD

The purpose of this document is to describe the characteristics and operation of the Silver Zinc Batteries which comprise the primary power supply for the Atmosphere Explorer B (AE-B) spacecraft.

CONTENTS

LIST OF ILLUSTRATIONS

Photos

SILVER ZINC BATTERIES POWER SUPPLY
FOR THE
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(AE-B)

INTRODUCTION

The basic power supply for the Atmosphere Explorer-B satellite is a modified primary battery system with recharge capability. It is comprised of eight batteries or series strings of Yardney modified HR-type silver oxide-zinc cells. It is essentially the same system as was used on Explorer XVII, with the following two major exceptions: (1) The AE-B has limited recharge capability through the use of body-mounted solar cells; (2) The power system for the AE-B is redundant, in that the major experiments, command receivers, programmers, and telemetry are redundant and are operated from different batteries. The loss of any one battery cannot result in the loss of the operation of the satellite. The cells for the AE-B, although similar to those used on Explorer XVII, have been substantially improved in capacity, reduced wet stand losses and outgassing, as shown in Figure 1. A proposed battery capacity table and a servicing and inspection sheet are also included in this report.

CELL CHARACTERISTICS

The HR-type silver oxide-zinc cell has several distinguishing characteristics which are of particular interest. (1) It is the highest capacity type cell that has been fully developed; under certain conditions these cells can deliver up to 100 watt hours per pound. (2) The output voltage is essentially flat as shown in Figure 1. (3) Although basically a primary cell, it is capable of a limited number of recharges. (4) Being dry-charged, it is capable of extended storage prior to activation. Like everything else, it has several drawbacks such as, once activated it will self-discharge and has a limited wet stand life, approximately one year; it will also outgas hydrogen gas on discharge or open circuit, thus causing a pressure problem in a sealed container. When the cell is approaching full charge, it will evolve oxygen.

DESIGN

The basic design of the power system is derived from that utilized on Explorer XVII. (Refer to report X-636-63-206.) The useful life of the payload is determined by the capacity of the battery system. This life can be increased by reducing the load, increasing the capacity of the batteries, and/or by providing some recharge capability. All of these means are being employed on the Atmosphere Explorer B satellite. The command load has been reduced from

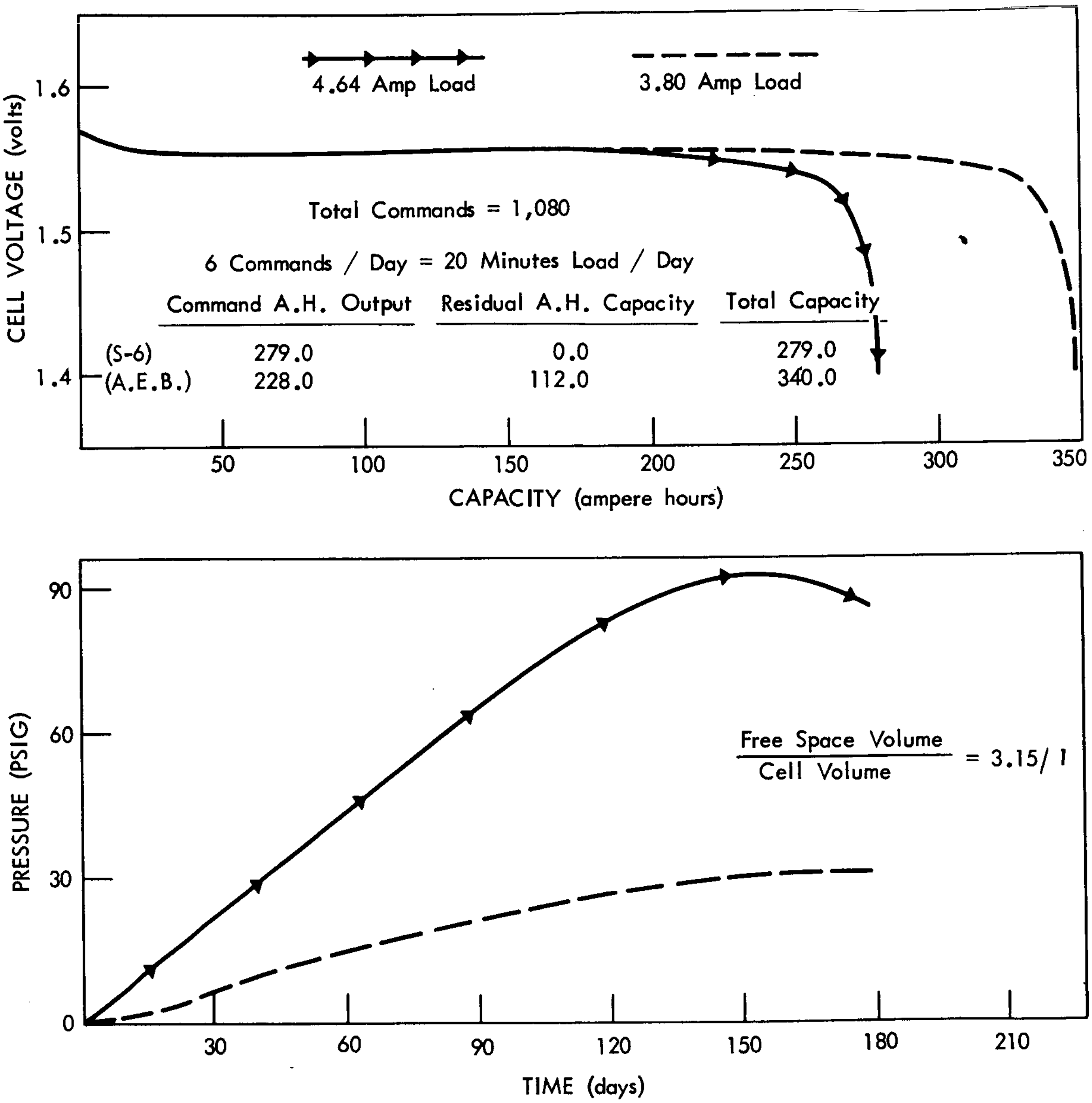

Figure 1–Yardney Silvercels AgZn Initial Discharge at Room Temperature
HR–200(S–6) vs HR–200(AE–B)

112 watts to 85 watts and the command time period reduced from 5 minutes to 4 minutes. The capacity of the cells has been increased approximately 10 to 20 per cent, and limited recharge capability is available from the body-mounted solar cells.

Figure 2 is a diagram of the battery layout, which shows the load distribution and depicts the redundancy of the system. There is sufficient battery capacity to maintain the payload at five commands per day for over eight months, without the benefit of any recharge. The useful life of the satellite payload can be extended beyond one year by replenishing 50% of the cells' capacities, and then will probably be limited by the wet-stand life of the batteries.

One of the major obstacles to be overcome on Explorer XVII was the control or retardation of the pressure rise due to the outgassing of the electrochemical cells. Palladium monoxide was used as a recombination material on Explorer XVII; however, on the Atmosphere Explorer B, the pressure will be controlled by a commandable relief valve and by the use of recombination cells, which will absorb hydrogen and/or oxygen that may evolve from the battery cells.

CHARGING TECHNIQUE

The battery charger for the AE-B spacecraft is described in detail, in report X-636-65-271, "The Battery Charger for the Atmosphere Explorer B Spacecraft."

There is no undervoltage protection or any charge control system on the AE-B power supply. The depth of discharge and percent recharge must be calculated from usage data, and will be controlled by ground commands from the Technical Control Center at Goddard. Figure 3 gives a typical profile of the HR-200 cell as regards capacity, stand life and outgassing characteristics. Figure 4 shows the effect of high temperature on cell capacity.

The batteries shall be charged prior to depletion of 70 per cent of their rated capacity, in order to prevent any cell reversal; this recharge shall be limited to 75% of the calculated discharge in order to prevent overcharging of a cell.

The charging philosophy is that the cells should never approach the fully charged condition, in order to prevent the formation of oxygen. Simulated charge-discharge tests are being conducted in the laboratory; some of these tests have been in progress for over one year.

Table 1 is a proposed operational schedule based on 5 commands/day, at the present anticipated current drains, and based on a recharge capability of

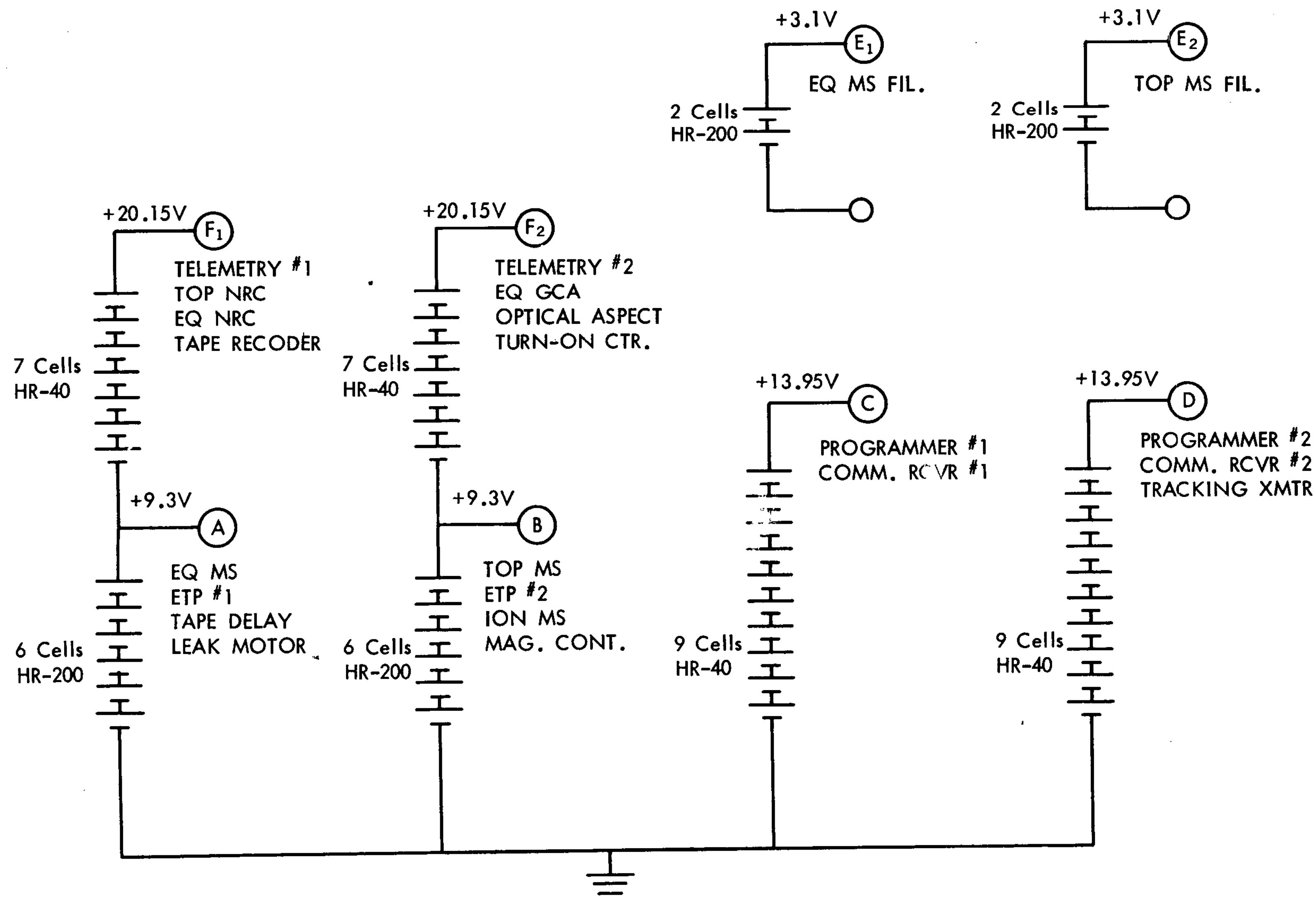

Figure 2-AE-B Battery Pack

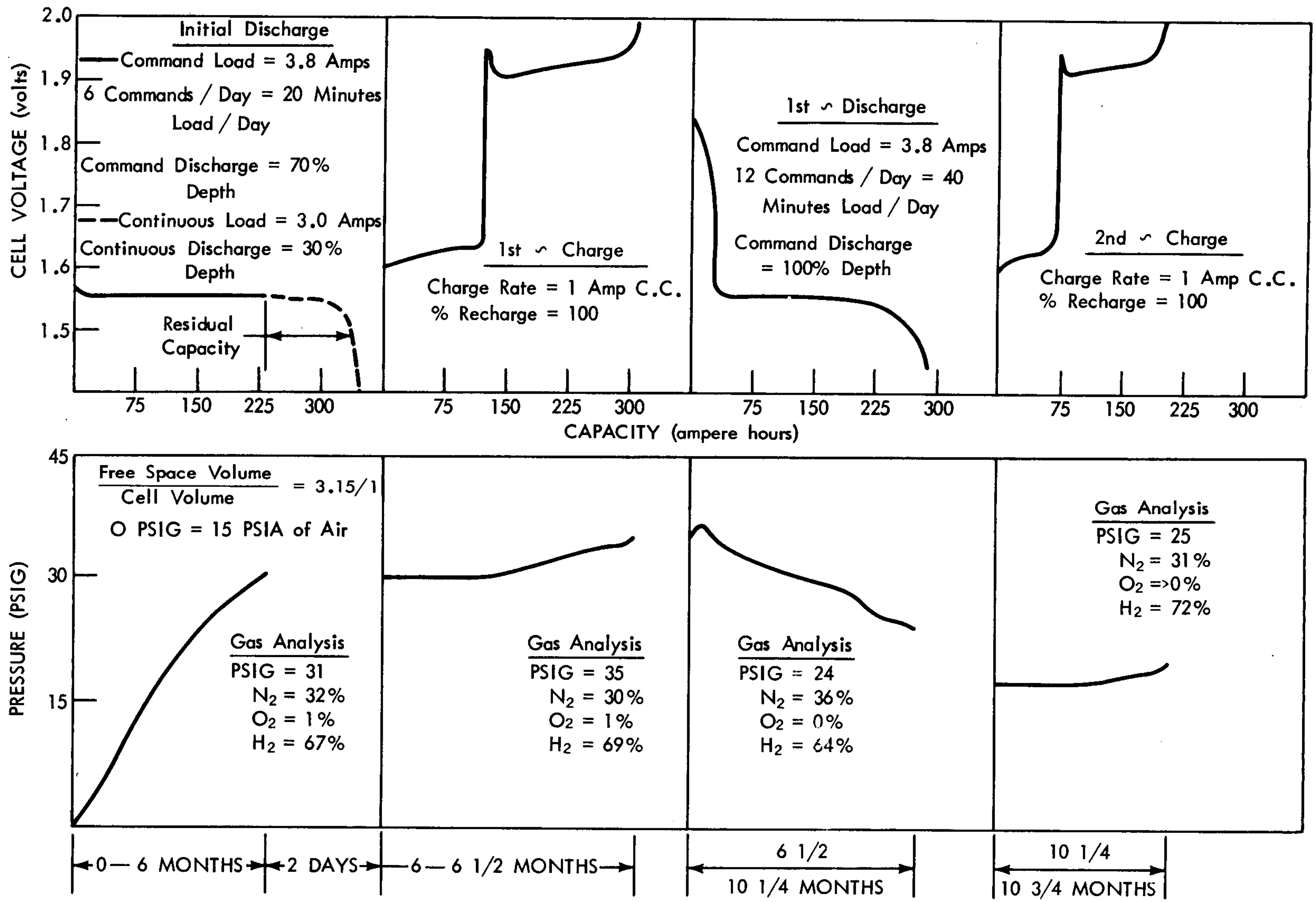

Figure 3–HR–200 D.C. (4NM) Yardney Silvercel AgZn AE–B Charge/Discharge Characteristics at Room Temperature

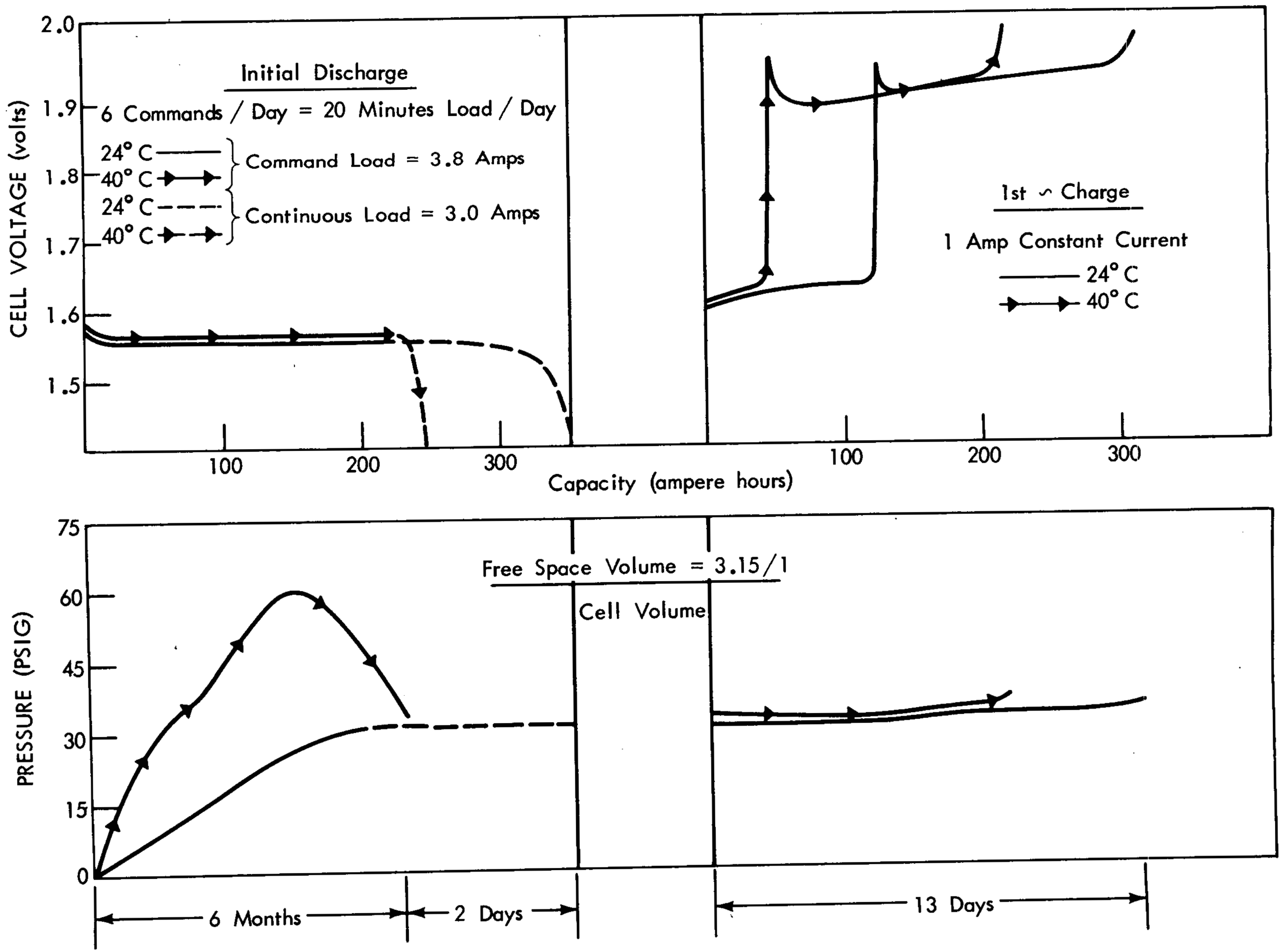

Figure 4–HR–200 D.C. (4NM) Yardney Silvercel AgZn Temperature Effects (24° vs 40°C)

7.5 watts available for battery charging at the end of six months. The satellite should operate on battery power exclusively for about six months or until the original battery capacity has been approximately 2/3 depleted. It should then be recharged 75% of its depleted capacity. In that the satellite is limited in its recharge capability to the charging of a single battery at one time, and that the batteries will have been discharged various amounts, a recharge schedule must be established and adhered to. This procedure should assure sufficient battery capacity to extend the payload beyond one year.

Hydrogen gas is evolved from the batteries on open circuit stand and while the cells are being discharged; also, this outgassing is aggravated at elevated temperatures. In view of the above, it is quite obvious that the evolution of oxygen must be held to a minimum or entirely avoided. Due to self-discharge, the battery charge acceptance will decrease with time, and inasmuch as no voltage limiting device or other charge control method is employed, the only precautionary means to assure that the batteries will not generate oxygen is to limit the amount of recharge to a quantity less than that removed from the battery by discharging.

The charging system is a modified two-step constant current method. These two steps are caused by the two plateaus of the silver electrodes. At the beginning of the charge, the silver oxide plates will be on the monovalent level and the cell voltage will be approximately 1.62 volts; this plateau will hold up to 40 per cent of the charge, at which time the divalent level will take over and the cell voltage will rapidly rise to a plateau of 1.92 volts, where it will remain relatively constant for the remainder of the charge period.

The discharge voltage is also dependent on the oxide state of the silver electrodes and will be approximately 1.75 volts per cell on the divalent level and gradually decline to the monovalent plateau of 1.60 to 1.55 volts per cell for the remainder of the discharge period.

PROPOSED SCHEDULE

Based on laboratory data, manufacturers' data, Explorer XVII test data, and other available information, a proposed schedule for battery operation and recharge has been prepared and is shown in Table 1. The expected life of the payload, based on Table 1, is one year. An appendix is included which contains:

Proposed Battery Schedule
Inspection and Servicing Instructions
Wiring Schematic
Cell and Battery Photos

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GR-AEB-1006-686
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Appendix I

Table 1

Proposed Battery Schedule

BATTERY	F1	A	F2	B	C	D	E1	E2	Units
Cell Type HR-	40	200	40	200	40	58	200	200	-
Rated Capacity	50	300	50	300	50	75	300	300	A.H.
Number of Cells	7 →	6	7 →	6	9	9	2	2	#
*Charge Voltage	26	12	26	12	18	18	4	4	Volts
Load Voltage	20.15	9.3	20.15	9.3	13.95	13.95	3.1	3.1	Volts
*Avg. Command Load	0.325	2.33	0.255	2.45	0.014	0.026	3.0	3.0	Amps
Continuous Load					7.0	7.0			M.A.
Avg. Drain Per Day	0.108	0.77	0.085	0.810	0.178	0.185	0.99	0.99	A.H.
Drain Per Month	3.27	23.5	2.56	24.75	5.42	5.65	30.25	30.25	A.H.
6 Month Output	19.62	141.00	15.36	148.50	32.52	33.90	181.50	181.50	A.H.
Residue Capacity	30.38	159.0	34.64	151.50	17.48	41.10	118.50	118.50	A.H.
% Rated Capacity	61.0	53.0	69.0	50.0	35.0	55.0	39.0	39.0	%
Max. Charge Current	0.310	0.600	0.310	0.600	0.440	0.440	1.60	1.60	Amps
*Max. A.H. Input Per Day	5.72	10.80	5.72	10.80	7.92	7.92	26.8	26.8	A.H.
*Total Charge	14.80	106.0	11.5	111.3	24.3	25.4	126.2	126.2	A.H.
Restored Capacity	45.2	265.0	46.1	262.8	41.8	66.5	244.7	244.7	A.H.
12 Month Output	19.6	141.0	15.4	148.5	32.5	33.9	181.5	181.5	A.H.
Residue Capacity	25.6	124.0	30.7	114.3	9.3	32.4	63.2	63.2	A.H.
% Rated Capacity	51.0	41.0	61.0	38.0	19.0	43.0	21.0	21.0	%
Charge Current	0.310	0.600	0.310	0.600	0.440	0.440	1.60	1.60	A.H.
*Max. A.H. Input Per Day	5.72	10.80	5.72	10.80	7.92	7.92	26.8	26.8	A.H.
*Total Charge	14.80	106.0	11.5	111.3	24.3	25.4	126.2	126.2	A.H.
Restored Capacity	40.40	230.0	42.2	125.6	33.6	57.8	189.4	189.4	A.H.

*All data is related to operation of Batteries at Room Temperature.

*Charge Voltage is a Maximum Voltage, not to be exceeded during Payload Operation.

*Avg. Command Load is calculated on each Transmitter and Programmer operating for 50% of Total Commands.

*Capacity Inputs calculated for 18 Hours Charge/Day.

Table I-1

Cell and Battery Information

Type Cell	Amount of KOH	Weight	Torque (Top Terminal Nuts)
HR-40DC(10NM)	90 cc	25 oz.	35-40 In.-Lb.
HR-58DC(2NM)	120 cc	32.3 oz.	50-65 In.-Lb.
HR-200DC(4NM)	350 cc	101 oz	55-60 In.-Lb.

Battery	No. of Cells	Weight (oz.)	Voltage
A(HR-200)	6	606.0	9.3
B(HR-200)	6	606.0	9.3
C(HR-40)	9	225.0	13.95
D(HR-58)	9	290.7	13.95
E_1(HR-200)	2	202.0	3.1
E_2(HR-200)	2	202.0	3.1
F_1(HR-40)	7	175.0	*20.15
F_2(HR-40)	7	175.0	†20.15
	48	2481.7 oz.	
		155.1 Lbs.	

*Battery F_1 is connected in series with Battery A.
†Battery F_2 is connected in series with Battery B. (A_2)

Table I-2

Inspection and Servicing Instructions—HR-Type Silver Zinc Cells

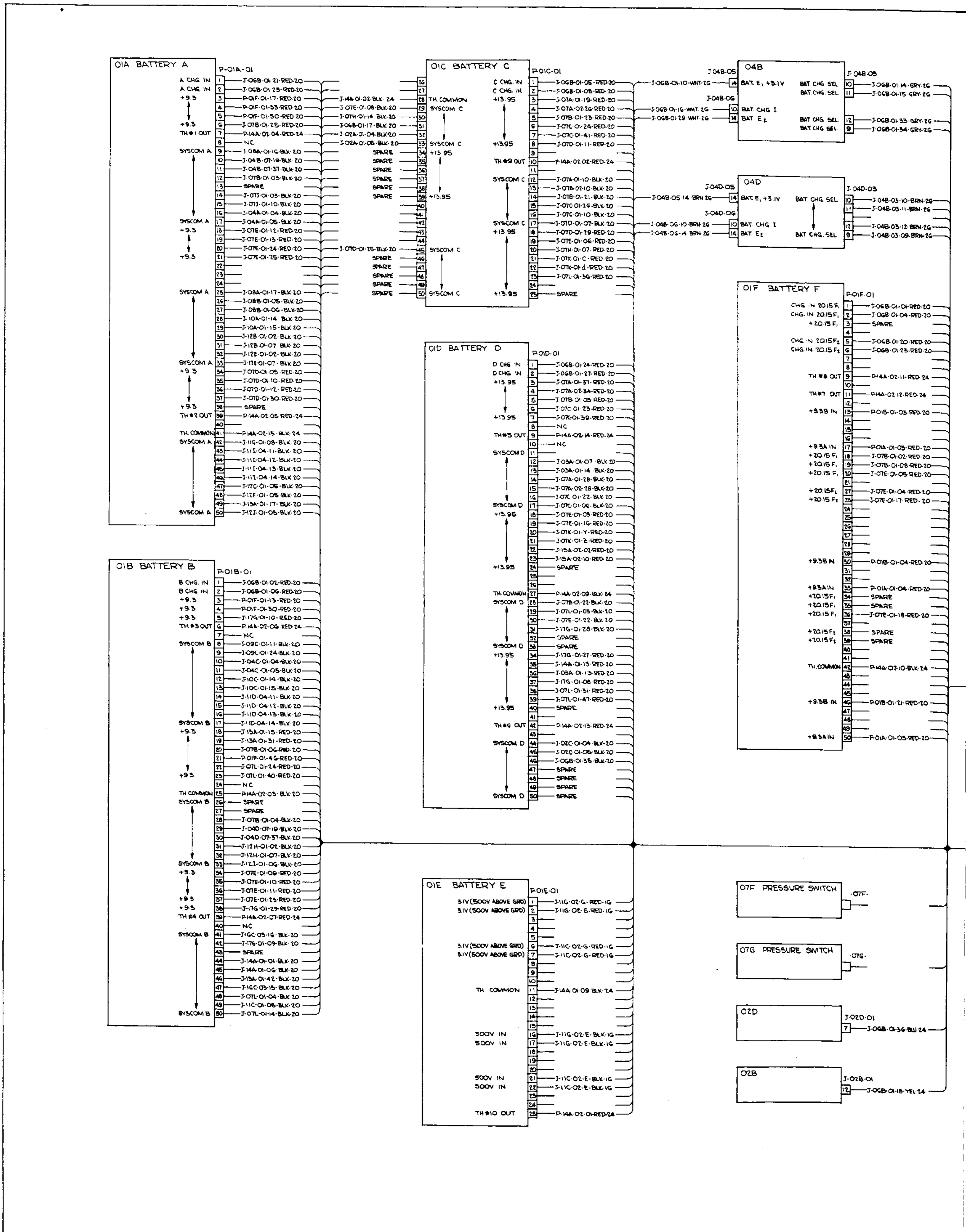
Atmospheric Explorer B Satellite

I. Initial Inspections
   A. Check—Nomenclature, Polarity, Dimensions and Workmanship. Discrepancies in any of the above may be cause for rejection.
   B. Cell Cases—Deep scratches or stress crazing lines diagonally across corners shall be cause for rejection.
   C. Impedance Check—(Prior to filling) Cells with resistance measurements less than one megohm shall be rejected.

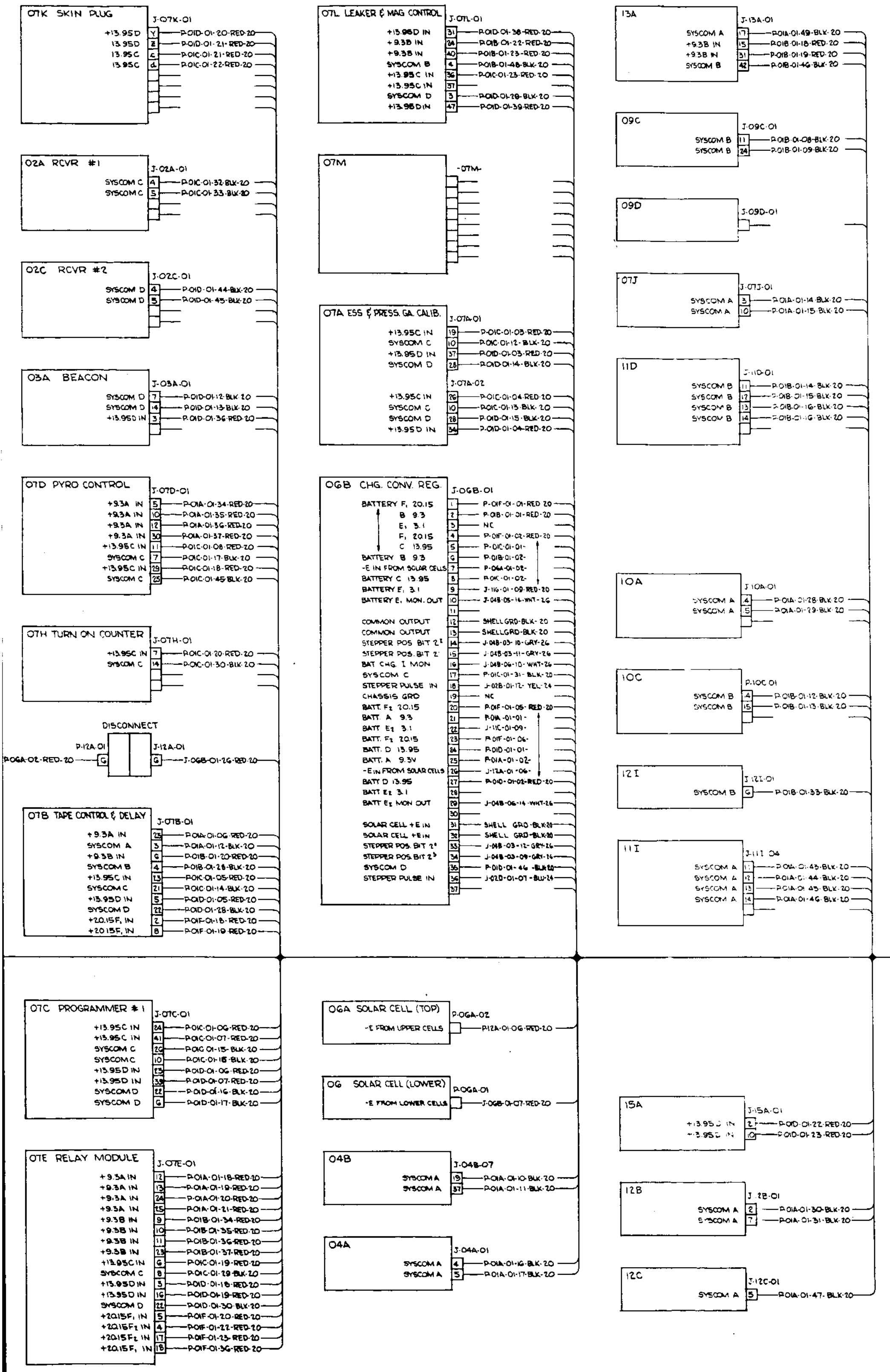
II. Filling Instructions
   A. Use only electrolyte furnished with cells.
   B. Specified amount for each type cell is as follows:
      HR-40 90 cc; HR-58 120 cc; HR-200 350 cc.
   C. Partially evacuate cell (Pull vacuum of 25 inches) during and after filling.
   D. Repeat cell evacuation periodically at least three times, prior to assembly of cells in battery boxes.
   E. Record—Dates of manufacturer, filling, cell evacuations, open circuit and load voltages.

III. Battery Assembly Instructions
   A. Install cells in accordance with layout.
   B. Install thermister cards.
   C. Install polyethylene film covers on vent spouts.
   D. Install flexible intercell connectors.
   E. Install battery connector.
   F. Install star washers and nuts (Torque as specified).

IV. Final Inspection
   A. Check wiring and pin connections for workmanship and continuity.
   B. Conduct electrical check with load simulator (Record open circuit and load voltages).
   C. Install echofoam and battery box cover (Do not tighten adjusting screws).
   D. Flight batteries will be subjected to 2 commands with the load simulator at 2°C and 29°C stabilized temperatures.
   E. Deliver to Mechanical Systems Group for final adjustments and installation into satellite shell.



01A BATTERY A
P-01A-01
01B BATTERY B
P-01B-01
01C BATTERY C
P-01C-01
01D BATTERY D
P-01D-01
01E BATTERY E
P-01E-01
01F BATTERY F
P-01F-01
04B
04D
07F PRESSURE SWITCH
07G PRESSURE SWITCH
02D
02B


07K SKIN PLUG
J-07K-01
+13.95D Y P-01D-01-20-RED-20
13.95D Z P-01D-01-21-RED-20
13.95C c P-01C-01-21-RED-20
13.95C d P-01C-01-22-RED-20
02A RCVR #1
J-02A-01
SYSCOM C 4 P-01C-01-32-BLK-20
SYSCOM C 5 P-01C-01-33-BLK-20
02C RCVR #2
J-02C-01
SYSCOM D 4 P-01D-01-44-BLK-20
SYSCOM D 5 P-01D-01-45-BLK-20
03A BEACON
J-03A-01
SYSCOM D 7 P-01D-01-12-BLK-20
SYSCOM D 14 P-01D-01-13-BLK-20
+13.95D IN 3 P-01D-01-36-RED-20
07D PYRO CONTROL
J-07D-01
+9.3A IN 5 P-01A-01-34-RED-20
+9.3A IN 10 P-01A-01-35-RED-20
+9.3A IN 12 P-01A-01-36-RED-20
+9.3A IN 30 P-01A-01-37-RED-20
+13.95C IN 11 P-01C-01-08-RED-20
SYSCOM C 7 P-01C-01-17-BLK-20
+13.95C IN 29 P-01C-01-18-RED-20
SYSCOM C 25 P-01C-01-45-BLK-20
07H TURN ON COUNTER
J-07H-01
+13.95C IN 7 P-01C-01-20-RED-20
SYSCOM C 14 P-01C-01-30-BLK-20
DISCONNECT
P-12A-01
J-12A-01
P-06A-02-RED-20 G
G J-06B-01-26-RED-20
07B TAPE CONTROL & DELAY
J-07B-01
+9.3A IN 25 P-01A-01-06-RED-20
SYSCOM A 3 P-01A-01-12-BLK-20
+9.3B IN 6 P-01B-01-20-RED-20
SYSCOM B 4 P-01B-01-28-BLK-20
+13.95C IN 13 P-01C-01-05-RED-20
SYSCOM C 21 P-01C-01-14-BLK-20
+13.95D IN 5 P-01D-01-05-RED-20
SYSCOM D 22 P-01D-01-28-BLK-20
+20.15F₁ IN 2 P-01F-01-18-RED-20
+20.15F₁ IN 8 P-01F-01-19-RED-20
07L LEAKER & MAG CONTROL
J-07L-01
+13.95D IN 31 P-01D-01-38-RED-20
+9.3B IN 24 P-01B-01-22-RED-20
+9.3B IN 40 P-01B-01-23-RED-20
SYSCOM B 4 P-01B-01-48-BLK-20
+13.95C IN 36 P-01C-01-23-RED-20
+13.95C IN 37
SYSCOM D 3 P-01D-01-29-BLK-20
+13.95D IN 47 P-01D-01-39-RED-20
07M
J-07M-
07A ESS & PRESS. GA. CALIB.
J-07A-01
+13.95C IN 19 P-01C-01-03-RED-20
SYSCOM C 10 P-01C-01-12-BLK-20
+13.95D IN 37 P-01D-01-03-RED-20
SYSCOM D 28 P-01D-01-14-BLK-20
J-07A-02
+13.95C IN 26 P-01C-01-04-RED-20
SYSCOM C 10 P-01C-01-13-BLK-20
SYSCOM D 28 P-01D-01-15-BLK-20
+13.95D IN 34 P-01D-01-04-RED-20
06B CHG. CONV. REG.
J-06B-01
BATTERY F₁ 20.15 1 P-01F-01-01-RED-20
B 9.3 2 P-01B-01-01-RED-20
E₁ 3.1 3 NC
F₁ 20.15 4 P-01F-01-02-RED-20
C 13.95 5 P-01C-01-01-
BATTERY B 9.3 6 P-01B-01-02-
-E IN FROM SOLAR CELLS 7 P-06A-01-02-
BATTERY C 13.95 8 P-01C-01-02-
BATTERY E₁ 3.1 9 J-11G-01-09-RED-20
BATTERY E₁ MON. OUT 10 J-04B-05-14-WHT-26
11
COMMON OUTPUT 12 SHELL GRD-BLK-20
COMMON OUTPUT 13 SHELL GRD-BLK-20
STEPPER POS BIT 2² 14 J-04B-03-10-GRY-26
STEPPER POS. BIT 2¹ 15 J-04B-03-11-GRY-26
BAT CHG I MON 16 J-04B-06-10-WHT-26
SYSCOM C 17 P-01C-01-31-BLK-20
STEPPER PULSE IN 18 J-02B-01-12-YEL-24
CHASSIS GRD 19 NC
BATT F₂ 20.15 20 P-01F-01-05-RED-20
BATT A 9.3 21 P-01A-01-01-
BATT E₂ 3.1 22 J-11C-01-09-
BATT F₂ 20.15 23 P-01F-01-06-
BATT D 13.95 24 P-01D-01-01-
BATT A 9.3V 25 P-01A-01-02-
-E IN FROM SOLAR CELLS 26 J-12A-01-06-
BATT D 13.95 27 P-01D-01-02-RED-20
BATT E₂ 3.1 28
BATT E₂ MON OUT 29 J-04B-06-14-WHT-26
30
SOLAR CELL +E IN 31 SHELL GRD-BLK-20
SOLAR CELL +E IN 32 SHELL GRD-BLK-20
STEPPER POS BIT 2⁰ 33 J-04B-03-12-GRY-26
STEPPER POS BIT 2³ 34 J-04B-03-09-GRY-26
SYSCOM D 35 P-01D-01-46-BLK-20
STEPPER PULSE IN 36 J-02D-01-07-BLU-24
37
13A
J-13A-01
SYSCOM A 17 P-01A-01-49-BLK-20
+9.3B IN 15 P-01B-01-18-RED-20
+9.3B IN 31 P-01B-01-19-RED-20
SYSCOM B 42 P-01B-01-46-BLK-20
09C
J-09C-01
SYSCOM B 11 P-01B-01-08-BLK-20
SYSCOM B 24 P-01B-01-09-BLK-20
09D
J-09D-01
07J
J-07J-01
SYSCOM A 3 P-01A-01-14-BLK-20
SYSCOM A 10 P-01A-01-15-BLK-20
11D
J-11D-01
SYSCOM B 11 P-01B-01-14-BLK-20
SYSCOM B 12 P-01B-01-15-BLK-20
SYSCOM B 13 P-01B-01-16-BLK-20
SYSCOM B 14 P-01B-01-16-BLK-20
10A
J-10A-01
SYSCOM A 4 P-01A-01-28-BLK-20
SYSCOM A 5 P-01A-01-29-BLK-20
10C
P-10C-01
SYSCOM B 4 P-01B-01-12-BLK-20
SYSCOM B 15 P-01B-01-13-BLK-20
12I
J-12I-01
SYSCOM B G P-01B-01-33-BLK-20
11I
J-11I-04
SYSCOM A 11 P-01A-01-43-BLK-20
SYSCOM A 12 P-01A-01-44-BLK-20
SYSCOM A 13 P-01A-01-45-BLK-20
SYSCOM A 14 P-01A-01-46-BLK-20
07C PROGRAMMER #1
J-07C-01
+13.95C IN 24 P-01C-01-06-RED-20
+13.95C IN 41 P-01C-01-07-RED-20
SYSCOM C 26 P-01C-01-15-BLK-20
SYSCOM C 10 P-01C-01-16-BLK-20
+13.95D IN 13 P-01D-01-06-RED-20
+13.95D IN 38 P-01D-01-07-RED-20
SYSCOM D 22 P-01D-01-16-BLK-20
SYSCOM D G P-01D-01-17-BLK-20
07E RELAY MODULE
J-07E-01
+9.3A IN 12 P-01A-01-18-RED-20
+9.3A IN 13 P-01A-01-19-RED-20
+9.3A IN 24 P-01A-01-20-RED-20
+9.3A IN 25 P-01A-01-21-RED-20
+9.3B IN 9 P-01B-01-34-RED-20
+9.3B IN 10 P-01B-01-35-RED-20
+9.3B IN 11 P-01B-01-36-RED-20
+9.3B IN 23 P-01B-01-37-RED-20
+13.95C IN 6 P-01C-01-19-RED-20
SYSCOM C 8 P-01C-01-29-BLK-20
+13.95D IN 3 P-01D-01-18-RED-20
+13.95D IN 16 P-01D-01-19-RED-20
SYSCOM D 22 P-01D-01-30-BLK-20
+20.15F₁ IN 5 P-01F-01-20-RED-20
+20.15F₂ IN 4 P-01F-01-22-RED-20
+20.15F₂ IN 17 P-01F-01-23-RED-20
+20.15F₁ IN 18 P-01F-01-36-RED-20
06A SOLAR CELL (TOP)
P-06A-02
-E FROM UPPER CELLS P-12A-01-06-RED-20
06 SOLAR CELL (LOWER)
P-06A-01
-E FROM LOWER CELLS J-06B-01-07-RED-20
04B
J-04B-07
SYSCOM A 19 P-01A-01-10-BLK-20
SYSCOM A 37 P-01A-01-11-BLK-20
04A
J-04A-01
SYSCOM A 4 P-01A-01-16-BLK-20
SYSCOM A 5 P-01A-01-17-BLK-20
15A
J-15A-01
+13.95D IN 2 P-01D-01-22-RED-20
+13.95D IN 10 P-01D-01-23-RED-20
12B
J-12B-01
SYSCOM A 2 P-01A-01-30-BLK-20
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12C
J-12C-01
SYSCOM A 5 P-01A-01-47-BLK-20

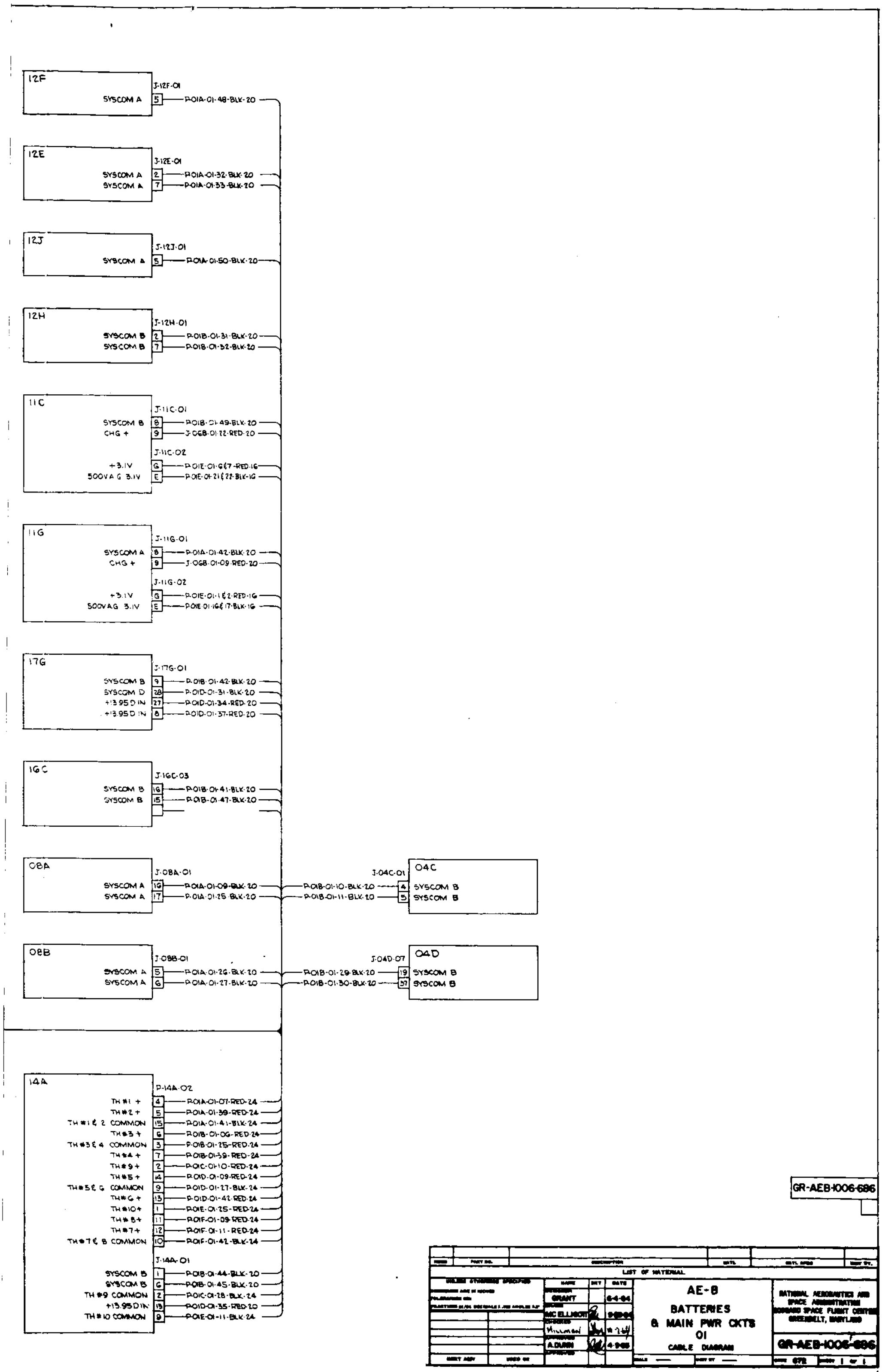

Table I-3
Wiring Schematic GR-AEB-1006-686

3

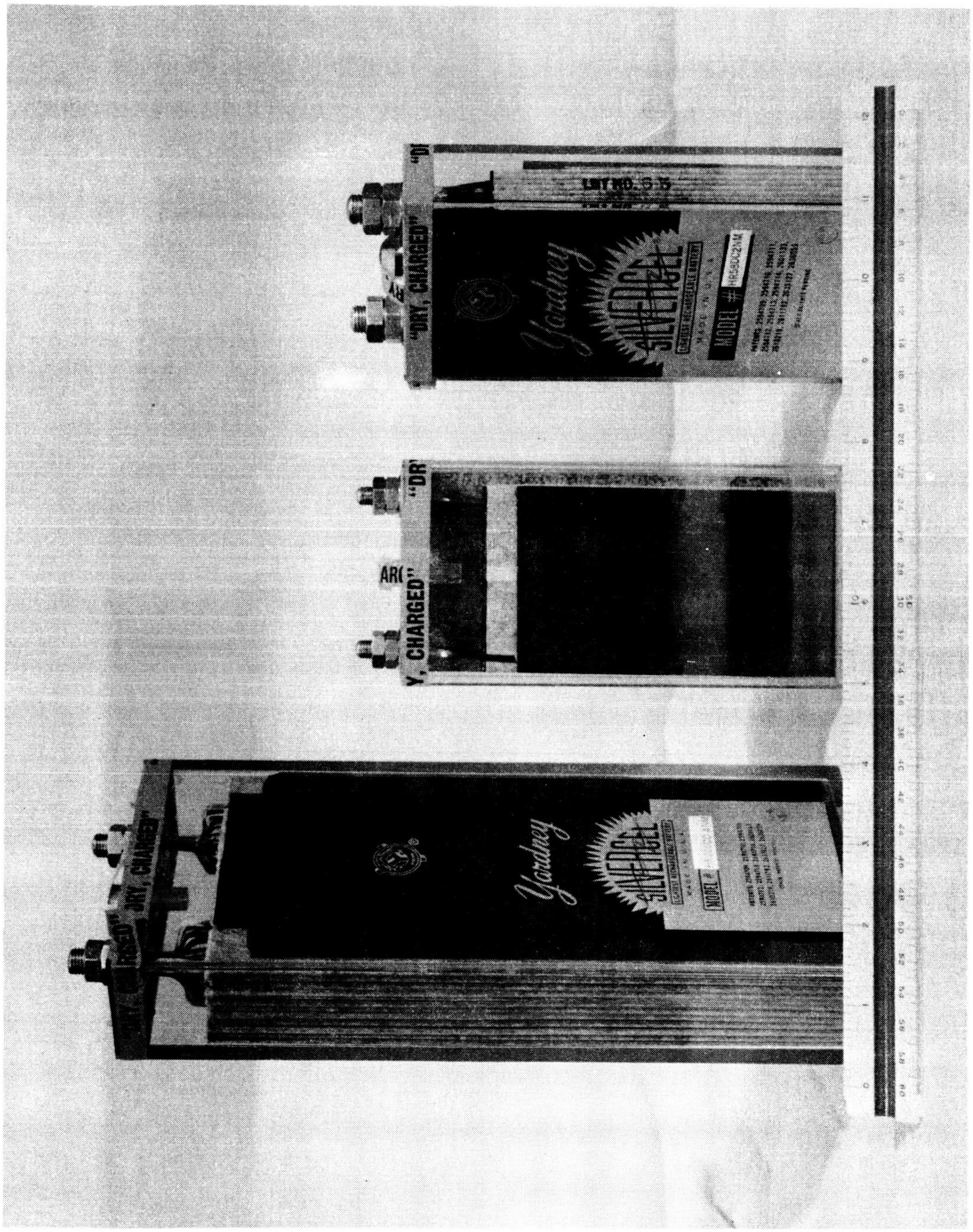

Photo A-4—HR-40, HR-58, HR-200 Cells (NASA G-66-1754)

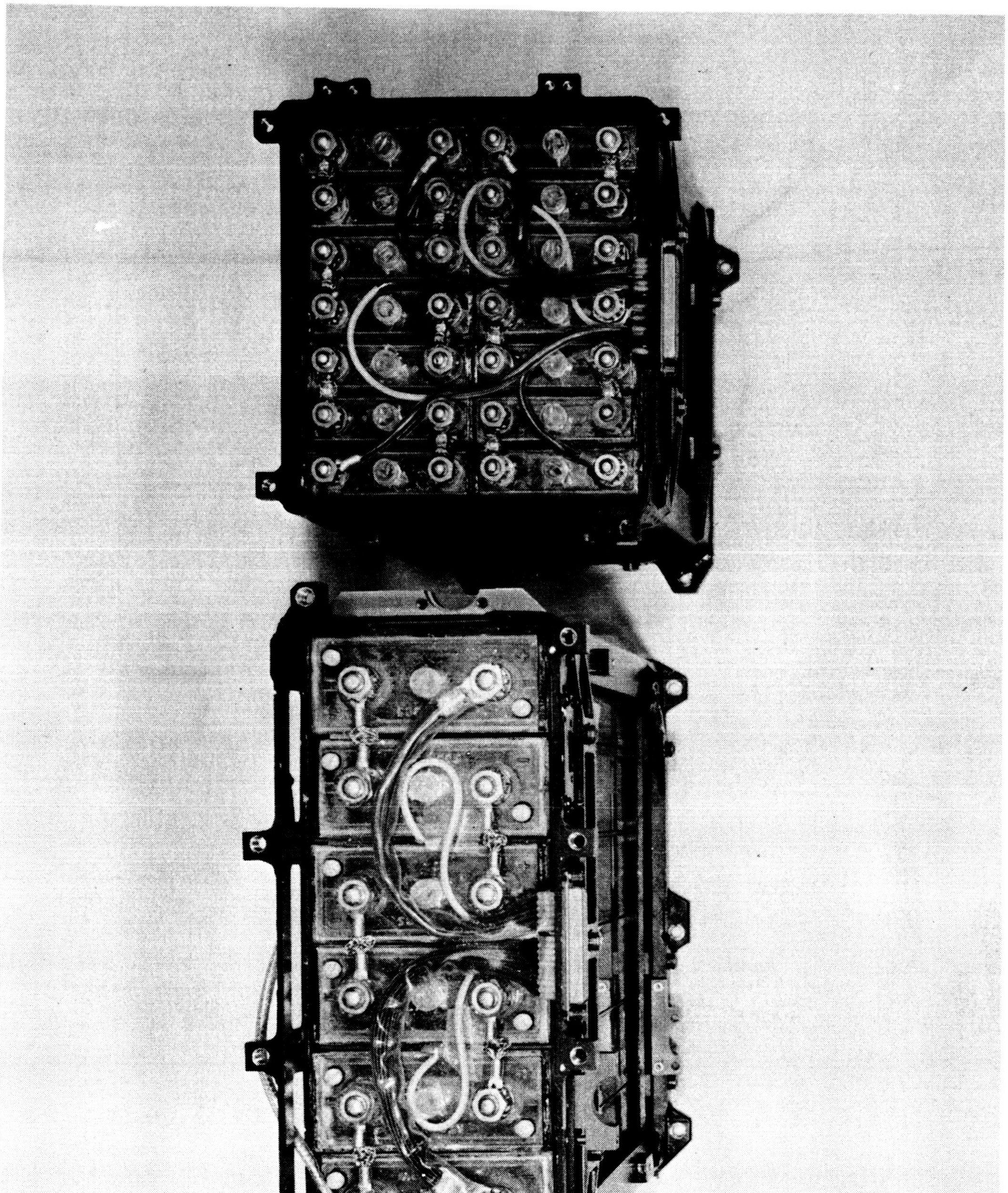

Photo A-5–Top View of Batteries B and F_1, F_2 (NASA G-66-1751)

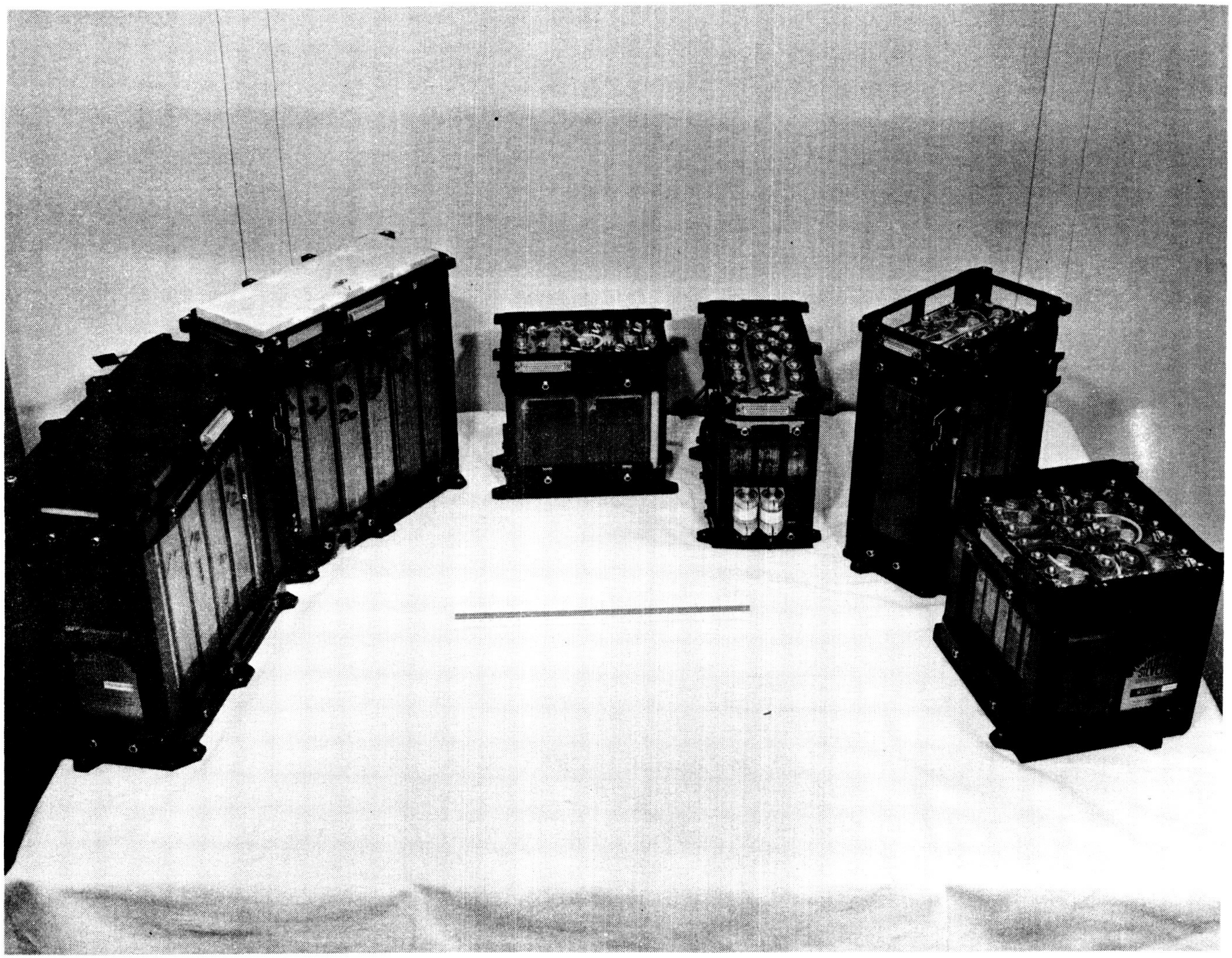

Photo A-6–Complete AE-B Battery Pack (NASA G-66-1753)