

FOURTH INTERIM TECHNICAL REPORT For The STUDY ON INTEGRATION OF SILVER-ZINC BATTERY IMPROVEMENTS

(1 January 1970 - 30 June 1970)

Contract No.: NAS 5-11579

GODDARD SPACE FLIGHT CENTER

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ABSTRACT

This report covers the technical progress and status on Goddard Space Flight Center Contract NAS 5-11579 for the period of 1 January 1970 through 30 June 1970. The object of this program is to develop an advanced single cell design for incorporation into a 12-amp-hr five-cell, sealed silver-zinc battery. During this reporting period the component and single cell design was developed for the five-cell battery.

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1.0 INTRODUCTION

1.1 OBJECTIVES

1.1.1 General

This report covers the period from 1 January 1970 to 30 June 1970, the first 6 months of the Third Phase of this contract. During this reporting period, the cell component tests were completed and the battery cell design was developed.

During Phases I and II of this contract, six, five-cell cavity monoblock case, silver-zinc batteries were designed, characterized, and delivered to NASA-GSFC.

The Phase III program objectives are to develop an advanced single cell design, fabricate and evaluate six, five-cell hermetically sealed batteries, and study the feasibility of encapsulating the cell core as an alternate case design.

1.1.2 Phase III - Statement of Work

This contract specifies five items to be accomplished during the third phase:

- 1) Develop a single cavity case with minimum interior draft angle and thin walls
- 2) Establish feasibility of epoxy encapsulating the cell core as an alternate case construction
- 3) Optimize separator system with a mechanical design to minimize zinc plate shape change
- 4) Design and fabricate six 12 amp-hr, five-cell batteries. Two separator configurations will be utilized
- 5) All cell and battery components shall be subject to 100 percent engineering inspection.

1.1.3 Technology Goals

The development of an improved silver-zinc battery for synchronous earth orbit, 3-year space applications is the primary purpose of this contract. There are three main battery design goals for this program: 1) 3-year battery wet life, 2) 270 cycles at 60 percent depth of discharge, and 3) battery seal integrity for 3 years. Achievement of the cycle life and wet stand goals are most dependent upon the availability of improved separator systems. During the third phase of this contract, the separator design will be optimized for increased zinc electrode capacity and improved chemical stability. Although state of the art cell terminal seal technology has been satisfactory for long life space applications, possible improvements in terminal-cover seal design will be investigated.

1.2 BACKGROUND

1.2.1 State of the Art Silver-Zinc Cells

Many Government-sponsored technology contracts over the last 3 to 4 years have led to specific improvements in the silver-zinc system. However, while improved components (i. e., plates, separators, and seals) have been developed on independent programs, there has been little effort made to incorporate several of these improvements into one silver-zinc battery. The purpose of this program is to combine several independently developed improvements, along with lighter weight aerospace packaging, into one battery designed for optimum performance.

2.0 TECHNICAL DISCUSSION

2.1 PLATES

2.1.1 Requirements

The required deliverable discharge capacity is 12 amp-hr with a 7.2-ampere use rate. The battery cycle life design goal is 270 cycles at a 60 percent depth of discharge over a 3-year period. The 24-hour synchronous earth orbit duty cycle consists of 23 hours charge and 1 hour discharge.

2.1.2 Parameters

The following battery plate parameters have been considered for establishing the optimum design.

- 1) Total positive plate capacity
- 2) Negative-to-positive capacity ratio
- 3) Coulombic efficiency
- 4) Active material plate density
- 5) Plate current density
- 6) Number and dimensions of plates

Based on the design requirements discussed in Paragraph 2.1.1, the total silver plate capacity was established at 16 amp-hr. The increased positive plate capacity over the nominal 12 amp-hr provides for a possible 25 percent loss of negative plate surface area caused by zinc plate shape change. The negative-to-positive plate capacity ratio has been set at 2.5 to 1.0 with an active material coulombic efficiency of 70 percent for both silver and zinc oxide plates. The positive and negative active material plate densities, 74 grams silver per cubic inch and 47.5 grams zinc oxide per cubic inch, respectively, have been selected for low rate operation. The maximum discharge plate current per unit area is 0.064 ampere per square inch of plate area with the battery use rate at 7.2 amperes. The total positive plate surface area is defined by the following relationship:

$$\text{Total plate area (in}^2\text{)} = \frac{\text{Battery use rate current (amperes)}}{\text{Current per unit area of plate (amp/in}^2\text{)}}$$

The computed total positive plate area is 112 square inches. The individual plate area (one side) is 9.33 square inches, based upon the use of six silver plates and seven zinc oxide plates per cell. Plate dimensions selected are 2.50 inches wide and 3.80 inches high to permit use of a 1.5 to 1.0 height to width ratio.

The active material plate thickness is defined by the following relationships:

$$\text{Total mass (gm)} = \frac{\text{Total plate capacity (amp-hr)}}{\text{Coulombic equivalent (amp-hr/gm) x efficiency}}$$

$$\text{Total active material volume (in}^3\text{)} = \frac{\text{Total mass (gm)}}{\text{Active material density (gm/in}^3\text{)}}$$

$$\text{Active material thickness (inch)} = \frac{\text{Total active material volume (in}^3\text{)}}{\text{Total plate area (in}^2\text{)}}$$

The computed silver and zinc oxide active material thickness is 0.0111 and 0.0326 inch, respectively. The general plate design is summarized in Table 1.

TABLE 1. GENERAL DESIGN SUMMARY

Total silver plate capacity	16.0 amp-hr
Total zinc oxide to silver capacity ratio	2.5:1.0
Total plate area	112 square inches (64.5 ma/in ² at 7.2 ampere)
Number of plates	
Silver	6
Zinc oxide	7
Height to width plate ratio	1.5:1.0

2.1.3 Positive Plate Characteristics

The chemical and physical characteristics of the positive plates to be utilized in the batteries for the third phase of this program are described in Table 2.

2.1.4 Negative Plate Characteristics

The chemical and physical characteristics of the negative plates to be utilized in the batteries for the third phase of this program are described in Table 3.

TABLE 2. CHEMICAL AND PHYSICAL CHARACTERISTICS OF SILVER PLATES

Dimensions:	
Width	2.500 ± 0.030 inches
Height	3.800 ± 0.030 inches
Thickness	0.012 ± 0.001 inch
Corner radii, typical	0.125 ± 0.010 inch
Density	74.0 gm/in ³ , 43 percent
Weight	
Active material, silver	7.60 ± 0.10 grams
Grid	1.17 ± 0.04 grams
Tab	0.03 ± 0.01 grams
Total	8.80 ± 0.15 grams
Area (one side)	9.33 square inches
Capacity	2.67 amp-hr

TABLE 3. CHEMICAL AND PHYSICAL CHARACTERISTICS OF ZINC OXIDE PLATES

Dimensions:	
Width	2.500 ± 0.030 inches
Height	3.800 ± 0.030 inches
Thickness	0.033 ± 0.002 inch
Density	47.5 gm/in ³ , 52 percent
Weight	
Active material	
ZnO	14.53 ± 0.10 grams
HgO	0.030 gram
Grid	1.00 ± 0.05 gram
Lead wires (4)	0.34 ± 0.05 grams
Total	16.17 ± 0.20 grams
Capacity	6.67 amp-hr

2.1.5 Specifications

The silver and zinc oxide plate procurement specifications were prepared and delivered to NASA-GSFC. The following NASA-GSFC specifications are described in Appendix I.

- 1) Requirements for Unformed Zinc Oxide Plates for Aerospace Application
- 2) Requirements for Unformed Silver Plates for Aerospace Application

2.2 SEPARATOR SYSTEM

2.2.1 Design Goals

Two main design goals have been established for the separator system: 1) extended wet life of 3 years in 40 percent potassium hydroxide solution at 25° C, and 2) provide mechanical support for the zinc oxide plate to minimize the shape change. Conventional silver-zinc cells utilize cellophane as the primary separator material. Cellophane unfortunately is subject to extensive degradation in potassium hydroxide solution and is limited to a maximum of 18 months wet life. The RAI Research Corporation, 2291 Permion, polyethylene separator material is apparently capable of extended wet life and will be used in batteries for this program. Although Permion 2291 has satisfactory chemical stability, it provides poor mechanical support for the zinc plate because of the low swell factor (5 percent) when soaked in 40 percent potassium hydroxide solution. An auxiliary support member will be incorporated in the separator system for the purpose of increasing negative plate mechanical support. An additional design goal is to optimize the separator system for the following operating conditions: 1) use rate: 7.2 amperes, and 2) temperature range: 0 to 25° C.

2.2.2 Configuration

The separator system is comprised of three components: 1) positive plate absorber, 2) separator material, and 3) negative plate support member. The absorber and support member aid electrolyte mobility between the separator material and plates. The support member also functions as a mechanical support structure for the negative plate. The separator system component sequence starting with the silver plate is as follows, and is illustrated in Figure 1:

Silver plate/absorber/separator/support/zinc oxide plate

2.2.3 Candidate Materials

The component materials selected for evaluation in the single cell screening tests are listed in Table 4.

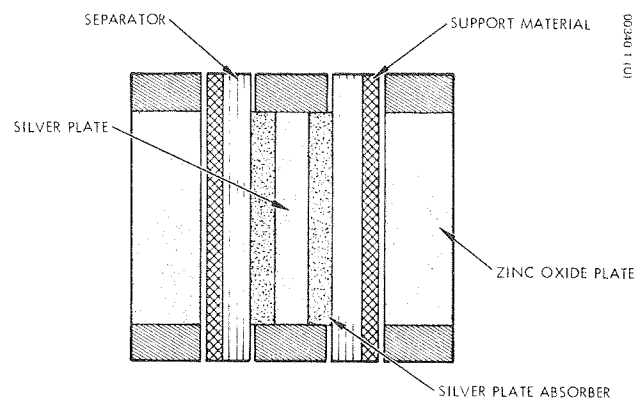


Figure 1. Separator Component Configuration

TABLE 4. CANDIDATE SEPARATOR MATERIALS

	Thickness, mils	Layers
Absorber		
Dynel - EM 470	1.	1
Pellon - 2505K	5.	1
KT-LPM 174-67	10.	1
Asbestos - F. C. A.	10.	1
Separator		
Polyethylene - 2291	1.5	4 to 5
Cellophane - 193 PUDO	1.	5
Support		
Pellon - 2505K	5.	1
Asbestos - FCA	10.	1
Cellophane - 193 PUDO	1.	2 to 3
KT-LPM 174-67	10.	1
Visking	3.	1

The materials were selected for component function and compatibility with the design goals discussed in Paragraph 2.2.1. Although cellophane has been eliminated as a separator material for this program, it has been selected as a separator material for comparative purposes in the single cell screening tests. Cellulosic materials have been selected as candidate support materials because the functional requirements for support members differ from that of separator materials.

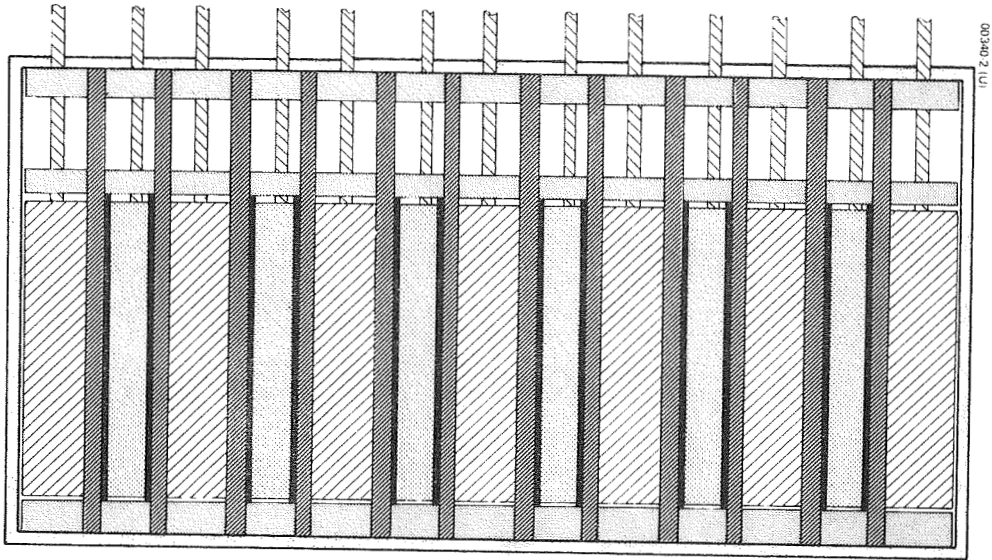
2.3 FRAME-SEPARATOR SPACER

2.3.1 Requirements

The frame-separator spacer serves four functions: 1) retains electrolyte in the plate region, 2) forms an interseparator gasket seal, 3) supports the silver and zinc plate edges, and 4) positions and separates the plate tabs leaving the cell stack. Electrolyte management within the cell is most critical when long cycle life is required. As discussed in Paragraph 3.1.1, electrolyte interaction with the zinc electrode is a primary cause of negative plate shape change.

2.3.2 Configuration Cross Section

Figure 2 illustrates the frame-separator spacer and plate stackup configuration. The separator, frame, and plate are sequentially positioned to complete the stackup of seven negative plates and six positive plates.










- | | | | |
|---|-------------------|---|--------------------------------|
|  | PLATE TABS |  | SEPARATOR AND SUPPORT MATERIAL |
|  | SILVER PLATES |  | ABSORBER |
|  | ZINC OXIDE PLATES |  | SEPARATOR FRAME |
|  | EPOXY | | |

Figure 2. Cell Stack Cross Section

2.3.3 Alternate Design

Zinc plate shape change typically occurs first in the upper plate region. The availability of excess free electrolyte in this region is considered an important cause of zinc plate slumping. Three frame patterns were selected for screen testing as illustrated in Figure 3. These frames are configured as follows: 1) Pattern A surrounds the plate, 2) Pattern E is extended above the upper plate edge, and 3) Pattern AE surrounds the plate and is extended above the plate forming a rectangular closure. Frame pattern AE is unique because it incorporates an integral electrolyte reservoir above the plate with an opening to the plate compartment for electrolyte mobility. Pattern A provides no free electrolyte volume above the plate, while Pattern E exposes the upper plate edge to free electrolyte which is similar to conventional cells.

2.4 SINGLE CELL SCREENING TESTS

2.4.1 Test Configuration

The single cell test configuration consists of a three-plate cell, two silver plates and one zinc oxide plate, as illustrated in Figure 4. The cell case construction includes two epoxy glass fiber reinforced sheets positioned on the sides of the cell stack and epoxy encapsulated on the edges. The positive and negative plates utilized in the separator and frame screening tests were procured during Phase II of this program. Although the Phase III plate design is different, Phase II plates were used to ensure conformance to the program schedule. Eighteen single cells were fabricated and assembled into a cell pack, as shown in Figure 5. Six cells incorporated frame design modifications and the remaining twelve cells included separator system variations.

2.4.2 Test Cycle Description

An accelerated 8-hour test cycle was selected for component evaluation. The test cycle consisted of 7.5 hours charge at 0.072 ampere with a voltage limit of 2.00 volts per cell and 0.5 hour discharge at 1.0 ampere. The nominal depth of discharge is 25 percent. The maximum overcharge is 10 percent with the voltage limit set for 2.00 volts per cell x 18 cells for the series connected circuit. All tests were conducted at room ambient temperature.

2.4.3 Separator Evaluation

The purpose of the separator screening test is to optimize the individual separator system components for reducing zinc electrode shape change. A standard separator system configuration was selected as follows: 1) positive absorber - one layer Pellon 2505K, 2) separator - four layers 2291 polyethylene, and 3) support member - two layers cellophane 193 PUDO. The candidate separator materials for each component are listed in Table 4. The candidate materials for one component category were each incorporated in test cells with standard materials in the other categories as shown in Table 5.

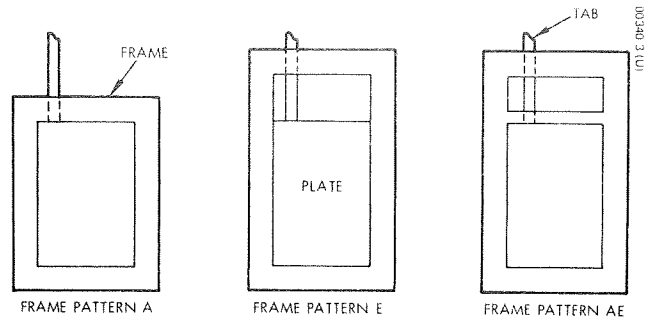


Figure 3. Frame - Separator Spacer Designs

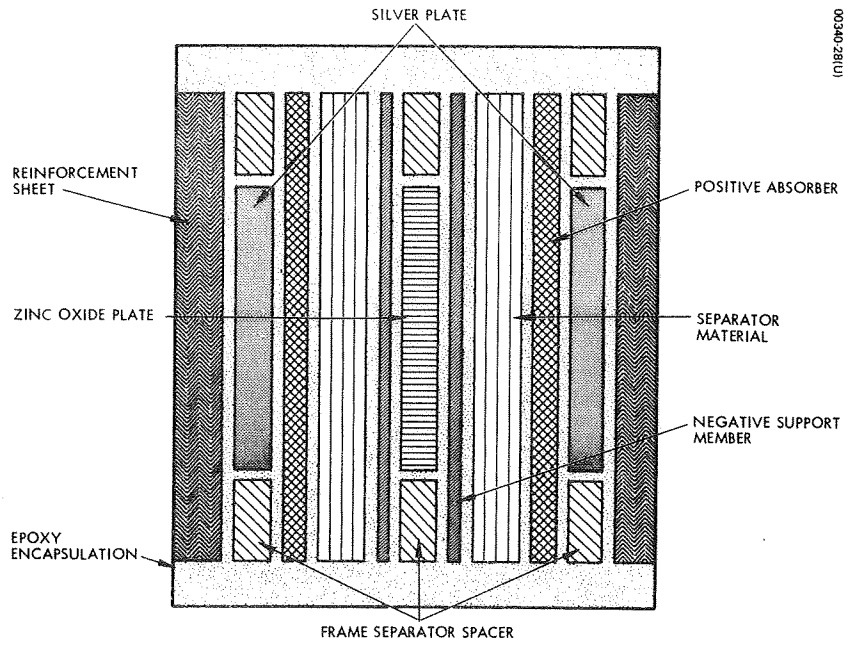


Figure 4. Test Cell Configuration

TABLE 5. SEPARATOR MATERIAL TEST PLAN

Configuration	Category 1 (Positive Absorber)	Category 2 (Separator)	Category 3 (Support Member)
A	<u>Variables</u>	<u>Standard</u>	<u>Standard</u>
B	One layer - Pellon	Four layers - 2291	Two layers - cellophane
C	One layer - Dynel	↓	↓
D	One layer - KT		
	One layer - asbestos	<u>Variables</u>	<u>Standard</u>
	<u>Standard</u>	Four layers - 2291	Two layers - cellophane
E	One layer - Pellon	Five layers - 2291	↓
F	↓	Five layers - cellophane	
G			
	<u>Standard</u>	<u>Standard</u>	<u>Variables</u>
H	One layer - Pellon	Four layers - 2291	One layer - Pellon
I	↓	↓	One layer - asbestos
J			Three layers - cellophane
K			Two layers - cellophane
L			One layer - KT
M			One layer - Visking

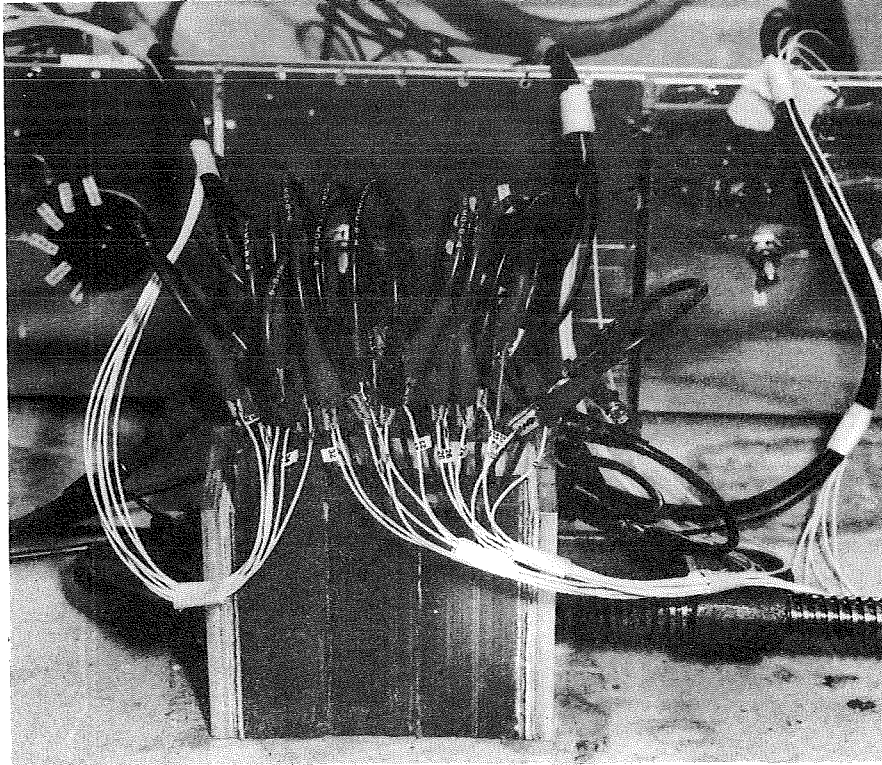


Figure 5. Screening Tests, Cell Pack
(Photo A27183)

Test cells were subjected to 60 cycles in accordance with Paragraph 2.4.2. Cell performance was evaluated for percentage of zinc electrode shape change and average discharge voltage. Results of the testing program indicated that a definite improvement in cell performance can be attained by proper selection of separator components, as shown in Table 6. Based on the results of the component screening tests and the separator design goals discussed in Paragraph 2.2.1, the following components have been selected for further evaluation:

- 1) Category 1, positive absorber – Pellon 2505K
- 2) Category 2, separator – Permion 2291
- 3) Category 3, negative support – KT-LMP174-67 and cellophane 193 PUDO

Although the cellophane separator test cell performance was much superior to any other cell tested, the poor wet life capability of cellophane precludes its usage as a separator material.

2.4.4 Frame Evaluation

The three frame separator-spacer patterns, A, E, and AE, described in Paragraph 2.3.3, each were incorporated in two test cells. All cells were assembled in a cell pack as illustrated in Figure 6 and were subjected to accelerated cycling as described in Paragraph 2.4.2. Both A-pattern cells failed after 20 cycles because this design provides no excess electrolyte storage above the plates; it promotes loss of electrolyte during cell out-gassing. The remaining cells completed 60 cycles and were inspected for negative plate shape change. Table 7 summarizes the frame evaluation test results. The AE frame pattern has been selected for incorporation in Phase III batteries based on frame evaluation results. Teksun Inc., Los Angeles, is the subcontractor that will develop the tooling and will injection mold these frames.

TABLE 6. RESULTS OF SEPARATOR SCREENING TESTS

Category	Material	Shape Change, Zinc-Area, percent	Discharge Voltage, volts			Component Choice
			Cycle 20	Cycle 40	Cycle 60	
Positive absorber	Pellon	30	1.37	1.42	1.41	1st
	Dynel	40	1.29	1.34	1.30	
	KT	40	1.36	1.38	1.37	2nd
	Asbestos	20	1.39	Failed	Failed	
Separator system	4-2291	30	1.42	1.42	1.41	1st
	5-2291	30	1.32	1.33	1.37	2nd
	5-cellophane	5	1.42	1.46	1.46	
Negative support member	Pellon	45	1.46	1.44	1.42	
	Asbestos	35	1.44	1.43	1.41	
	3-cellophane	30	1.37	1.42	1.41	
	2-cellophane	35	1.38	1.40	1.39	2nd
	KT	25	1.45	1.42	1.43	
	Visking	30	1.42	1.42	1.41	

TABLE 7. RESULTS OF FRAME-SEPARATOR SCREENING TESTS

Pattern Design	Shape Change, Zinc-Area, percent	Discharge Voltage, volts			Component Choice
		Cycle 20	Cycle 40	Cycle 60	
A	30	1.39	Failed	Failed	
	25	1.32	Failed	Failed	
E	40	1.36	1.25	1.32	2nd
	50	1.31	1.30	1.28	
AE	40	1.35	1.39	1.38	1st
	30	1.43	1.41	1.43	

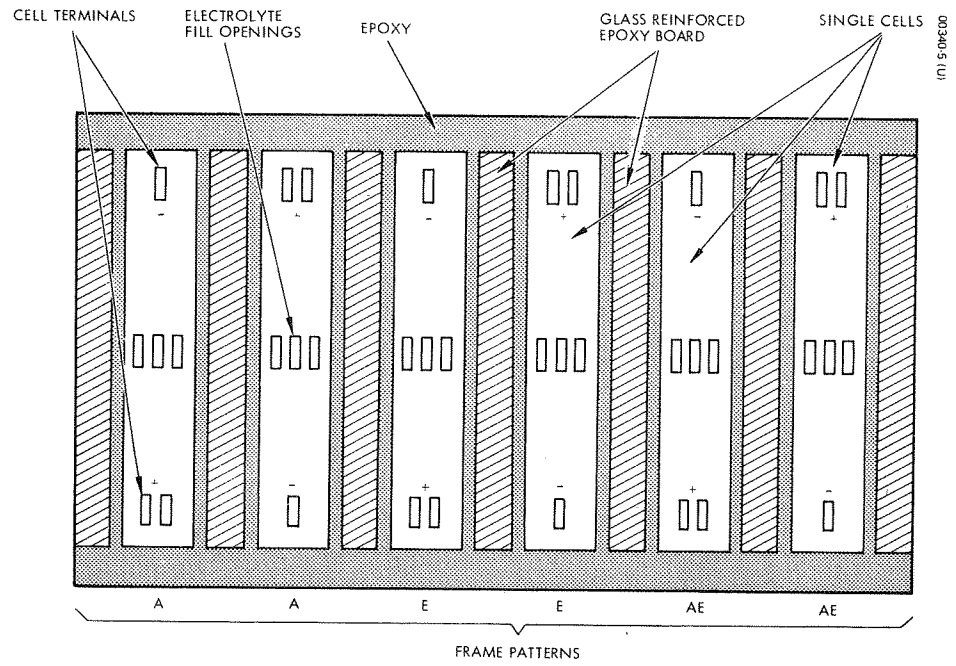


Figure 6. Frame Evaluation Cell Pack, Top View

2.5 CELL STACK

2.5.1 Configuration Options

Batteries for this program will use two cell configuration options as summarized in Table 8. The configurations are based on the separator and frame screening test results discussed in Section 2.4. The configurational options differ only in the material utilized for the negative plate support member, Option 1, incorporates Potassium Titanate paper and Option 2 incorporates Cellophane.

TABLE 8. SUMMARY OF CELL CONFIGURATION OPTIONS

Category or Component	Material	Option 1	Option 2
Positive absorber	Pellon 2505K	One layer 0.005 inch thick	One layer 0.005 inch thick
Separator	RAI Permion 2291	Four layers each 0.0015 inch thick	Four layers each 0.0015 inch thick
Negative support member	1) Mead KT-LMP174-67 2) DuPont Cellophane 193 PUDO	One layer KT 0.010 inch thick	Three layers cellophane each 0.001 inch thick
Frame	GE NORYL 731-701	Pattern AE	Pattern AE

2.5.2 Assembly

The cell case fabrication procedure entails stacking the components in the order listed below:

- 1) Negative plate frame
- 2) Zinc oxide plate
- 3) Separator system
- 4) Positive plate frame
- 5) Silver plate

- 6) Separator system
- 7) Repeat Items 1 through 6 six times
- 8) Negative plate frame
- 9) Zinc oxide plate

The cell core peripheral surfaces are epoxy encapsulated to immobilize the assembly for insertion into the cell case as illustrated in Figure 6.

2.5.3 Electrolyte Reservoir

The frame pattern AE provides a compartmentalized electrolyte reservoir for each plate as shown in Figure 7. Functionally the reservoir stores excess free electrolyte and regulates the electrolyte access to the upper plate edge. Additionally, the reservoir forms a free gas volume storage region. The advantages of this unique design are discussed in greater detail in Section 3.1.

2.6 CELL CASE AND COVER

2.6.1 Requirements

The physical design requirements for the single cell cavity case and cover are as follows:

- 1) Minimum interior case wall draft angle, $0^{\circ} 0'$ to $0^{\circ} 30'$ maximum
- 2) Thin case wall, 0.100 to 0.150 inch maximum thickness
- 3) Parallel outside case walls
- 4) Retain internal cell pressure 50 psig
- 5) Resealable electrolyte fill tube in the cover

The minimum interior case wall draft angle is particularly important for optimizing the separator system-plate interface. This battery design relies heavily on the case walls to provide support for the negative plates because the 2291 separator system offers only a 5 percent swell factor when wet with 40 percent weight KOH. The cell and cover material design requires chemical stability for 3 years in a caustic solution with an operating temperature range of 0° to 25° C.

2.6.2 Material and Process

Based on the physical and chemical design requirements discussed in Paragraph 2.6.1, the material selected for the case and cover is General Electric 731-701 Noryl. The primary constituents of Noryl are 50 percent

polyphenylene oxide with about 30 percent polystyrene. This material also was selected as the packaging material for the batteries developed during the second phase of this contract. The case and cover will be injection molded with special highly polished steel tooling. Because Noryl thermoplastic requires elevated temperature and increased pressure for injection molding, low cost aluminum tooling is considered unsatisfactory for this application. Jupiter Engineering Inc. , Menlo Park, California, is the subcontractor that will develop the tooling and will injection mold the cell cases. Teksun Inc. , Los Angeles, will provide the cell covers to Hughes drawing requirements.

2.7 CELL TERMINAL AND VENT SEAL

2.7.1 Requirements

Prevention of electrolyte leakage is the prime design requirement for the metal-to-plastic terminal and vent tube seals. The seal must withstand exposure to forty weight percent potassium hydroxide solution in combination with oxygen gas for three years and retain fifty pounds per square inch internal gas pressure within the operating temperature range of 0° to 25° C.

2.7.2 Seal Techniques

The stratified seal technique was selected for this plastic-to-metal seal application in conjunction with an "O" ring gland seal as illustrated in Figure 8. Each terminal and vent tube seal is a series of three metal-to-plastic seals consisting of one stratified seal at both the top and bottom surfaces of the cell cover, with an "O" ring gland seal positioned between the stratified seals, as shown in Figure 9. Generally, the stratified seal technique consists of alternate layers of epoxy adhesive and neoprene elastomer bridged between the metal terminal and plastic cover. The neoprene elastomer is chemically solvent-welded to the cover and mechanically immobilized with the epoxy adhesive for improved seal integrity. A detailed discussion of this seal technique and failure mechanism is presented in the New Technology Section of this report. Ethylene propylene rubber was selected as the "O" ring seal material because it has excellent chemical stability in potassium hydroxide solution. The "O" ring gland design developed for this program differs significantly from conventional designs in the number of metal and plastic "O" ring interfaces as illustrated in Figure 10. The improved design provides two metal and two plastic interfaces with the "O" ring, compared with one metal and three plastic interfaces for the conventional design.

2.8 CELL ASSEMBLY

2.8.1 Fabrication Sequence

Cell fabrication entails three main steps: 1) cell core assembly, 2) cell cover assembly, and 3) case, cover, and cell core assembly. The cell core assembly procedure has been described in detail in Section 2.5.

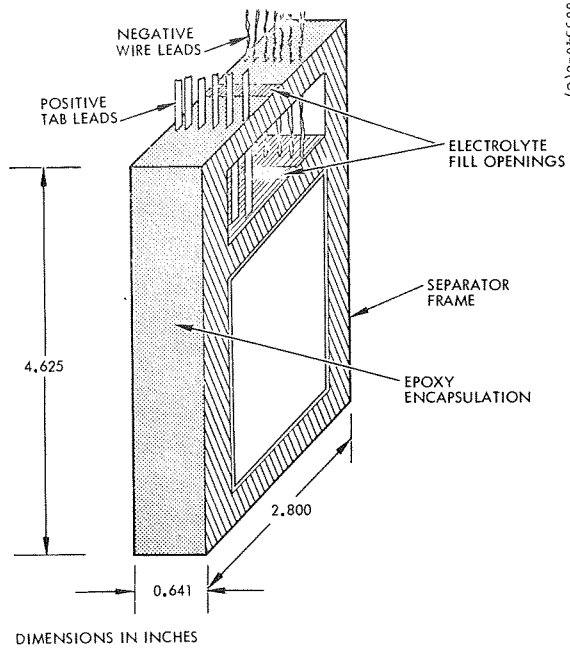


Figure 7. Cell Core Assembly

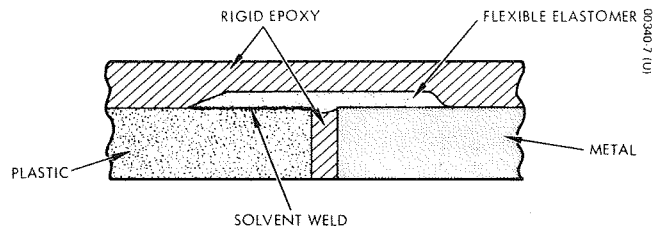


Figure 8. Stratified Seal Design

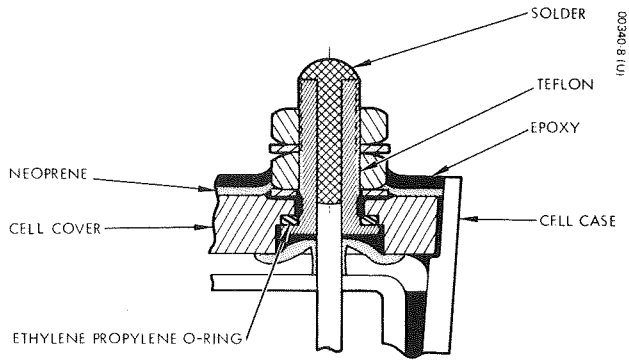


Figure 9. Cell Terminal Seal Configuration

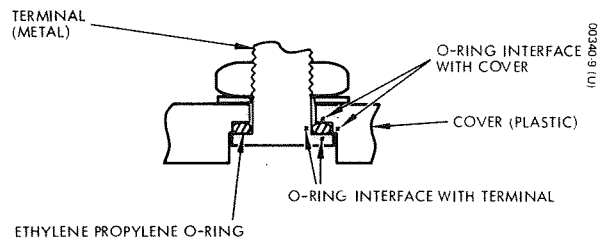


Figure 10. New "O" Ring Gland Design

The cover assembly fabrication sequence is based on the seal technique covered in the previous paragraph and is illustrated in the fabrication sequence charts, Figure 11. The complete cell core, cover, and cap assembly procedure is diagrammed in Figure 11.

2.9 BATTERY PACK

2.9.1 Assembly Configuration

The five-cell battery pack is retained in position with a four thru-bolt end-plate laboratory assembly. The end plates are constructed from 0.50 inch thick 6061 aluminum plate stock, anodized black.

The individual cell terminal polarity orientation is alternated in the battery pack for series electrical connection. A complete set of battery assembly and component drawings are included in Appendix II.

2.9.2 Electrical Wiring

The battery power wiring and intercell connector configuration is shown in Figure 12. Power connections from the positive terminal of cell 5 and negative terminal of cell 1 to the battery connector plug are made with six teflon insulated 20 AWG wires. The cell and battery instrumentation wiring diagram is illustrated in drawing number X3205978, Appendix II.

2.9.3 Connector Plug

The 25-pin battery electrical connector plug is mounted on a retainer end plate. The connector plug pin utilization is shown in Figure 13.

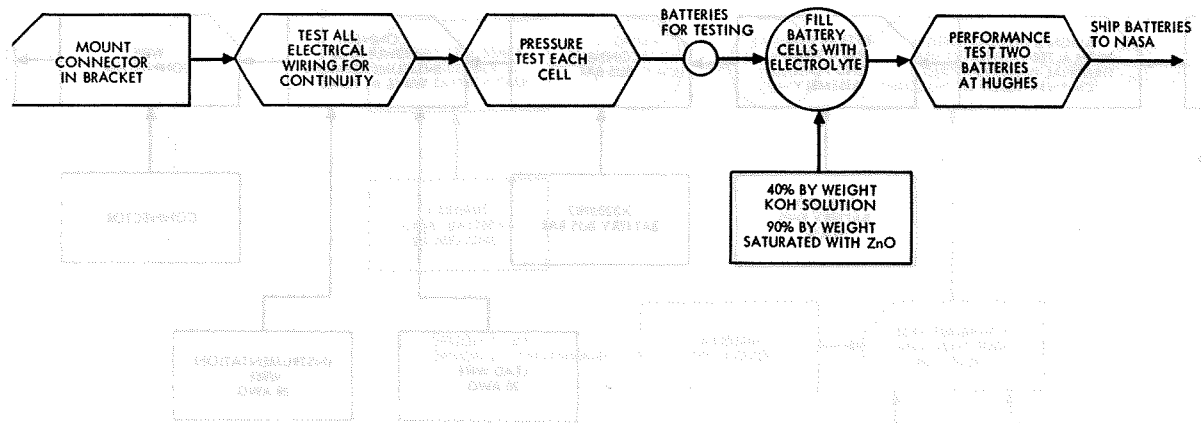


Figure 11. Fabrication Sequence Chart

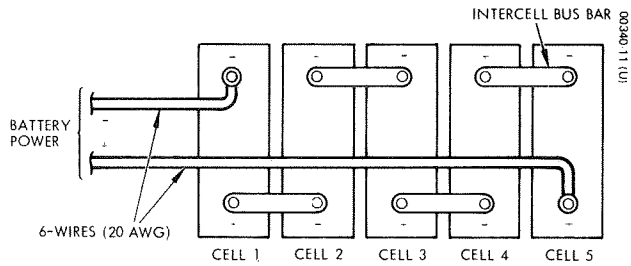


Figure 12. Battery Power Electrical Connection Diagram

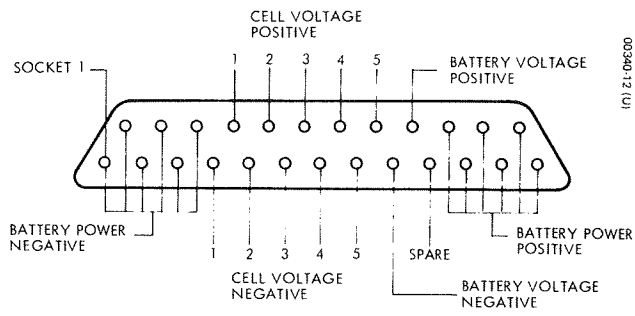


Figure 13. Battery Connector Plug Pin Utilization

3.0 NEW TECHNOLOGY

3.1 ELECTROLYTE RESERVOIR

3.1.1 Electrode-Electrolyte Interaction

The zinc electrode is highly soluble in 40 percent potassium hydroxide solution. The soluble zincate ion tends to selectively form in the upper plate region because of excess electrolyte availability. The zincate then redistributes uniformly throughout the cell and recombines with the zinc electrode. The net result of the selective dissolution and uniform recombination of zinc species is negative electrode shape change, i. e., active zinc material tends to redistribute lower on the plate. The negative plate shape change reduces the apparent geometrical plate surface area and decreases the usable cell capacity.

3.1.2 Transport Zone

Greater quantities of electrolyte tend to move through the upper plate region during cell operation because cell outgassing decreases the available electrolyte volume in the plate area. Therefore, electrolyte is transported upward into the zone above the plates. Regulation of the electrolyte flow in the transport zone is considered important for decreasing selective zinc dissolution and negative plate shape change.

3.1.3 Improved Design

A new separator-frame configuration has been developed incorporating an electrolyte reservoir with an opening to the top of the electrode. The opening regulates the zone which excess electrolyte enters or leaves the upper plate region. The reservoir is formed by a rectangular frame positioned above the electrode, as shown in Figure 7. Results of the single cell screening tests indicate this design reduces zinc plate shape change by 10 to 15 percent, as shown in Table 7.

3.2 SEAL TECHNIQUE – STRATIFIED

3.2.1 Cause of Seal Failure

The most common cell seal failure occurs at the electrical terminal cell cover interface. The conventional terminal seal consists of a flat ring gasket encapsulated with epoxy. Electrolyte leakage develops because epoxy is chemically degraded in the caustic environment and the plastic ring gasket tends to cold flow, resulting in failure of the terminal seal.

3.2.2 Cover-to-Case Seal

Typically, the plastic cell cover and case are sealed adhesively in a rigid joint. Seal integrity may be improved with the addition of a flexible elastomer layer between rigid adhesive layers. The elastomer layer is solvent-welded to the plastic cover and case, forming a flexible film layer between them, as illustrated in Figure 14. This unique stratified seal provides an added margin of safety when mechanical fractures of the rigid adhesive occur.

3.2.3 Terminal-Cover Seal

The terminal seal utilizes two new sealing methods, modified "O" ring gland and stratified adhesive joint, as shown in Figure 9. The stratified seal consists of alternating flexible elastomer and rigid adhesive layers between the metal terminal and plastic cover. The elastomer is solvent welded to the cover and terminal, then supported with rigid adhesive. The optimum number of elastomer-adhesive layers will depend on the particular application. The modified "O" ring gland seal utilizes two metal terminal and two plastic cover interfaces with the "O" ring material. Conventional gland designs incorporate one metal and three plastic to "O" ring interfaces. The modified design balances the interface surfaces and doubles the metal terminal surface interface area.

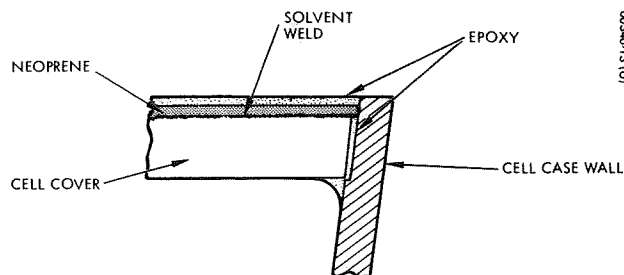


Figure 14. Case-to-Cover Seal

4.0 PROGRAM FOR NEXT REPORTING PERIOD

4.1 BATTERY FABRICATION

4.1.1 Cell Assembly

The cell fabrication sequence previously discussed in Paragraph 2.8.2 will be utilized for the 65 cells required for Phase III. The established cell assembly assignment schedule includes 40 cells for deliverable battery fabrication and 25 cells for experimental and engineering tests, as shown in Table 9.

4.1.2 Cell Capacity Matching

The average capacity of three formation cycles will be the basis for categorizing cells and their subsequent assignment to a battery. Formation capacity categories will be designated to optimize battery performance for extended cycle life. Cells will be incorporated into five-cell battery assemblies after formation cycle testing.

TABLE 9. CELL UTILIZATION SCHEDULE

Number of Cells	Number of Batteries	Utilization Description
30	6	Contract deliverable
10	2	Spares
10	—	Engineering test
15	—	Experimental test
65	8	Total

4.1.3 Battery Configuration Options

Six deliverable batteries will be fabricated with the two separator configuration options discussed in Paragraph 2.5.1. Option I incorporates an inorganic KT paper as a negative support member, and 193 PUDO cellophane is used for the support member in Option II. Each configuration option will be utilized in three batteries.

4.2 BATTERY PERFORMANCE

4.2.1 Capacity Testing

Batteries will be subject to two discharge capacity cycle tests. The discharge current for capacity test I is 5 ampere constant with a 1.30 volt per cell cutoff. Capacity test II discharge current will be 7.2-ampere constant with a 1 volt per cell cutoff. The charge current for both tests is 1 ampere constant with an end charge voltage limit of 1.98 volts per cell. Volumetric gas generation measurements will be conducted during tests I and II.

4.2.2 24-Hour Cycle Testing

After capacity testing, two batteries will be placed on the 24-hour cycle testing, one battery will be selected from each configuration option. The batteries will be subjected to 20 cycles, 10 continuous cycles at $25 \pm 2^\circ \text{C}$, followed by 10 cycles at $0 \pm 2^\circ \text{C}$. The final battery discharge capacity will be determined following the low temperature continuous cycling test. The 24-hour cycle regime charge period is 23 hours with a 1 ampere constant potential charge voltage of 1.98 volts per cell and current cutoff of 160 milliamperes, followed by a reduced charge potential of 1.87 volts per cell. The discharge current is 7.2 amperes for a 1 hour period. The testing program summary is detailed in Appendix III.

4.2.3 Gas Evolution Analysis

Volumetric gas evolution data will be recorded for the 24-hour cycle testing. Based on the rate of oxygen and hydrogen evolution and recombination, the maximum internal cell pressure will be determined. Battery cycling modifications will be recommended for minimizing internal cell pressure based on the gas evolution analysis.

4.3 ENCAPSULATED CELL FEASIBILITY STUDY

4.3.1 Design Goal

The objective of this study is to evaluate the feasibility of eliminating the cell case altogether by encapsulating the cell stack with epoxy. The encapsulated case design, if feasible, would simplify cell construction as well as improve the plate and separator interface geometry.

4.3.2 Cell Fabrication

Three prototype cells will be constructed for evaluation of the case design, as shown in Figure 15. The advantages of this design would be as follows:

- 1) Lightweight construction
- 2) Simplicity of fabrication
- 3) Reduced case cost
- 4) No case draft angle, plate-separator interface optimized

The cell core is sandwiched between two plastic sheets and epoxy encapsulated around the edges, as shown in Figure 16.

4.3.3 Evaluation

The cell capacity tests will be performed on the prototype cells after electrochemical formation. The following operating characteristics will be evaluated:

- 1) Discharge capacity uniformity
- 2) Cell voltage performance
- 3) Electrolyte leakage
- 4) Cell case structural integrity

Performance data and photographs will be reported in the final technical report for this program.

4.4 PROGRAM SCHEDULE

4.4.1 Program Delay

The program schedule has been delayed by up to 90 days to accommodate an unexpected delay in the NASA-GSFC battery plate procurement. The plate manufacturer is undergoing a plant relocation and, therefore, is incurring a slippage in the delivery schedule.

All work on the program will be terminated on June 30, 1970 for up to 90 days.

5.0 RECOMMENDATIONS AND CONCLUSIONS

Recommendations and conclusions will be deferred until the next reporting period.

APPENDIX I
PLATE SPECIFICATIONS

REQUIREMENTS FOR UNFORMED ZINC OXIDE PLATES
FOR AEROSPACE APPLICATION
GSFC SPECIFICATION

1.0 SCOPE

An unformed zinc oxide plate for aerospace application is covered within this requirement.

2.0 APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

STANDARDS

Military

MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes.
MIL-STD-202	Test Methods for Electronic and Electrical Component Parts
MIL-STD-454	Standard General Requirements for Electronic Equipment.
MIL-STD-810	Environmental Test Methods for Aerospace and Ground Equipment.

DRAWINGS

NASA/Goddard Space Flight Center

3.0 REQUIREMENTS

In general, dry, unformed, 5.5 amp-hr zinc oxide plate is required for use in a 12 amp-hr nominal capacity silver zinc cell. This cell will consist of six positive and seven negative plates.

3.1 Physical Requirements - Plates shall be in conformance with NASA/Goddard Drawing

3.1.1 Plate Dimensions

Width	2.500 ± 0.030 inches
Height	3.800 ± 0.030 inches
Thickness	0.033 ± 0.002 inch
Corners	Square

3.1.2 Plate Weight and Composition

Zinc oxide	98 percent	14.53 grams
Mercuric oxide	2 percent	0.30
<hr/>		
Total active mix	100 percent	14.83 ± 0.10 grams
5 Ag 5-2/0 expanded grid		1.00 ± 0.05
Ag wire, 4 each		0.34 ± 0.05
<hr/>		
Finished plate weight		16.17 ± 0.20 grams

Plate manufacturer will inspect plates 100 percent and lot plot each of the following weights:

Grid weights
Core Structure (i. e., grid and tab)
Finished plate

Plates must be identified in three groups according to weight:

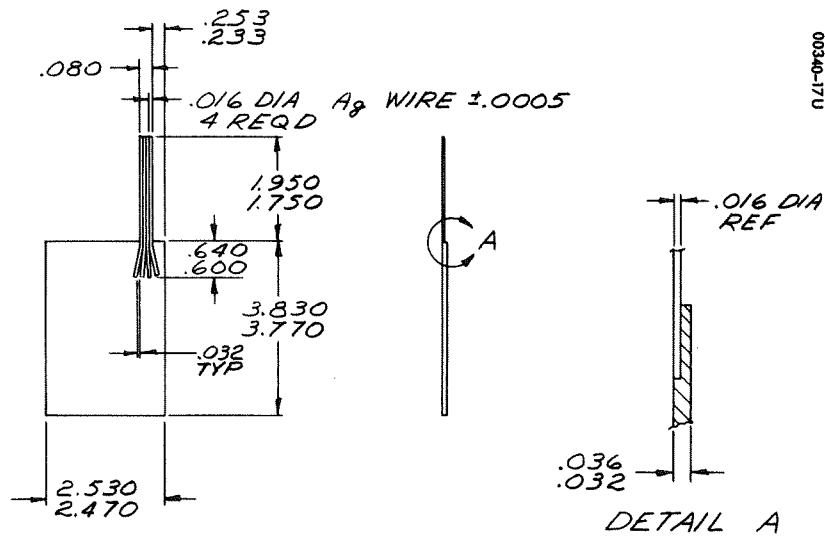
$$L = \bar{X} - (3 \text{ to } 5 \text{ percent})$$

$$N = \bar{X} \pm 3 \text{ percent}$$

$$H = \bar{X} + (3 \text{ to } 5 \text{ percent})$$

3.1.3 Density - The density of zinc oxide shall be 47.5 grams per cubic inch.

3.1.4 Plate Electrical Connections - A wire type of electrical connection is required. These wires shall extend from the top of the negative plate 1.85 ± 0.10 inches and shall be four conductors, 0.016 inch in



NOTES:
 1. ALL PROCEDURES AND REQUIREMENTS TO BE IN ACCORDANCE WITH DOCUMENTED SPECIFICATION INTITLED, RE REQUIREMENTS FOR HARDED ZINC OXIDE PLATES FOR APOSPACE APPLICATION.

Figure I-1. Zinc Oxide Plate

diameter. The wire material used for this tab shall be 99.9 percent pure silver minimum and shall be in the "full anneal" condition. The tab shall be attached to the silver EXMET-type grid of the negative plate utilizing localized coining of the plate and a capacitive spot weld. Evidence of optimum weld process conditions shall be available for review by GSFC personnel.

3.1.5 Exmet-Type Grid - The supporting structure of the negative plate shall be a 5 Ag 5-2/0, 99.9 percent silver, pierced and expanded 0.105 ± 0.005 grams per square inch, Exmet-type grid. The grid shall be 2.500 inches by 3.800 inches.

3.2 Chemical Requirements

3.2.1 Zinc Oxide Powder - The zinc oxide powder shall be equivalent to A. C. S. reagent grade in purity. Particle size shall be such that this powder has been thoroughly tested in the battery manufacturer's normal acceptance procedures, which shall include evidence of successful operation of silver-zinc cells manufactured from this powder. This evidence, in the form of engineering or quality control records, shall be made available to GSFC personnel, upon request.

3.2.2 Mercuric Oxide - The mercuric oxide used in the negative plate shall be A. C. S. reagent grade purity. It shall be used to make up 2 percent of the total active mix weight.

3.2.3 Exmet-Type Grid - The silver Exmet-type grid used in negative electrodes shall be 99.9 percent silver, with no single metallic or nonmetallic impurity exceeding 500 ppm.

3.3 Electrical Requirements

3.3.1 Capacity - Individual negative plates shall deliver a minimum capacity of 4.4 amp-hr when discharged at the one hour rate at 25°C. Prior to discharge, negative plates shall be charged at 25°C by constant current of 21 ma/in.² for 21 hours.

3.3.2 Current Density - The plate specified herein must operate at the following design points:

- | | | |
|----|-----------|--------------------------------|
| a) | Charge | 6.0 to 10.0 ma/in ² |
| b) | Discharge | 60 to 100 ma/in ² |

3.3.3 Depth-of-Discharge - The battery into which the plates of this specification will be incorporated, will operate between a 40 and 60 percent depth-of-discharge. The discharge current density figures of 3.3.2 reflect this depth-of-discharge.

3.4 Quality Requirements

3.4.1 Inspection – All nondestructively determined variables shall be measured on a 100 percent sampling basis. The following variables shall be measured:

- 1) Plate thickness, height, and width
- 2) Exmet-type grid weight
- 3) Total plate weight
- 4) Active mix weight, by difference.

Individual plate identifications need not be maintained; however, a frequency distribution plot, or equivalent tabular statistical information, shall be submitted for all variables measured. Evidence of rejection of plates falling outside the tolerance limits for any variable, shall be provided by the supplier to GSFC.

3.4.2 Manufacturing Lot – All negative plates supplied shall be fabricated from not more than three mix batches of active material. Documentation shall be available for review by GSFC to attest that not more than three active material mix batches are used. Copies of this documentation shall be sent to GSFC upon request.

3.5 Environmental Requirements

3.5.1 Operating Temperature Range – The negative plates shall be designed and fabricated for optimum performance within the temperature range of 30 to 100°F.

3.5.2 Electrolyte – Plates shall be manufactured for optimum performance in 40 percent weight, KOH solution.

4.0 TESTS

4.1 Physical

4.1.1 Dimensions – All plate dimensions, particularly thickness, height and width shall be measured on a 100 percent sampling basis to show conformance to Paragraph 3.1.1, and GSFC Drawing Measurement data shall be recorded and presented to GSFC in either tabular form or in the form of a frequency distribution curve for each dimension measured.

4.1.2 Weight – Exmet-type grids and completed plates shall be weighed and the data recorded to demonstrate conformance to Paragraph 3.1.2. Weights shall be determined by 100 percent sampling with the data submitted to GSFC as described in Paragraph 4.1.1.

4.2 Chemical

4.2.1 Zinc Oxide – A receiving inspection lot analysis record will suffice to demonstrate conformance to Paragraph 3.2.1. A certificate of conformance will be acceptable only if traceability to the material supplier's analytical records can be established.

4.2.2 Mercuric Oxide – A receiving inspection lot analysis record will suffice to demonstrate conformance to Paragraph 3.2.2. A certificate of conformance will be acceptable only if traceability to the material supplier's analytical records can be established.

4.2.3 Grid – A receiving inspection lot analysis record will suffice to demonstrate conformance to Paragraph 3.2.3. A certificate of conformance will be acceptable only if traceability to the material supplier's analytical records can be established.

5.0 PREPARATION FOR DELIVERY

5.1 Packaging – Four plates shall be stacked together with pieces of cardboard 0.075 to 0.100 inch thick interleaved between plates, with one piece of cardboard over each outer plate in the stack. The width and height of the cardboard shall be equivalent or slightly larger than that of the plates. The plate-cardboard sandwich shall be wrapped with adhesive coated glass tape, two wraps widthwise, one wrap heightwise. Plates shall be positioned in the shipping container such that they ride on edge rather than flat. Zinc plates shall be shipped with the Viskon retainer intact.

5.2 Identification – Each shipping container shall be externally identified with the following identification:

- 1) GSFC drawing number
- 2) Seller's part number
- 3) Date of completion of manufacture
- 4) Manufacturing lot number
- 5) GSFC contract number of purchase order number

5.3 Information Label – In a conspicuous place near the address label, the following information shall be plainly visible on the shipping container.

Attention: This box contains fragile battery plates. Do not open without first contacting GSFC Technical Monitor.

6.0 QUALITY ASSURANCE PROVISIONS

6.1 General – The materials, processes and assembly techniques used to fabricate the hardware covered by these requirements shall be subject to extensive inspection by both the Seller and by GSFC.

6.2 Inspection

6.2.1 Seller Inspection – Product quality assurance shall be provided by a series of in-process inspections commencing with the receipt of raw materials and parts continuing through the finished product. Selected inspection points shall have the approval of GSFC. A record shall be maintained of all inspection and be subject to review by GSFC.

6.2.2 GSFC Source Inspection – Goddard Space Flight Center shall at its option provide inspection to adequately monitor the Seller's quality control effort including in-process inspection and in-process tests. The complete hardware may be source inspected by GSFC to assure that the product conforms to all the requirements specified in applicable drawings listed above.

6.2.3 Rejected Assemblies – Rejected assemblies shall not be resubmitted for approval without furnishing full particulars concerning the rejection, the measure taken to overcome the defects and the prevention of future occurrence. Each rejected assembly or part shall be identified by a serialized rejection tag. This rejection tag shall not be removed until rework requirements have been complied with, and the tag shall be removed only by, or in the presence of, an authorized representative of GSFC.

REQUIREMENTS FOR UNFORMED SILVER PLATES
FOR AEROSPACE APPLICATION
GSFC SPECIFICATION

1.0 SCOPE

An unformed plate for aerospace application is covered within this requirement.

2.0 APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

STANDARDS

Military

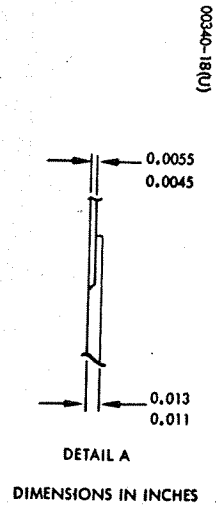
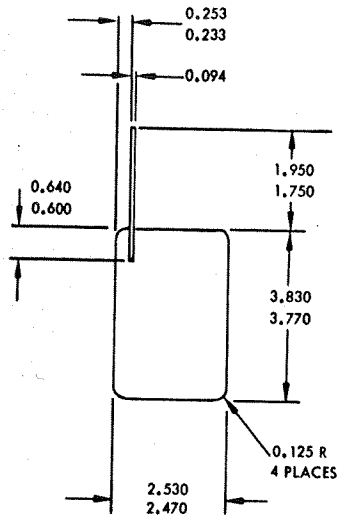
MIL -STD -105	Sampling Procedures and Tables for Inspection by Attributes
MIL -STD -202	Test Methods for Electronic and Electrical Component Parts
MIL -STD -454	Standard General Requirements for Electronic Equipment
MIL -STD -810	Environmental Test Methods for Aerospace and Ground Equipment.

DRAWINGS

NASA/Goddard Space Flight Center

3.0 REQUIREMENTS

In general, a sintered, unformed 2.2 amp-hr nominal capacity silver plate is required. This plate will be used in a high cycle life silver zinc battery. The design goal for cycle life is 270 cycles with a 60 percent depth-of-discharge at the 1 hour rate. The charge time will be in the range of 12 to 16 hours.



NOTE:
 ALL PROCEDURES AND REQUIREMENTS TO BE IN ACCORDANCE WITH
 DOCUMENTED SPECIFICATION ENTITLED, "REQUIREMENTS FOR
 UNFORMED ZINC OXIDE PLATES FOR AEROSPACE APPLICATION".

Figure I-2. Silver Plate

3.1 Physical Requirements - Plates shall be in conformance with NASA Goddard Drawing

3.1.1 Plate Dimensions

Width	2.500 ± 0.030 inches
Height	3.800 ± 0.030 inches
Thickness	0.012 ± 0.001 inch
Corners	0.125 + 0.010 inch typical maximum radius

3.1.2 Plate Weight

Active Silver	7.60 ± 0.10 grams
Total Plate	9.05 ± 0.10 grams*

*Active silver, grid, and tab.

Plate weight will be controlled as follows:

Weigh grid in sheets sized to make six plates. Weigh 100 percent and reject outside of range $X \pm 3$ percent. Lot plot measured weights.

Weigh sintered blanks 100 percent. Lot plot group into L, N, and H groups using above categories. Reject all blanks outside range of $X \pm 5$ percent.

Spotweld ribbon to plate. Inspect for dimensions and weld integrity. Paint weld with epoxy and cure. Measure finished plate weight. Lot plot.

3.1.3 Plate Density - The density of the silver plate shall be 74 gm/in³.

3.1.4 Plate Electrical Connection - A tab type of electrical connection is required. This tab shall extend from the top of the negative plate 1.85 ± 0.10 inches and shall be 0.094 ± 0.005 inch wide by 0.005 ± 0.0005 inch thick. The strip material used for this tab shall be 99.9 percent pure silver minimum and shall be in the "full anneal" condition. The tab shall be attached to the silver EXMET-type grid of the negative plate utilizing localized coining of the plate and a capacitive spot weld. Evidence of optimum weld process conditions shall be available for review by GSFC personnel.

3.1.5 EXMET-Type Grid - The supporting structure of the negative plate shall be 5 Ag 8-1/0, 99.9 percent silver, pierced and expanded, 0.125 ± 0.006 gm/in², EXMET-type grid. The grid shall be 2.500 by 3.800 inches.

3.2 Chemical Requirements

3.2.1 Silver Powder – The silver powder used for positive electrodes shall be 99.9 percent pure silver, with no single metallic or non-metallic impurity exceeding 500 ppm.

3.2.2 Grid – The silver Exmet-type grid used in positive electrodes shall be 99.9 percent pure silver, with no single metallic or nonmetallic impurity exceeding 500 ppm.

3.3 Electrical Requirements

3.3.1 Capacity – Individual positive plates shall deliver a minimum capacity of 2.10 amp-hr when discharged at the one hour rate at 25°C. Prior to discharge, positive plates shall be charged at 25°C by constant current charge at 6.5 ma/in² to 1.98 volts with respect to a pair of zinc plates. Charge and discharge shall be performed against two zinc plates, each equal in area to the silver plate. The ampere-hour capacity of the pair of zinc plates shall exceed the silver plate's capacity by at least 50 percent.

3.3.2 Current Density – The plate specified herein must operate at the following design points:

- | | | |
|----|-----------|--------------------------------|
| 1) | Charge | 6.0 to 10.0 ma/in ² |
| 2) | Discharge | 60 to 100 ma/in ² |

3.4 Quality Requirements

3.4.1 Inspection – All non-destructively determined variables shall be measured on a 100 percent sampling basis. The following variables shall be measured:

Plate thickness, height, width.

Grid weight for six plate assembly.

Sintered plate blank weight.

Compute active material weight based upon the measured mean grid weight for each six-plate biscuit group.

Refer to Section 3.1.2 for further description of measurements required.

Individual plate identifications need not be maintained; however, a frequency distribution plot, or equivalent tabular statistical information, shall be submitted for all variables measured. Evidence, of rejection of plates falling outside the tolerance limits for any variable, shall be provided by the supplier to GSFC.

3.4.2 Manufacturing Lot - All positive plates shall be fabricated from only one lot of active material. One mix batch of silver powder and one lot of resin will constitute one lot of active material. Documentation shall be available for review by GSFC to attest that only one active material mix batch is used. Copies of this documentation shall be sent to GSFC upon request.

3.5 Environmental Requirements

3.5.1 Operating Temperature Range - The positive plates shall be designed and fabricated for optimum performance within the temperature range of 30 to 100°F.

3.5.2 Electrolyte - Plates shall be manufactured for optimum performance in 40 percent weight KOH solution.

4.0 TESTS

4.1 Physical

4.1.1 Dimensions - All plate dimensions, particularly thickness, height, and width shall be measured on a 100 percent sampling basis to show conformance to Paragraph 3.1.1, and GSFC Drawing Measurement data shall be recorded and presented to GSFC in either tabular form or in the form of a frequency distribution curve for each dimension measured.

4.1.2 Weight - Exmet-type grids and completed plates shall be weighed and the data recorded to demonstrate the conformance to Paragraph 3.1.2. Weights shall be determined by 100 percent sampling with the data submitted to GSFC as described in Paragraph 4.1.1.

4.2 Chemical

4.2.1 Silver Powder - A receiving inspection lot analysis record will suffice to demonstrate conformance to Paragraph 3.2.1. A certificate of conformance will be acceptable only if traceability to the material supplier's analytical records can be established.

4.2.2 Grid - A receiving inspection lot analysis record will suffice to demonstrate conformance to Paragraph 3.2.1. A certificate of conformance will be acceptable only if traceability to the material supplier's analytical records can be established.

5.0 PREPARATION FOR DELIVERY

5.1 Packaging - Thirty-two plates shall be stacked together with two similarly sized piece of 0.075 to 0.100 inch cardboard on each end of the stack. Adhesive coated glass tape shall be wrapped around the outside

of this sandwich, at least two wraps in separate places in the 2.1 inch widthwise direction and one wrap in the 3.1 inch height direction. Glass taped, cardboard-plate sandwiches shall then be placed in wooden shipping containers. Not more than one-third of the total number of plates ordered shall be placed into any one wooden shipping container.

5.2 Identification – Each shipping container shall be externally identified with the following identification:

- 1) GSFC drawing number
- 2) Seller's part number
- 3) Date of completion of manufacture
- 4) Manufacturing lot number
- 5) GSFC contract number of purchase order number

5.3 Information Label – In a conspicuous place near the address label, the following information shall be plainly visible on the shipping container:

Attention: This box contains fragile battery plates. Do not open without first contacting GSFC Technical Monitor

6.0 QUALITY ASSURANCE PROVISIONS

6.1 General – The materials, processes and assembly techniques used to fabricate the hardware covered by these requirements shall be subject to extensive inspection by both the Seller and by GSFC.

6.2 Inspection

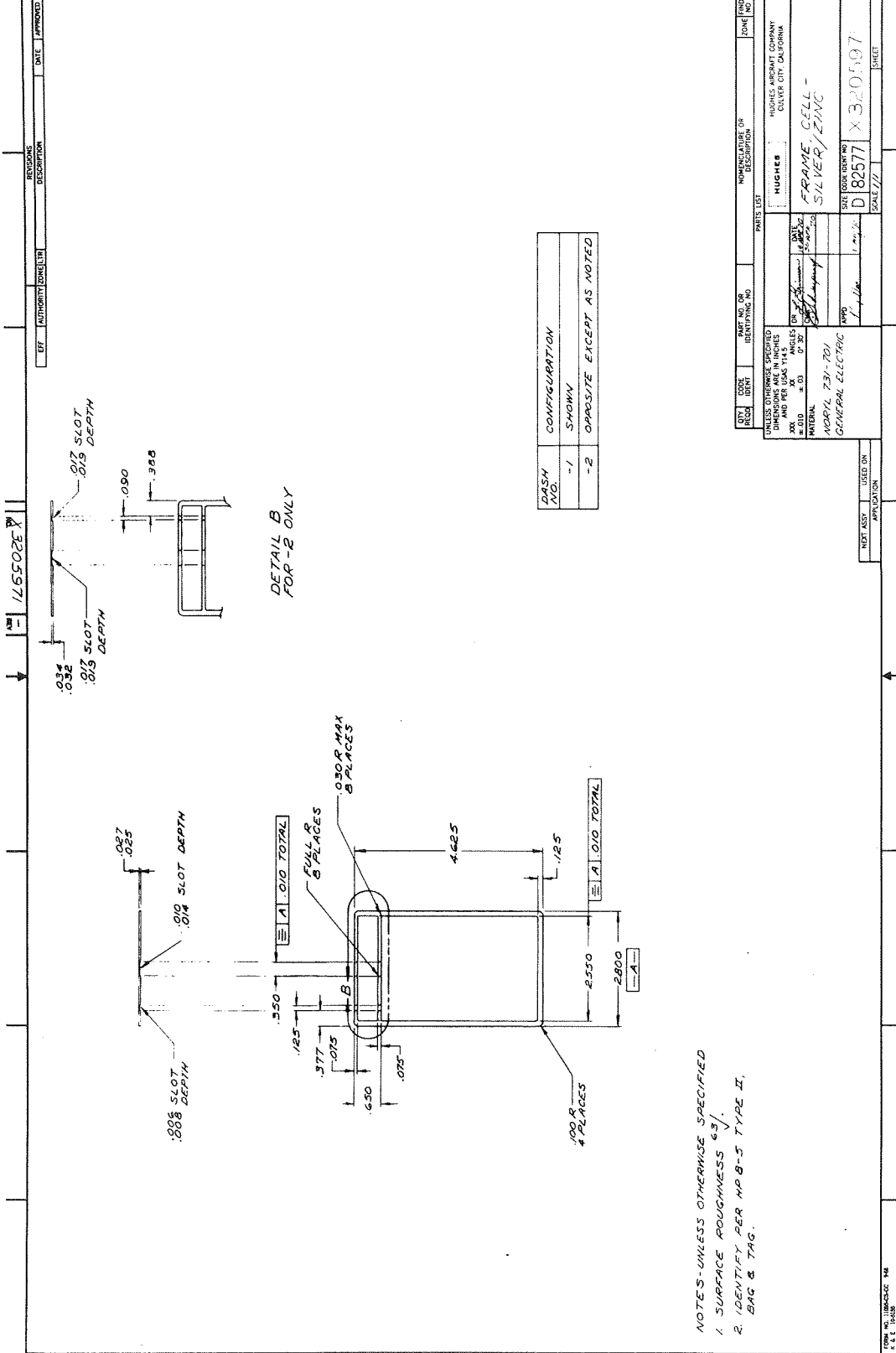
6.2.1 Seller Inspection – Product quality assurance shall be provided by a series of in-process inspections commencing with the receipt of raw materials and parts continuing through the finished product. Selected inspection points shall have the approval of GSFC. A record shall be maintained of all inspection and be subject to review by GSFC.

6.2.2 GSFC Source Inspection – Goddard Space Flight Center shall at its option provide inspection to adequately monitor the Seller's quality control effort including in-process inspection and in-process tests. The complete hardware may be source inspected by GSFC to assure that the product conforms to all the requirements specified in applicable drawings listed above.

6.2.3 Rejected Assemblies — Rejected assemblies shall not be resubmitted for approval without furnishing full particulars concerning the rejection, the measure taken to overcome the defects and the prevention of future occurrence. Each rejected assembly or part shall be identified by a serialized rejection tag. This rejection tag shall not be removed until rework requirements have been complied with and the tag shall be removed only by, or in the presence of, an authorized representative of GSFC.

APPENDIX II

FIVE-CELL, 12 AMP-HR SILVER-ZINC BATTERY DRAWINGS



DASH NO.	CONFIGURATION
-1	SHOWN
-2	OPPOSITE EXCEPT AS NOTED

NOTES - UNLESS OTHERWISE SPECIFIED
 1. SURFACE ROUGHNESS 63/
 2. IDENTIFY PER MPB-3 TYPE II, BAG & TAG.

REVISE	DESCRIPTION	DATE	APPROVED
EFF	AUTHORITY CONTROL		
QTY	CODE	IDENTIFYING NO.	PARTS LIST
	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND PER USA Y14.5		
	XXX ON ANGLES 9.25		
	MATERIAL		
	MODEL 731-701		
	GENERAL ELECTRIC		
	DATE	SCALE	
	1/16	D 82577	X 320:197
	NOT ASSY	USED ON	APPLICATION

REV 1
 X 3205969

REV 1
 X 3205969

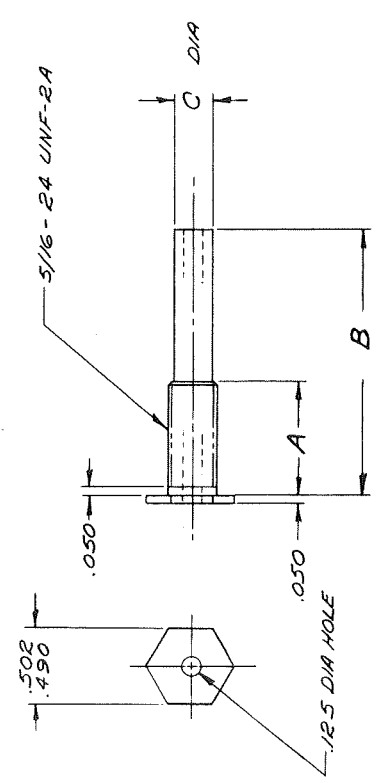
EFF	AUTHORITY	ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED
<p style="margin-top: 20px;"> NOTES - UNLESS OTHERWISE SPECIFIED 1. MAX DRAFT ANGLE 0°12' 2. SURFACE ROUGHNESS ⁶³ 3. IDENTIFY PER HPB-5 TYPE II, BAG & TAG. </p>						

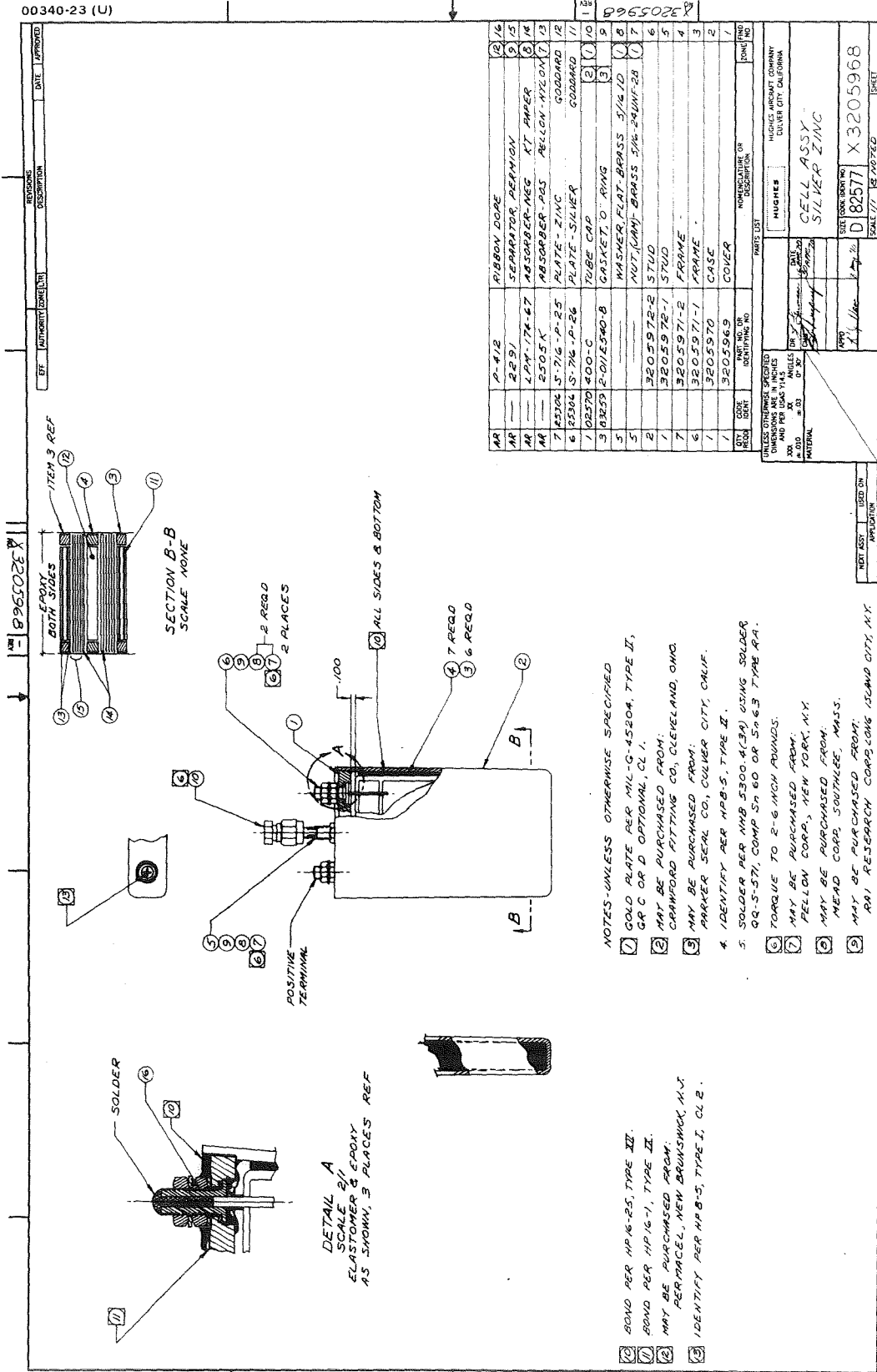
QTY REQD	CODE IDENT	PART NO. OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	ZONE	FIND NO.
			HUGHES		
PARTS LIST					
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND PER USAS Y14.5		DR <i>[Signature]</i>	DATE <i>11/22/70</i>	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	
XXX	ANGLES 0° 30'	<i>[Signature]</i>	<i>3/11/70</i>	COVER CELL - SILVER/ZINC	
±.010	±.03	APPD <i>[Signature]</i>	<i>11/24/70</i>		
MATERIAL		SIZE CODE IDENT NO.			
NORYL - 731-701		C 82577 X 3205969			
GENERAL ELECTRIC		SCALE 1/1			

NEXT ASSY	USED ON
	APPLICATION

REV 1
NO. X3205972

REV 1
NO. X3205972

EFF	AUTHORITY	ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED												
<div style="display: flex; justify-content: space-around; align-items: center;">  <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>DASH NO</th> <th>A</th> <th>B</th> <th>C</th> </tr> </thead> <tbody> <tr> <td>-1</td> <td>.700</td> <td>1.70</td> <td>.250</td> </tr> <tr> <td>-2</td> <td>.750</td> <td>—</td> <td>—</td> </tr> </tbody> </table> </div> <div style="margin-top: 20px;"> <p>NOTES</p> <ol style="list-style-type: none"> IDENTIFY PER HP 8-5 TYPE II, BAG & TAG. MAY BE MADE FROM A COMMERCIAL 5/16-24 UNF-2A GOLD PLATE PER MIL-G-4520A, TYPE II, GR C OR D OPTIONAL, CL 1. </div>							DASH NO	A	B	C	-1	.700	1.70	.250	-2	.750	—	—
DASH NO	A	B	C															
-1	.700	1.70	.250															
-2	.750	—	—															
CITY RECD	CODE IDENT	PART NO. OR IDENTIFYING NO.	PARTS LIST		NOMENCLATURE OR DESCRIPTION	ZONE FIND NO.												
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES XXX AND PER USAS Y14.5			APPROVED: <i>[Signature]</i> DATE: 12/20/70 BY: <i>[Signature]</i> 20/11/70		HUGHES HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STUD, CELL - SILVER/ZINC												
±.010	±.03	0°-30°	MATERIAL BAR, NAVAL BRASS, Q-Q-B-637, ALLOY #24, 1/2 HARD		SIZE CODE IDENT NO. C 82577	X 3205972												
NEXT ASSY			USED ON		SCALE 2/1													
APPLICATION			SHEET		SHEET													



- NOTES-UNLESS OTHERWISE SPECIFIED
- 1 GOLD PLATE PER MIL-Q-4520A, TYPE II, GR C OR D OPTIONAL, CL 1.
 - 2 MAY BE PURCHASED FROM: CRAWFORD FITTING CO, CLEVELAND, OHIO.
 - 3 MAY BE PURCHASED FROM: PARKER SEAL CO, CULVER CITY, CALIF.
 - 4 IDENTIFY PER HP B-5, TYPE II.
 - 5 SOLDER PER NHB 5300 (A.38) USING SOLDER O.R. S-571, COMP S₂ 60 OR S₂ 63 TYPE RA.
 - 6 TORQUE TO 2-6 INCH POUNDS.
 - 7 MAY BE PURCHASED FROM: FELLON CORP., NEW YORK, N.Y.
 - 8 MAY BE PURCHASED FROM: MEAD CORP. SOUTHLEE, MASS.
 - 9 MAY BE PURCHASED FROM: AMI RESEARCH CORP. LONG BEACH CITY, N.Y.

- 10 BOND PER HP B-5, TYPE III.
- 11 BOND PER HP B-5, TYPE II.
- 12 MAY BE PURCHASED FROM: PERMACEL, NEW BRUNSWICK, N.J.
- 13 IDENTIFY PER HP B-5, TYPE I, CL 2.

QTY	CODE	DESCRIPTION	UNIT	NO. OF IDENTIFYING NO.	DATE	BY	APPROVED
1		RIBBON CORE					
1		SEPARATOR PERMION					
1		ABSORBER-NCC KIT AMPER					
1		ABSORBER-ABS ALLEN-1120-01					
1		PLATE-ZINC					
1		TUBE CAP					
1		GASKET, O RING					
1		WASHER, FLAT, BRASS 5/16 ID					
1		NUT (CAN) BRASS 5/16-24 UNF-2B					
1		STUD					
1		320597E-1					
1		FRAME					
1		320597I-1					
1		CASE					
1		320597O					
1		COVER					

REVISIONS

DATE APPROVED

BY AUTHORITY (DATE)

RESIGNED (DESCRIPTION)

HUGHES

HUGHES HEWITT COMPANY
SILVER CITY, CALIFORNIA

CELL ASSY
SILVER ZINC

SCALE 1/1 X 3205968

SCALE 1/1 X 320760

DATE

BY

APPROVED

DATE

BY

APPROVED

DATE

BY

APPROVED

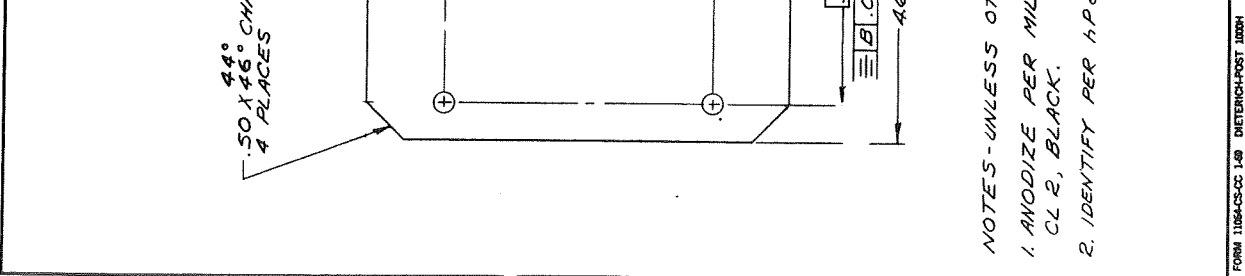
REV 1 X 3205979

NO X 3205979

REV	DESCRIPTION	DATE	APPROVED
1			

EFF	AUTHORITY	ZONE	LTR

QTY REQD	CODE IDENT	PART NO. OR IDENTIFYING NO.	PARTS LIST	NOMENCLATURE OR DESCRIPTION	ZONE	FIND NO.
				HUGHES		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND PER USAS Y14.5				HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA		
XX	±.010	XX	±.03	DR	DATE	
				CHK	5/11/70	
MATERIAL				APPD	DATE	
.50 PL, AL ALLOY				R. J. H...	1/20/70	
6061-T4						
QQ-A-250/11						
TEMP 74						
NEXT ASSY				USED ON APPLICATION		
				SCALE 1/1		
				SIZE CODE IDENT NO. C 82577		
				X 3205979		
				SHEET		



DASH NO.	CONFIGURATION
-1	WITHOUT TABS
-2	WITH TABS

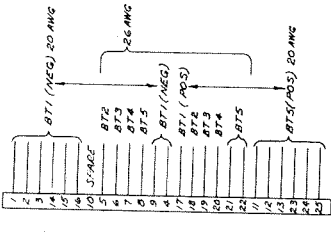
NOTES - UNLESS OTHERWISE SPECIFIED
 1. ANODIZE PER MIL-A-8625, TYPE II, CL 2, BLACK.
 2. IDENTIFY PER HPB-5, TYPE II.

REVISIONS		EFF	AUTHORITY	ZONE	LTR	DESCRIPTION	DATE	APPROVED
<p>NOTES:</p> <p>1. GOLD PLATE PER MIL-G-45204, TYPE II, GR C OR D OPTIONAL, CL 1.</p> <p>2. IDENTIFY PER HP 8-5, TYPE II.</p> <p>3. .062 SH NAVAL BRASS, QQ-B-639, ALLOY #64, 1/2 HARD.</p> <p>4. DIMENSIONAL LIMITS APPLY BEFORE PLATING.</p>		<p>QTY REQD</p> <p>CODE IDENT</p>		<p>PART NO OR IDENTIFYING NO.</p>		<p>NOMENCLATURE OR DESCRIPTION</p>		<p>FIND NO.</p>
<p>EXCEPT AS NOTED DIM ARE IN INCHES AND PER USAS Y14.5 XXX XX ANGLES ±.010 ±.03 ±0°30 MATERIAL</p>		<p>DR. S. BARR TO [Signature]</p> <p>CHKD [Signature]</p> <p>APPD [Signature]</p>		<p>HUGHES</p> <p>HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA</p>		<p>BAR, BUS, BATTERY-5 CELL</p>		<p>B 82577</p>
<p>3</p>		<p>USED ON</p> <p>APPLICATION</p>		<p>SIZE (CODE IDENT NO.)</p> <p>B 82577</p>		<p>DRAWING NO.</p> <p>X3205982</p>		<p>SCALE 1/1</p> <p>SHEET</p>

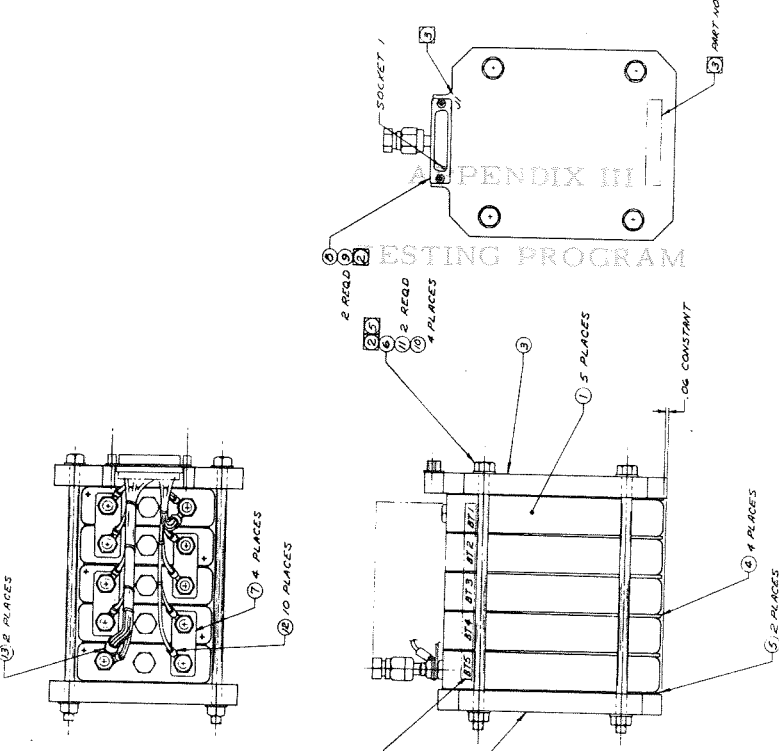
FORM NO. 11065-CS-CC 1/69 DIETRICH-POST CLEARPRINT 1000H

SYNOPSIS
DESCRIPTION
DETAILS
DRAWING

DATE: 12/1/57
BY: J. J. R.
CHECKED BY: J. J. R.
APPROVED BY: J. J. R.



WIRING DIAGRAM



- NOTES - UNLESS OTHERWISE SPECIFIED
- 1 ASSEMBLE PER MP 14-4
 - 2 TORQUE TO 3.0 - 4.0 INCH POUNDS.
 - 3 IDENTIFY PER MP 8-5, TIME I, CL 3, GR A, FORM 2.
 - 4 MAY BE PURCHASED FROM:
AMP COMP. MANUFACTURING, SA 1705.
 - 5 UNIT PER MP 14-1/2, TIME I (AT MINIMUM DRYING TEMP)
BOLT COLOR BLACK NO STOPS PER FED-STD-593,
BOLT NUTS UNFINISHED ONLY.
 - 6 1-5900E ITEM - SEE SPEC CONTROL DMG.

NO.	QTY.	DESCRIPTION	UNIT
1	1	WIRE 18 GAUGE	13
2	2	WIRE 18 GAUGE	14
3	2	WIRE 18 GAUGE	15
4	2	WIRE 18 GAUGE	16
5	2	WIRE 18 GAUGE	17
6	2	WIRE 18 GAUGE	18
7	2	WIRE 18 GAUGE	19
8	2	WIRE 18 GAUGE	20
9	2	WIRE 18 GAUGE	21
10	2	WIRE 18 GAUGE	22
11	2	WIRE 18 GAUGE	23
12	2	WIRE 18 GAUGE	24
13	2	WIRE 18 GAUGE	25
14	2	WIRE 18 GAUGE	26
15	2	WIRE 18 GAUGE	27
16	2	WIRE 18 GAUGE	28
17	2	WIRE 18 GAUGE	29
18	2	WIRE 18 GAUGE	30
19	2	WIRE 18 GAUGE	31
20	2	WIRE 18 GAUGE	32
21	2	WIRE 18 GAUGE	33
22	2	WIRE 18 GAUGE	34
23	2	WIRE 18 GAUGE	35
24	2	WIRE 18 GAUGE	36
25	2	WIRE 18 GAUGE	37
26	2	WIRE 18 GAUGE	38
27	2	WIRE 18 GAUGE	39
28	2	WIRE 18 GAUGE	40
29	2	WIRE 18 GAUGE	41
30	2	WIRE 18 GAUGE	42
31	2	WIRE 18 GAUGE	43
32	2	WIRE 18 GAUGE	44
33	2	WIRE 18 GAUGE	45
34	2	WIRE 18 GAUGE	46
35	2	WIRE 18 GAUGE	47
36	2	WIRE 18 GAUGE	48
37	2	WIRE 18 GAUGE	49
38	2	WIRE 18 GAUGE	50
39	2	WIRE 18 GAUGE	51
40	2	WIRE 18 GAUGE	52
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42	2	WIRE 18 GAUGE	54
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52	2	WIRE 18 GAUGE	64
53	2	WIRE 18 GAUGE	65
54	2	WIRE 18 GAUGE	66
55	2	WIRE 18 GAUGE	67
56	2	WIRE 18 GAUGE	68
57	2	WIRE 18 GAUGE	69
58	2	WIRE 18 GAUGE	70
59	2	WIRE 18 GAUGE	71
60	2	WIRE 18 GAUGE	72
61	2	WIRE 18 GAUGE	73
62	2	WIRE 18 GAUGE	74
63	2	WIRE 18 GAUGE	75
64	2	WIRE 18 GAUGE	76
65	2	WIRE 18 GAUGE	77
66	2	WIRE 18 GAUGE	78
67	2	WIRE 18 GAUGE	79
68	2	WIRE 18 GAUGE	80
69	2	WIRE 18 GAUGE	81
70	2	WIRE 18 GAUGE	82
71	2	WIRE 18 GAUGE	83
72	2	WIRE 18 GAUGE	84
73	2	WIRE 18 GAUGE	85
74	2	WIRE 18 GAUGE	86
75	2	WIRE 18 GAUGE	87
76	2	WIRE 18 GAUGE	88
77	2	WIRE 18 GAUGE	89
78	2	WIRE 18 GAUGE	90
79	2	WIRE 18 GAUGE	91
80	2	WIRE 18 GAUGE	92
81	2	WIRE 18 GAUGE	93
82	2	WIRE 18 GAUGE	94
83	2	WIRE 18 GAUGE	95
84	2	WIRE 18 GAUGE	96
85	2	WIRE 18 GAUGE	97
86	2	WIRE 18 GAUGE	98
87	2	WIRE 18 GAUGE	99
88	2	WIRE 18 GAUGE	100

FORM NO. 100-20-2
USE PREVIOUS EDITIONS
FOR SUPERSEDED DRAWINGS

APPENDIX III.

TESTING PROGRAM

APPENDIX III. TESTING PROGRAM

- 1) The following battery cycling and testing will be performed as required in NASA-GSFC RFP No. 716-89965/286.
 - a) Batteries will be given three formation cycles and then sealed.
 - b) All batteries will be cycled as follows: ($25^{\circ} \pm 2^{\circ}\text{C}$ ambient).
 - (1) Discharge each cell on 1 ohm to 1.0 volt
 - (2) Charge the sealed battery at 1.0 ampere constant current to 1.98 volts per cell. Discharge at 5.0 amperes to 1.3 volts per cell.
 - (3) Charge the battery at 1.0 ampere constant current to 1.98 volts per cell. Discharge at 7.2 amperes to 1.0 volts per cell.
 - (4) Discharge to be constant current. Record all cell voltages, total battery voltage, battery current, and battery temperature.
 - c) On two batteries, perform the following:
 - (1) Charge at 1.0 ampere to 1.98 volts per cell.
 - (2) Continuous cycle ten times at $25^{\circ} \pm 2^{\circ}\text{C}$ with a 7.2 amperes discharge for 1 hour followed by a constant potential charge. Voltage limit to be 1.98 volts per cell and the current limited to 1.0 amperes. When the charge current reaches 160 (+20, -00) milliamperes, reduce the charging voltage to 1.87 volts per cell. Total charge time will be 23 hours.
 - (3) On the discharge on the tenth cycle, remove all the capacity of the battery at the cycle rate to 1.0 volt per cell.
 - (4) Charge the battery per Item 1-c-1.

- (5) Lower the battery temperature in 6 hours to $0 \pm 2^{\circ}\text{C}$. Cycle per Item 1-c-2.
 - (6) On the discharge of the tenth cycle, remove all capacity at the cycle rate to 1.0 volt per cell.
 - (7) Raise the temperature of the battery to $25^{\circ} \pm 2^{\circ}\text{C}$ in 6 hours.
 - (8) Discharge each cell on 1 ohm to 1.0 volt.
 - (9) Capacity check the battery per Item 1-b-3. Capacity on discharge to be greater than 12 amp-hr.
- d) All charging voltage limits will be held within 1.0 percent. All current values (charge and discharge) will be held within 2.0 percent. Record cell voltages, total battery voltage, battery current, and battery temperature.