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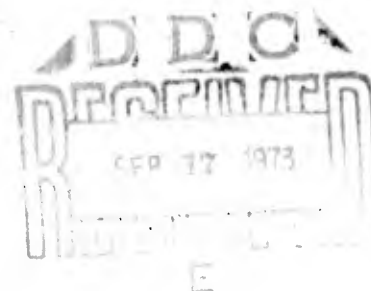
RESEARCH & DEVELOPMENT TECHNICAL REPORT
ECOM-0127-F

MINIATURE SEALED NICKEL-CADMIUM BATTERIES

FINAL REPORT

By
C.J. Menard
J.R. Walsh
K.C. Kohl

June 1973



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June 1973

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March 1971 - June 1972

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Mendota Heights, Minnesota 55118

For

U.S. Army Electronics Command
Fort Monmouth, New Jersey

ABSTRACT

The purpose of this program has been to design, develop, fabricate, and test miniature high-rate sealed nickel-cadmium batteries of the button cell construction. The battery types are BB-683()/U (50 mAh), BB-684()/U (100 mAh), BB-685()/U (150 mAh), and BB-686()/U (250 mAh).

The program was carried out as follows: design parameter study to select prototype models, qualification tests on the prototype batteries in accordance with the specification SCL-6899A, fabrication, and delivery of 100 cells and 20 12-volt batteries of each type. Within the cell dimension and weight limits imposed, the selection of the prototype batteries included investigations on two basic design assemblies; i.e., a 2-plate design and a 4-plate design.

The prototype design for the 50 mAh battery is the 2-plate construction; i.e., one positive and one negative. The other three types are of the 4-plate construction; i.e., two positives and two negatives. The four prototype designs met all the requirements (dimensions, weights, electrical, and other environmental tests). The weights of the three 4-plate batteries (100, 150, and 250 mAh sizes) were 8.3, 10.3, and 14.3 g compared to the requirements of 11.34, 12.76, and 17.01 g maximum. In general the minimum capacity requirements were easily exceeded. Batteries of each type are on long life cycle test. The batteries have passed the minimum 56 cycles that was required before the fabrication of the delivery items.

The qualification test results show that the program was successfully accomplished.

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Drawing No. ET 121	Can for BB-684()/U
Drawing No. ET 122	Can for BB-685()/U
Drawing No. ET 140	Can for BB-686()/U
Drawing No. ET 186	Insulator
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Drawing No. ET 189	Two-Plate Electrode Substrate Assembly
Drawing No. ET 190	Separator
Drawing No. ET 191/1	Cell Assembly for BB-684, BB-685, and BB-686()/U
Drawing No. ET 191/2	Cell Assembly for BB-683()/U
Drawing No. ET 191/3	Bill of Material
Drawing No. ET 191/4	Notes

I. INTRODUCTION

A. Program Objective

The objective of the work conducted on this program has been to design, develop, fabricate, and test miniature high-rate sealed nickel-cadmium batteries of the button cell construction. The battery types are BB-683()/U, BB-684()/U, BB-685()/U, and BB-686()/U. The rated capacities are 50, 100, 150, and 250 mAh, respectively.

B. Program Tasks

The program was carried out according to the following schedule:

Task I – Design and Development

- Design, fabricate, and test experimental cells to establish the design parameters of each battery type
- Evaluate the experimental cell designs against the electrical (capacity) requirements of USAECOM Technical Description SCL-6899A, dated 24 January 1969 (Batteries, Storage, Sealed, Nickel-Cadmium) and the applicable Technical Specification Sheets SCL-6899/12 through SCL-6899/15

Task II – Fabrication and Testing of Batteries

- Fabricate 20 cells each of type BB-683, BB-684, BB-685, and BB-686
- Fabricate 20 batteries (12 volt battery assemblies of 10 cells each) for each of type BB-683, BB-684, BB-685, and BB-686
- Evaluate the cells and batteries in accordance with the requirements of SCL-6899A

Task III – Fabrication of Batteries for Delivery

- Fabricate 100 cells of each type
- Fabricate 20 batteries (12 volt assemblies) of each type

C. Technical Approach

Within the cell dimension and weight limits imposed, the selection of the designs to achieve the high-rate discharge performance and other goals of the program included the following:

- An investigation of two basic electrode design assemblies
- Selection of cell diameters conforming to existing nickel-cadmium cells to allow use of commercial seal components
- Determination of electrode dimensions

- Selection of spring designs
- Negative/positive capacity ratios
- Cell electrolyte concentration and volume

The specified weights for the batteries were key factors in making the selection of the finalized cell designs.

II. RESULTS & DISCUSSION

A. Design and Development

1. Design Parameters Study

The physical characteristic requirements of the batteries are given in Table II-1. The values are those listed in the Technical Specification sheets except for the two approved changes indicated. One change represented an increase in the weight of battery type BB-683()/U from 6.52 to 7.2 g. The other change involved an increase in the height of BB-684()/U from 0.250 to 0.275 inch.

TABLE II-1. BATTERY DIMENSIONS & WEIGHT REQUIREMENTS

Battery Type	Rated Capacity ¹ (mAh)	Max. Cell Diameter (In.)	Max. Cell Height (In.)	Max. Cell Weight ² (g)
BB-683()/U	50	0.900	0.250	7.2 ³
BB-684()/U	100	0.900	0.275 ³	11.3
BB-685()/U	150	0.900	0.300	12.8
BB-686()/U	250	1.350	0.350	17.0

¹ 0.2 C rate

² Without jacket and lugs

³ Approved specification changes

Two basic electrode design assemblies were considered. One consisted of a 2-plate design (one positive, one negative). The other was a 4-plate design (two positives, two negatives). Because of the high-rate discharge requirement (3C) sintered electrodes were used exclusively in this design study. Furthermore, a pressure release device is called for under the requirement of the specification. With the use of safety devices in button cell constructions the space available for active elements is further limited. This factor had to be taken into consideration in the design study.

Another factor regarded in this study was the cell diameter. In order to use existing commercial cell hardware seal parts (e.g., covers, safety devices, gaskets, seal rings) and cell closure tools the cell diameters were selected from three standard sizes; namely, Sub C, C, and D. The cell diameter requirements for types BB-683, -684, and -685()/U is 0.90 in. maximum. Therefore, only the Sub C size (0.873 in.) was used for those three battery types. In the case of BB-686()/U both the C (1.008 in.) and D (1.270 in.) sizes were experimented with since the maximum allowable diameter was 1.350 in.

Table II-2 summarizes the physical characteristics of the 2-plate designs. The cell diameter for BB-686()/U was that of the D size. The cell heights and weights were within the specified requirements except for the weight of BB-686()/U. In the latter case the weight of the hardware seal components contributes heavily to the total weight of the cell. The capacities at the 0.2 C rate exceeded the minimum required values (Table II-2). However, two types (BB-684 and BB-685) failed to meet the 3C rate capacity requirements. This was due to the higher current densities in these two types.

TABLE II-2. CHARACTERISTICS OF EXPERIMENTAL 2-PLATE BATTERY DESIGNS

<u>Battery Type</u>	<u>Rated Capacity¹ (mAh)</u>	<u>Cell Diameter (In.)</u>	<u>Cell Height (In.)</u>	<u>Cell Weight (g)</u>	<u>Capacity @ 0.2 C₅ (mAh to 1.0V)</u>
BB-683()/U	50	0.873	0.220	6.9	60
BB-684()/U	100	0.873	0.248	8.5	125
BB-685()/U	150	0.873	0.297	10.1	180
BB-686()/U	250	1.270	0.305	20.7	315

¹ 0.2 C rate

From the performance of these 2-plate cells, as measured against the specification, it was concluded that this design was satisfactory for the 50 mAh size (BB-683()/U) but improved performance would result for the other sizes in the 4-plate designs. Table II-3 summarizes the cell dimensions and weights for the four prototype batteries of the selected designs. As stated above the 50 mAh size is the 2-plate design while the 100, 150, and 250 mAh sizes are the 4-plate designs. The 250 mAh cell diameter is that of the C size and its weight is well within the specification requirements (14.3 vs 17.0 g) and much less than the 2-plate design (20.7 g) which used the D size components. The four prototype designs met all the physical requirements (dimensions, weights). The performance of these prototype batteries are described in the qualification tests section (II.B.1).

In the process of designing the cells the following also had to be factored in:

- Negative/positive capacity ratio
- Thickness of separator
- Amount and concentration of electrolyte
- Spring design
- Can insulator

TABLE II-3. PROTOTYPE BATTERY DIMENSIONS & WEIGHTS

Battery Type	Cell Diameter (In.)		Cell Height (In.)		Cell Weight (g)	
	Max. Spec.	Actual	Max. Spec.	Actual	Max. Spec.	Actual
BB-683()/U	0.90	0.873	0.250	0.220	7.20	6.9 ± 0.2
BB-684()/U	0.90	0.873	0.275	0.270	11.34	8.3 ± 0.3
BB-685()/U	0.90	0.873	0.300	0.295	12.76	10.3 ± 0.3
BB-686()/U	1.35	1.008	0.350	0.335	17.01	14.3 ± 0.3

A negative/positive theoretical capacity ratio of 1.7 minimum was indicated. The criteria for selection was the overcharge and cycle life performances.

Non-woven nylon materials (Pellon) were used. The thickness of the separator was dependent on the cell design. In general, a separator 10 to 16 mil thick proved satisfactory.

The electrolyte was a 30% potassium hydroxide solution. This concentration was selected primarily because of the low temperature (-20°F) requirement. The amounts were 0.16, 0.28, 0.36, and 0.60 cc for the 50, 100, 150, and 250 mAh batteries, respectively. The criteria for selection of the amount of electrolyte was the overcharge.

To insure minimum resistance between the electrodes a spring was used to compress the components. The design was selected from a variety of commercial types. An insulator was designed to prevent the positive electrodes from contacting the can (negative polarity).

The details of the cell components are described in the section that follows.

2. Prototype Battery Components

Detailed drawings of the various cell components are given in Appendix A. They are briefly discussed in the paragraphs that follow.

a. Cross-Sections of Battery Designs

Drawing ET 191/1 – Cell Assembly for BB-684, -685, and -686()/U

Drawing ET 191/2 – Cell Assembly for BB-683()/U

Drawing ET 191/3 – Bill of Materials

Drawing ET 191/4 – Notes

Cross-sectional views of the 4-plate and 2-plate battery designs are shown in Drawings ET 191/1 and ET 191/2. Refer to these four drawings for a detailed description of the cell assemblies.

b. Cell Cans

Drawing ET 119 – Can for BB-683()/U

Drawing ET 121 – Can for BB-684()/U

Drawing ET 122 – Can for BB-685()/U

Drawing ET 140 – Can for BB-686()/U

The development quantities used were fabricated by cutting down commercial cans of the Sub C and C sizes. The resulting cans were reworked to fit the existing commercial seal components.

c. Electrode Substrates

Drawing ET 188 – Sintered Nickel Electrode Substrates

Drawing ET 189 – Two-Plate Electrode Substrate Assembly

The electrode configurations are given in these drawings. ET 188 shows the single electrode disk dimensions while ET 189 illustrates the assembly of two of these disks to form the dual electrodes used in the 4-plate battery designs.

d. Other Components

Drawing ET 186 – Insulator

Drawing ET 187 – Spring

Drawing ET 190 – Separator

Detailed descriptions of these parts are given their respective drawings. Reference was made to these in Section II.A.1.

3. 12 Volt Battery Assemblies

Twelve-volt batteries were constructed by connecting 10 cells in series and mounting in a shrinkable tubing. Insulators were placed between cells to prevent shorting. Lugs were provided at the battery terminals.

The maximum heights of the 10-cell batteries were 2.29, 2.79, 3.04, and 3.44 inches for battery types BB-683, -684, -685, and -686, respectively. Likewise, the battery diameters were 0.888 inch for the first three sizes and 1.023 inch for BB-686. The batteries weighed 72, 87, 107, and 148 grams.

B. Prototype Battery Performance

1. Qualification Tests of Prototype Batteries

a. *Test Requirements* – At the completion of the design and development phase of the program, 20 cells and 20 12-volt batteries of each type were fabricated and tested. The tests were conducted in accordance with the Electronics Command Technical Requirement SCL-6899A and the applicable Technical Specification sheets SCL-6899/12 through SCL-6899/15. The test procedure followed was that outlined in Sections 4.4.2.1, First Article Inspection and Tests and 4.4.2.2, Cycle Life Test. Table II-4 and II-5 summarize the test requirements along with a brief description of each test. The cycle life goal is 420 cycles. However, production of delivery items may start after the completion of 56 satisfactory cycles on four samples of each type (4.4.2.2).

b. *Test Results* – Tables II-6 and II-7 summarizes the results of the various capacity tests performed, the requirements of which were outlined in Table II-4 and Table II-5. Table II-6 gives the results for the cells and Table II-7 tabulates the results for the 12-volt batteries. The capacities shown are average values. All the cells and batteries passed these capacity test requirements. In general, the capacities were well in excess of the requirements with the exception of the low temperature test.

Figures II-1 through II-12 show representative discharge curves for the four battery types. The data are presented in the following sequence:

- Discharge curves at 0.2 C₅ and 3 C₅
- Discharge curves at -20° F
- Discharge curves following 7-day stands at 75° and 125° F

Each set of data is shown in the following manner:

- Figures 1 through 3 – BB-683()/U (50 mAh)
- Figures 4 through 6 – BB-684()/U (100 mAh)
- Figures 7 through 9 – BB-685()/U (150 mAh)
- Figures 10 through 12 – BB-686()/U (250 mAh)

The discharge voltages at 3C easily exceeded the requirements. For instance the five-second voltage was greater than 1.30 volts (1.15 volts required).

The other tests described in Table II-5 were also met. The requirements were also described in that table.

TABLE II-4. CAPACITY TEST REQUIREMENTS

Test Description ¹	Required Capacity – mAh To 1.0 Volts Per Cell			
	BB-683()/U	BB-684()/U	BB-685()/U	BB-686()/U
Full capacity discharge – 0.2 C ₅	50	100	150	250
Low temp discharge – 0.2 C ₅ @ -20°F	25	50	75	125
High-rate discharge – 3 C ₅	30	60	90	150
Overcharge test – 72 hr min @ 0.1 C ₅ followed by discharge at 0.2 C ₅	50	100	150	250
Charge retention Test I – 7-day stand @ 75°F followed by discharge @ 0.2 C ₅	45	90	135	225
Charge retention Test II - 7-day stand @ 125°F followed by discharge @ 0.2 C ₅ and 75°F	20	40	60	100
Full capacity discharge during vibration – 0.2 C ₅	50	100	150	250
Storage life test – 6 mo storage followed by charge at 0.1 C ₅ & discharge @ 0.2 C ₅	50	100	150	250
Cycle life test (cycling: 8.5 hr charge at 0.1 C ₅ , 0.5 hr rest, 2.5 hr discharge at 0.25 C ₅ , 0.5 hr rest) Full capacity discharge at 0.2 C ₅				
Cycle 56	45	90	135	225
Cycle 420	25	50	75	125

¹ 75° ± 5°F unless otherwise specified

TABLE II-5. TEST REQUIREMENTS OTHER THAN CAPACITY

<u>Test Description</u>	<u>Requirement</u>
Insulation Resistance — 500 volts DC across insulation	≥ 0.1 Megohm
Temperature Cycling — Method 102, test condition D of Mil-Std 202 except temp extremes of -40° to 160° F	No battery damage of any kind (short, leak, etc)
Mechanical Shock — Method 202B of Mil-Std 202 (50 gravity unitx max.)	No battery damage of any kind (short, leak, etc)
Internal Pressure Test ¹ — charge cells at rate high enough to puncture venting device	Vent relief device must re- lease before bursting point of the cover-to-case seal

¹ Modified procedure for the type of vent relief device used; charge at 1C₅ until fail-safe device vents, thus assuring that pressure build-up is not great enough to burst the cover-to-case seal.

TABLE II-6. CAPACITY TEST RESULTS – CELLS

Test Description ¹	Average Capacity – mAh To 1.0 Volts			
	BB-683()/U	BB-684()/U	BB-685()/U	BB-686()U
Full capacity discharge – 0.2 C ₅	60.1	136	203	319
Low temp discharge – 0.2 C ₅ @ -20° F	25.6	51.7	79	127
High-rate discharge – 3 C ₅	33.5	83.2	109	172
Overcharge test – 72 hr min @ 0.1 C ₅ followed by discharge @ 0.2 C ₅	81.4	139	227	289
Charge retention Test I – 7-day stand @ 75° F followed by discharge @ 0.2 C ₅	65.9	119	184	267
Charge retention Test II – 7-day stand @ 125° F followed by discharge @ 0.2 C ₅ and 75° F	38.0	72.7	122	135
Full capacity discharge during vibration – 0.2 C ₅	(2)	(2)	(2)	(2)
Storage life test – 6 mo storage followed by charge at 0.1 C ₅ & discharge at 0.2 C ₅	(3)	(3)	(3)	(3)
Cycle life test (cycling: 8.5 hr charge @ 0.1 C ₅ , 0.5 hr rest, 2.5 hr discharge @ 0.25 C ₅ , 0.5 hr rest) Full capacity discharge @ 0.2 C ₅				
Cycle 56	75	126	178	260
Cycle 420	(3)	(3)	(3)	(3)

¹ 75° ± 5° F unless otherwise specified; 0.12C₅ charge for 14 hr

² 12 volt battery assemblies only

³ Test in progress

TABLE II-7. CAPACITY TEST RESULTS - 12 VOLT BATTERIES

Test Description ¹	Average Capacity - mAh To 10 Volts			
	BB-683()/U	BB-684()/U	BB-685()/U	BB-686()/U
Full capacity discharge - 0.2 C ₅	58.8	133	195	309
Low temp discharge - 0.2 C ₅ @ -20°F	25.4	50.7	77.5	134
High-rate discharge - 3 C ₅	37.1	94.6	116	176
Overcharge test - 72 hr min @ 0.1 C ₅ followed by discharge @ 0.2 C ₅	73.4	133	204	307
Charge retention Test I - 7-day stand @ 75°F followed by discharge @ 0.2 C ₅	55.5	117	185	266
Charge retention Test II - 7-day stand @ 125°F followed by discharge @ 0.2 C ₅ and 75°F	22.3	71.3	> 90 ²	112
Full capacity discharge during vibration - 0.2 C ₅	> 55 ³	> 110 ³	> 165 ³	> 275 ³
Storage life test - 6 mo storage followed by charge at 0.1 C ₅ & discharge at 0.2 C ₅	(4)	(4)	(4)	(4)
Cycle life test (cycling: 8.5 hr charge @ 0.1 C ₅ , 0.5 hr rest, 2.5 hr discharge @ 0.25 C ₅ , 0.5 hr rest) Full Capacity discharge @ 0.2 C ₅				
Cycle 56	69.0	111	182	285
Cycle 420	(4)	(4)	(4)	(4)

¹ 75° ± 5°F unless otherwise specified; 0.12C₅ charge for 14 hr

² Missed end points

³ Capacity values at 5.5 hr into the discharge

⁴ Test in progress

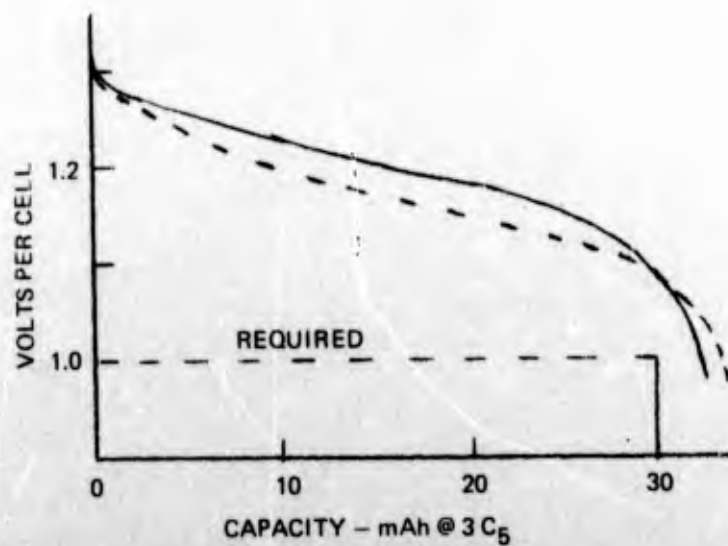
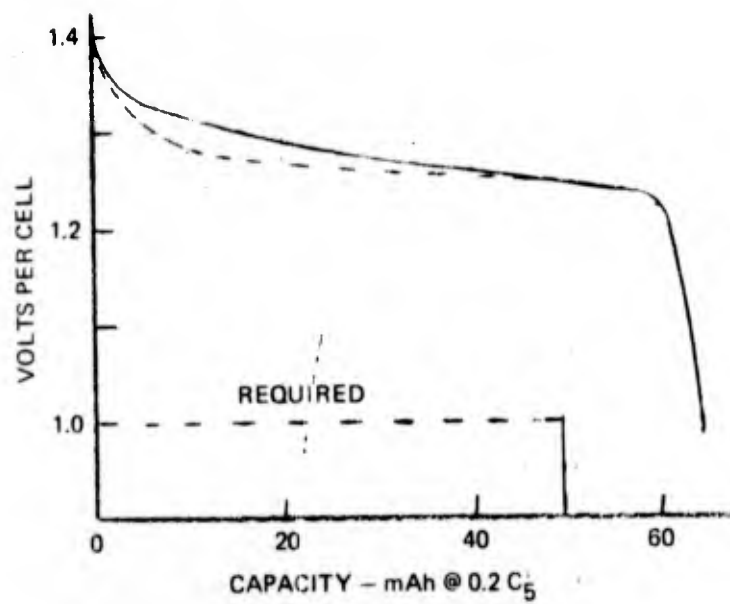


FIGURE II-1. DISCHARGE CURVES AT 0.2 C₅ & 3 C₅ FOR BB-683()/U

75°F

— CELL

--- 12-VOLT BATTERY

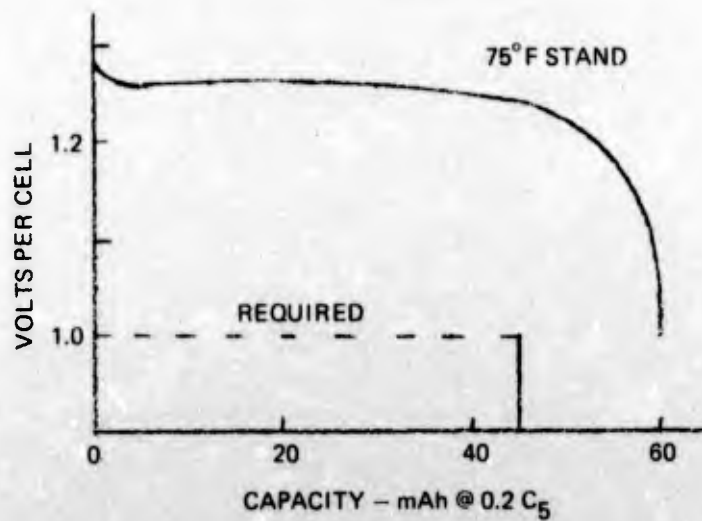
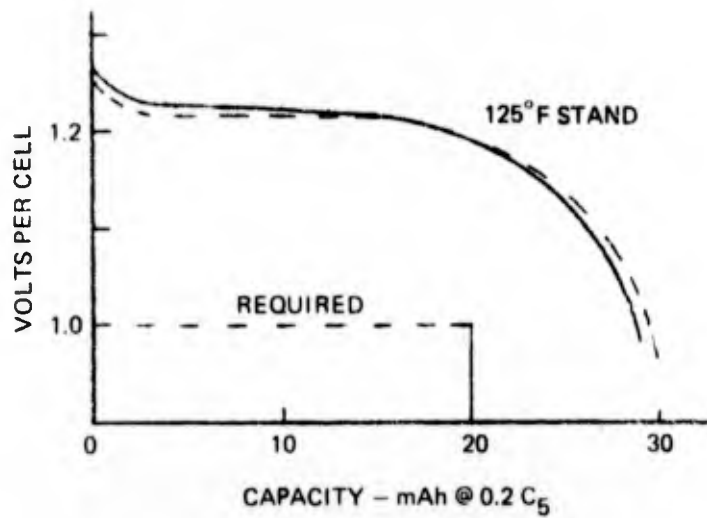


FIGURE II-3. DISCHARGE CURVES FOLLOWING 7-DAY STANDS AT
75° & 125° F FOR BB-683()/U

DISCHARGE AT 75°F

— CELL

--- 12-VOLT BATTERY

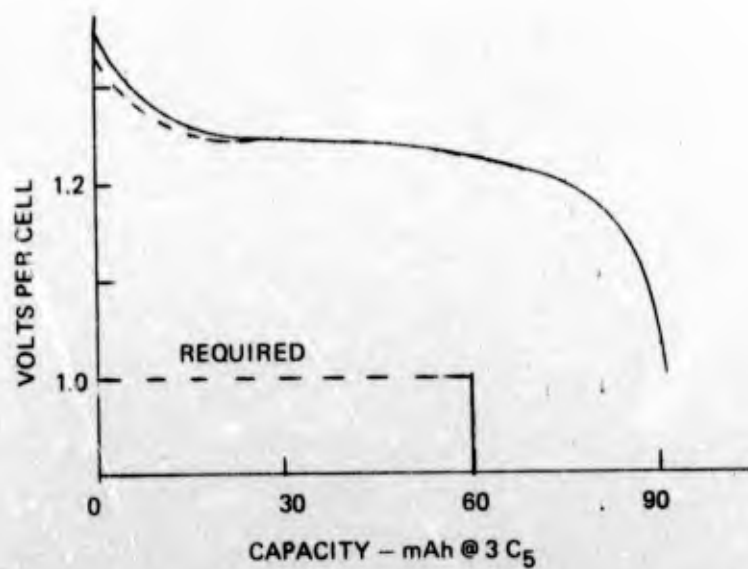
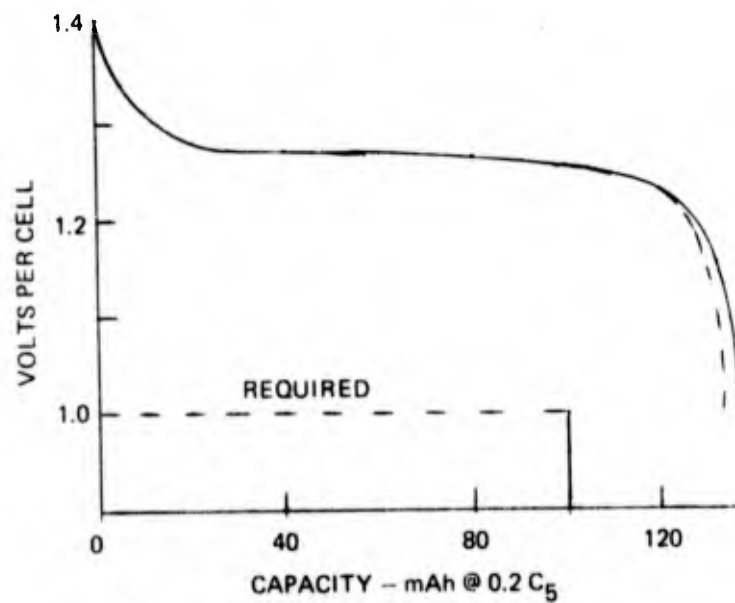


FIGURE II-4. DISCHARGE CURVES AT 0.2 C_5 & 3 C_5 FOR BB-684()/U

75°F

— CELL

--- 12-VOLT BATTERY

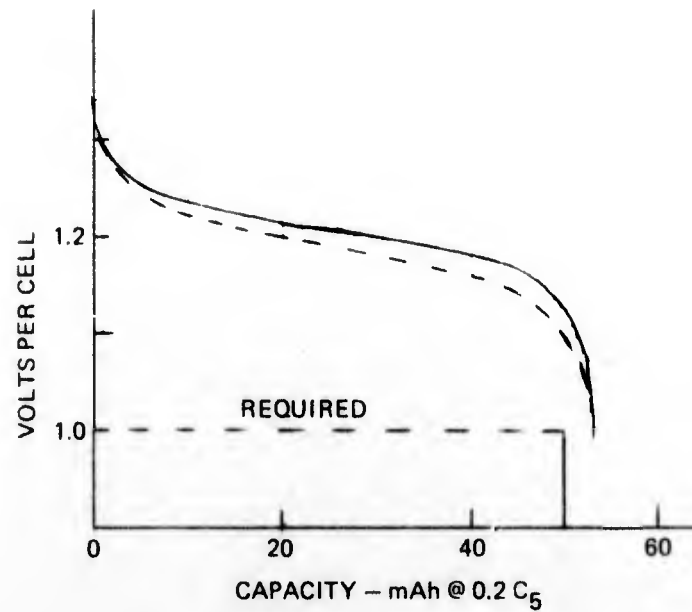


FIGURE II-5. DISCHARGE CURVES AT -20° F FOR BB-684')/U

— CELL
 ---- 12-VOLT BATTERY

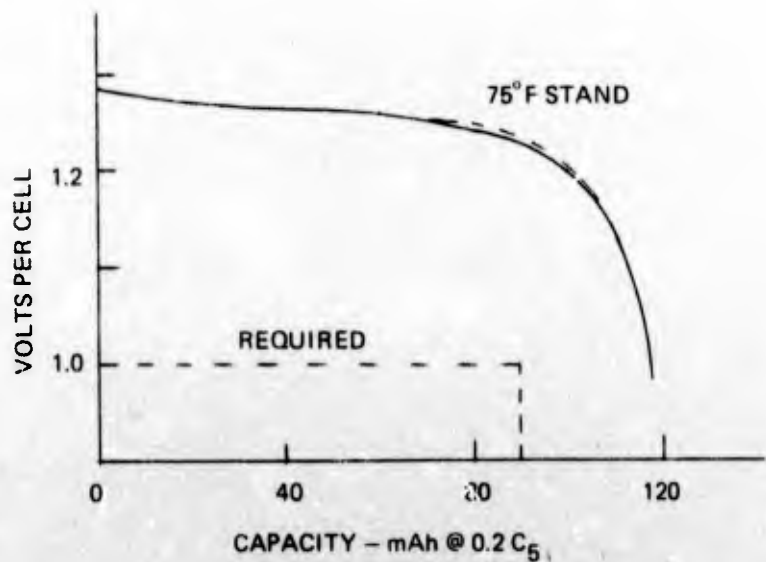
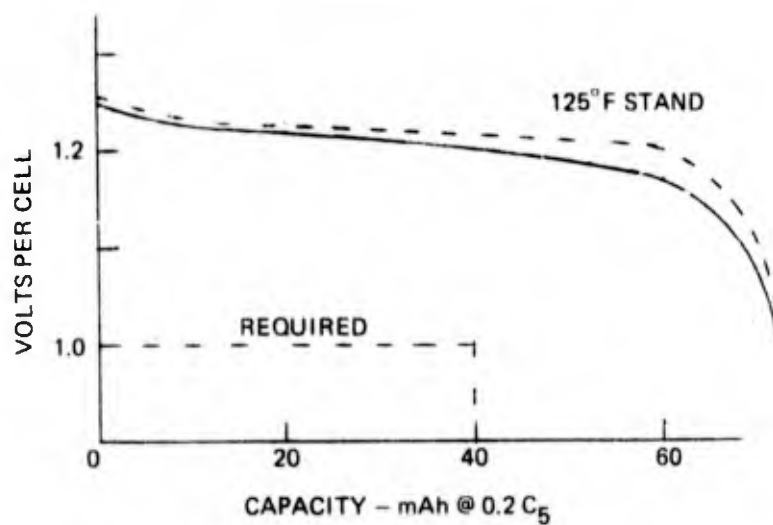


FIGURE II-6. DISCHARGE CURVES FOLLOWING 7-DAY STANDS AT 75° & 125°F FOR BB-684()/U

DISCHARGE AT 75°F

— CELL

--- 12-VOLT BATTERY

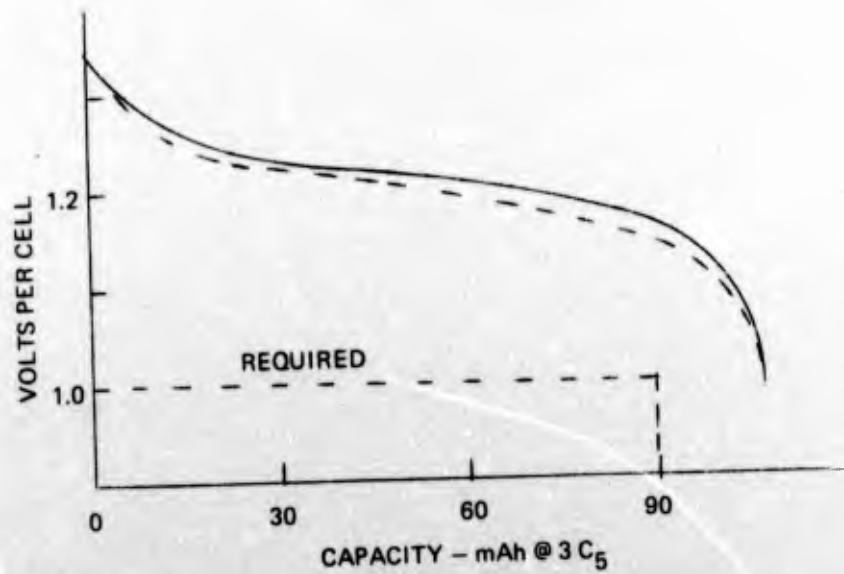
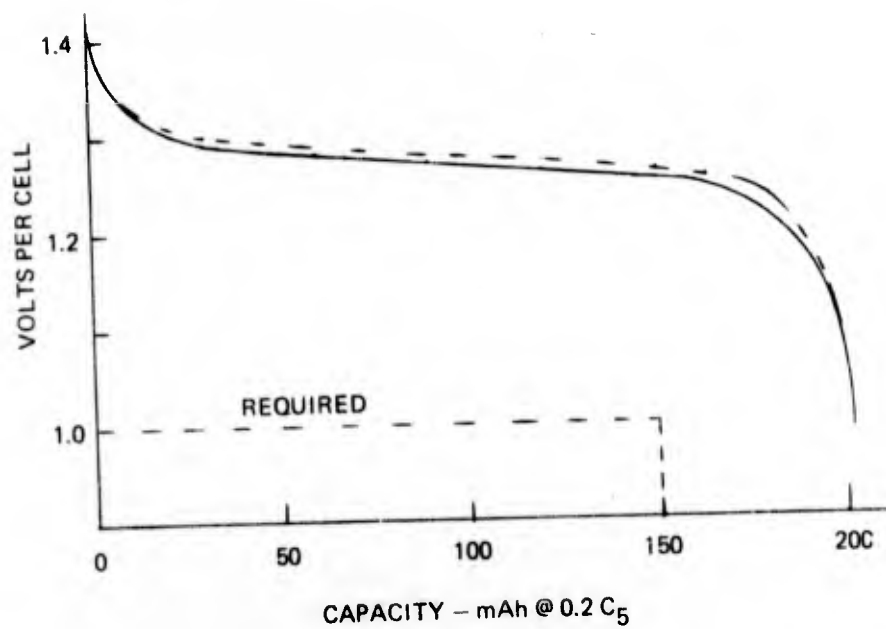


FIGURE II-7. DISCHARGE CURVES AT 0.2 C_5 & 3 C_5 FOR BB-685(1)/U

75°F

— CELL

--- 12-VOLT BATTERY

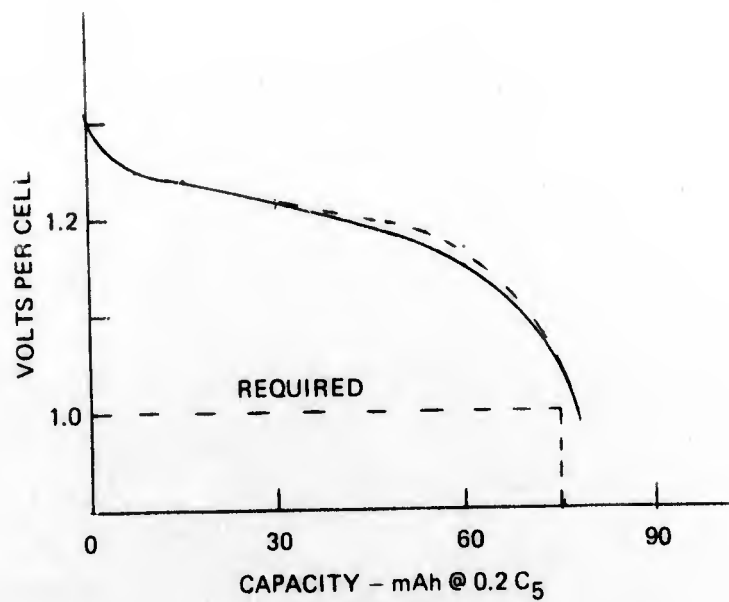


FIGURE II-8. DISCHARGE CURVES AT -20°F FOR BB-685()/U

— CELL
 --- 12-VOLT BATTERY

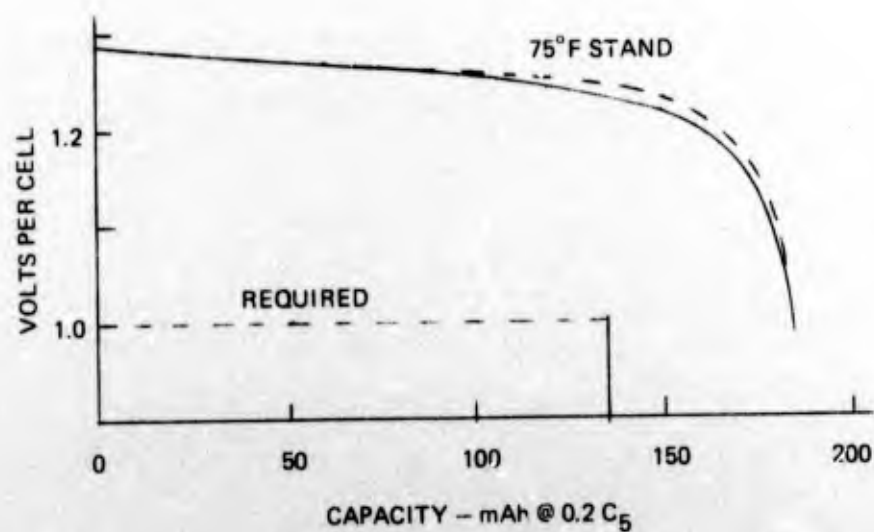
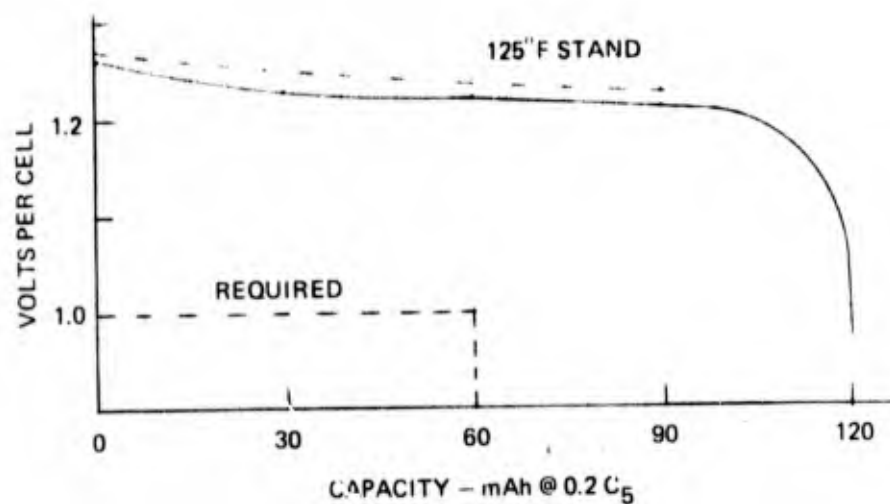


FIGURE II-9. DISCHARGE CURVES FOLLOWING 7-DAY STANDS AT
75° & 125° F FOR BB-685()/U

DISCHARGE AT 75°F
 — CELL
 --- 12-VOLT BATTERY

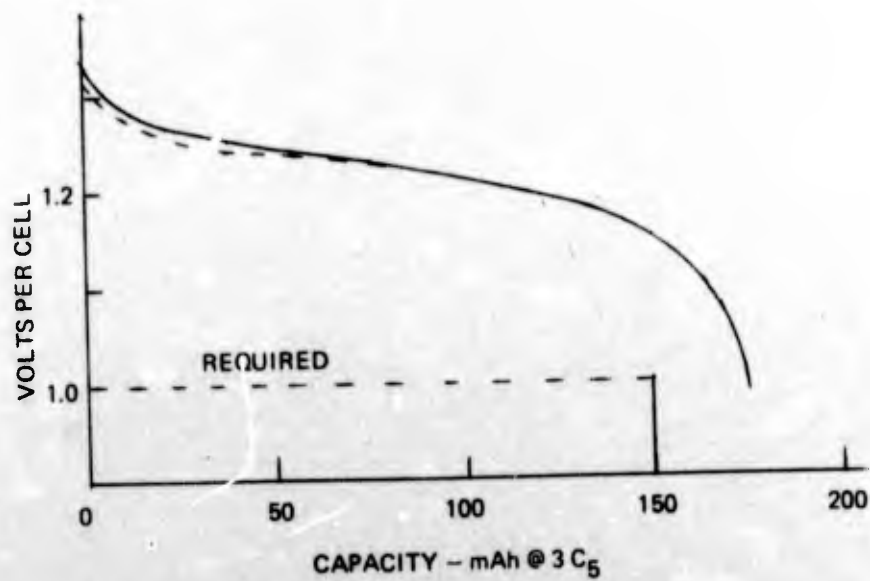
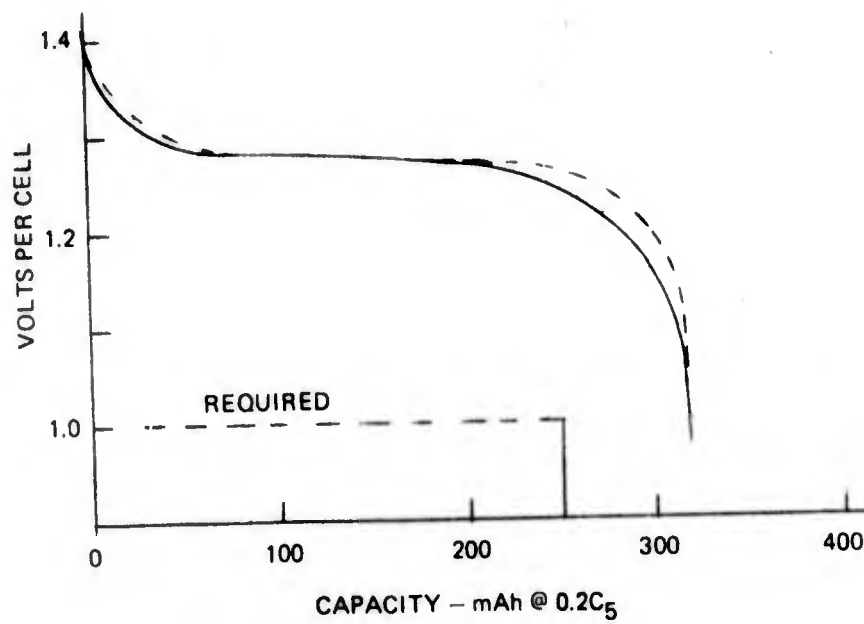


FIGURE II-10. DISCHARGE CURVES AT $0.2C_5$ & $3C_5$ FOR BB-686()/U

75°F

— CELL

---- 12-VOLT BATTERY

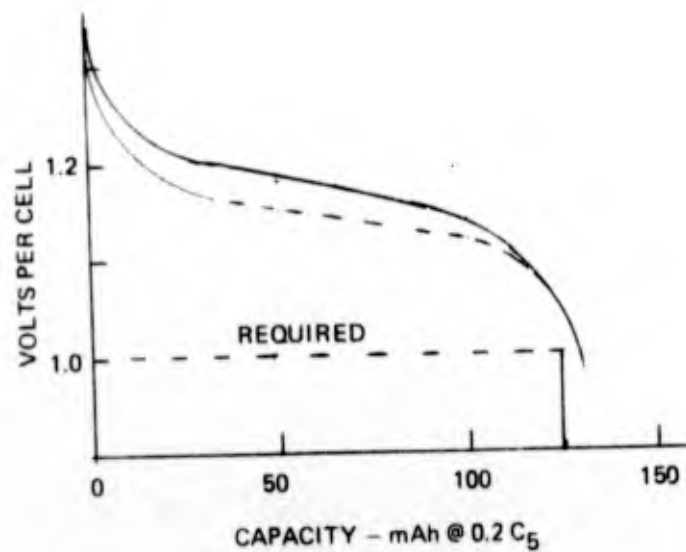


FIGURE II-11. DISCHARGE CURVES AT -20°F FOR BB-686(1)/U

— CELL
 --- 12-VOLT BATTERY

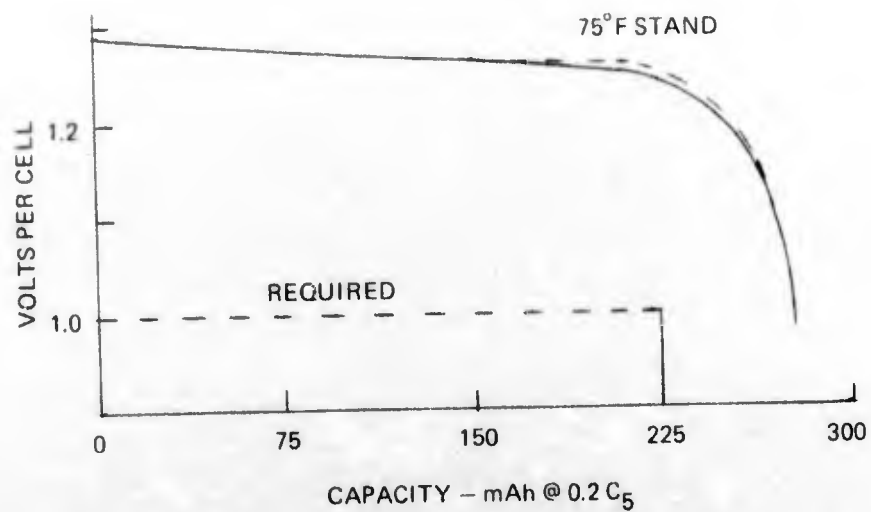
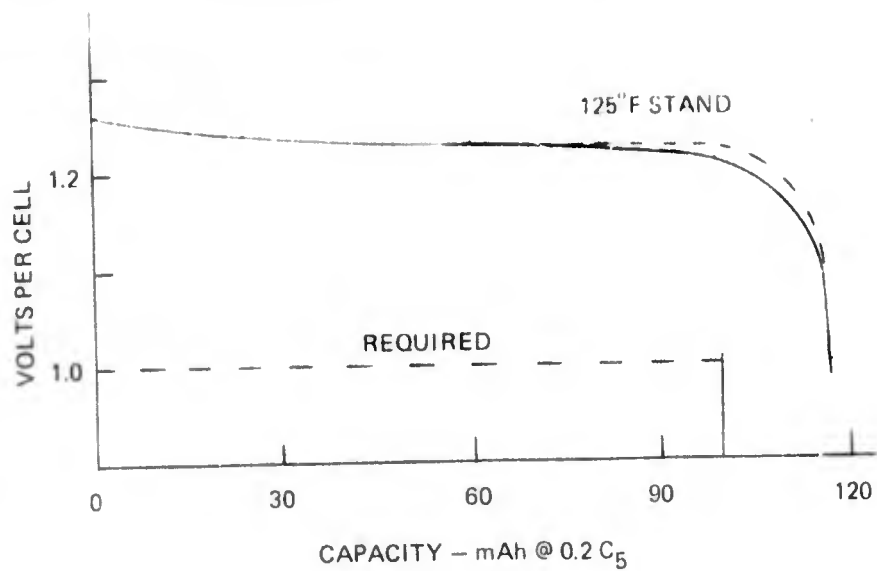


FIGURE II-12. DISCHARGE CURVES FOLLOWING 7-DAY STANDS AT
75° & 125° F FOR BB-686()/U

DISCHARGE AT 75°F
 — CELL
 ---- 12-VOLT BATTERY

2. Battery Performance Compared With Commercial Types

Figures II-13 through II-16 are included for the purpose of comparing the batteries developed under this program with commercial cells made from pressed type electrodes. Comparisons are made for the 0.2 C through the 3 C discharge rates.

Figure II-13 compares the prototype BB-683()/U (50 mAh) which is a 2-plate design with the commercial cells also of 2-plate design. The capacity of the prototype cell is far superior to the commercial cell at 3 C; namely, about 35 mAh vs 5 mAh.

Figure II-14 and II-15 again demonstrate that the prototype batteries BB-684 (100 mAh) and BB-685 (150 mAh) have much higher capacities at the high rates than the pressed types. These plots also show that even the experimental batteries with the 2-plate design have higher capacities.

In Figure II-16 the 4-plate prototype and the 2-plate experimental batteries of type BB-686 (250 mAh) are compared with 4-plate and 2-plate commercial pressed types (225 mAh). The superiority of both developmental batteries is clearly demonstrated.

C. Fabrication and Delivery of Batteries

Upon satisfactory completion of the required qualification tests including the first 56 life cycle tests, prototype batteries for delivery to the government as called for in the contract were fabricated. These were:

- 100 Cells type BB-683()/U
- 100 Cells type BB-684()/U
- 100 Cells type BB-685()/U
- 100 Cells type BB-686()/U
- 20 12-volt batteries type BB-683()/U
- 20 12-volt batteries type BB-684()/U
- 20 12-volt batteries type BB-685()/U
- 20 12-volt batteries type BB-686()/U

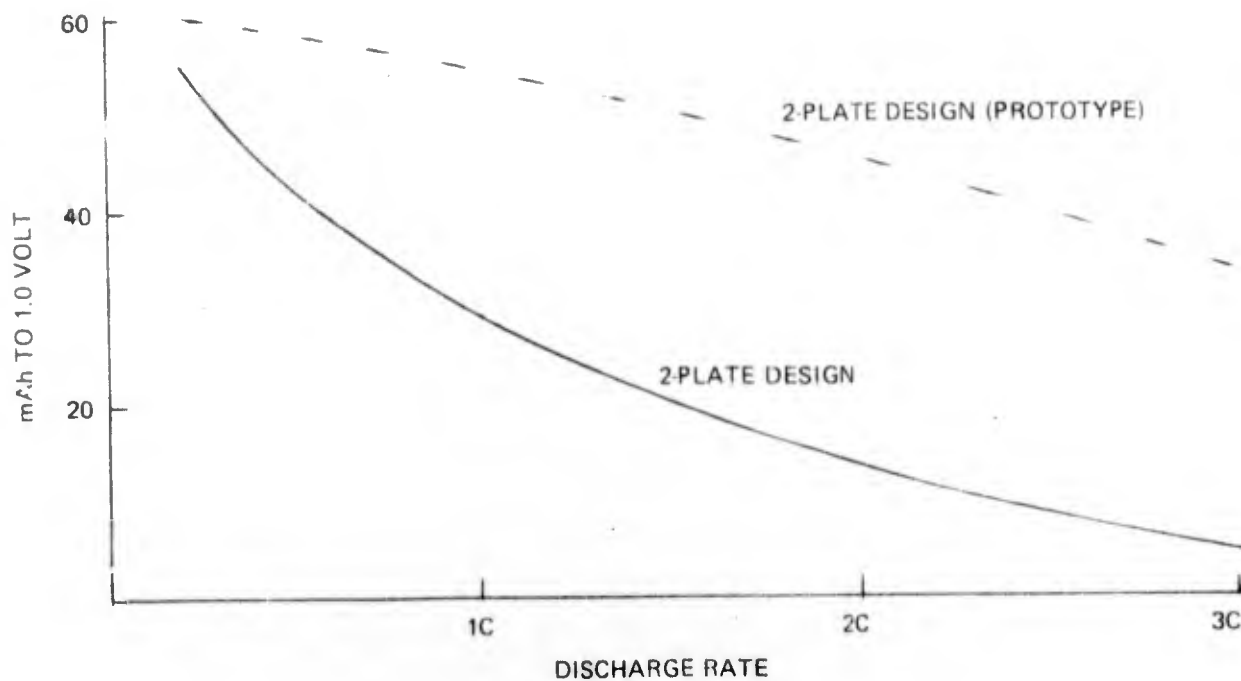


FIGURE II-13. CAPACITIES OF BB-683()/U AND COMMERCIAL CELLS
AT VARIOUS DISCHARGE RATES

----- BB-683()/U (SINTERED ELECTRODES)
 — GOULD TYPE 50B (PRESSED ELECTRODES)

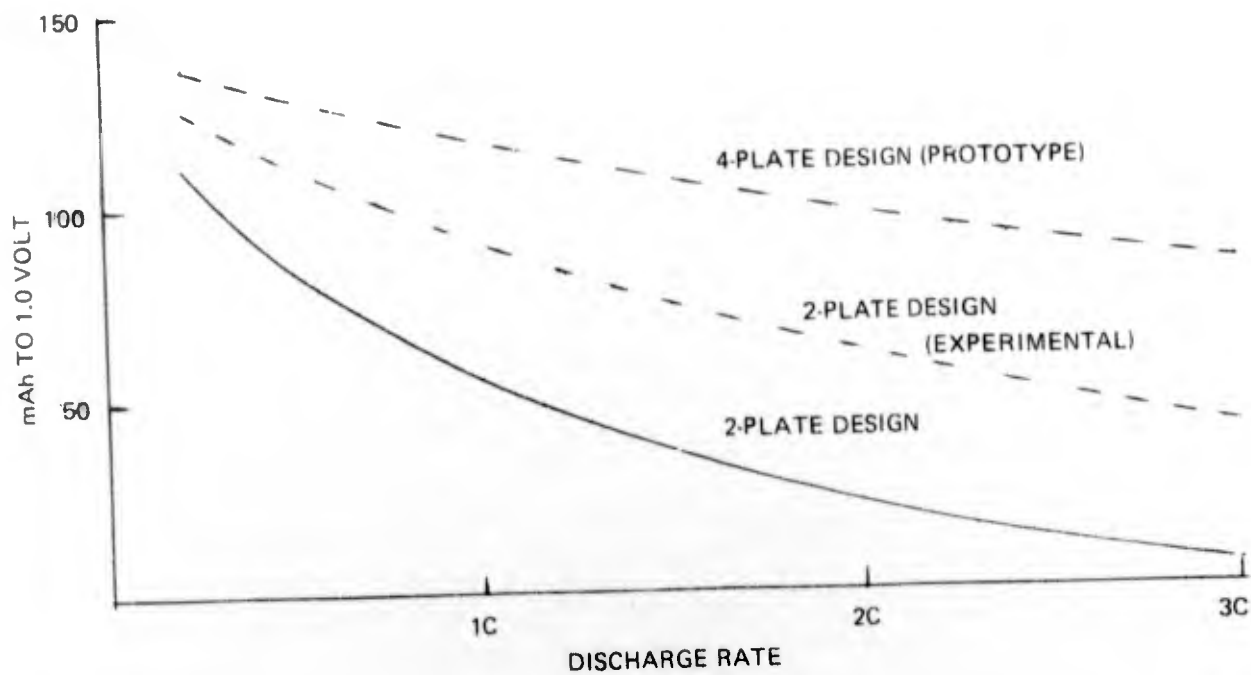


FIGURE II-14. CAPACITIES OF BB-684()/U AND COMMERCIAL CELLS AT VARIOUS DISCHARGE RATES

----- BB-684()/U (SINTERED ELECTRODES)
 — GOULD TYPES 100B (PRESSED ELECTRODES)

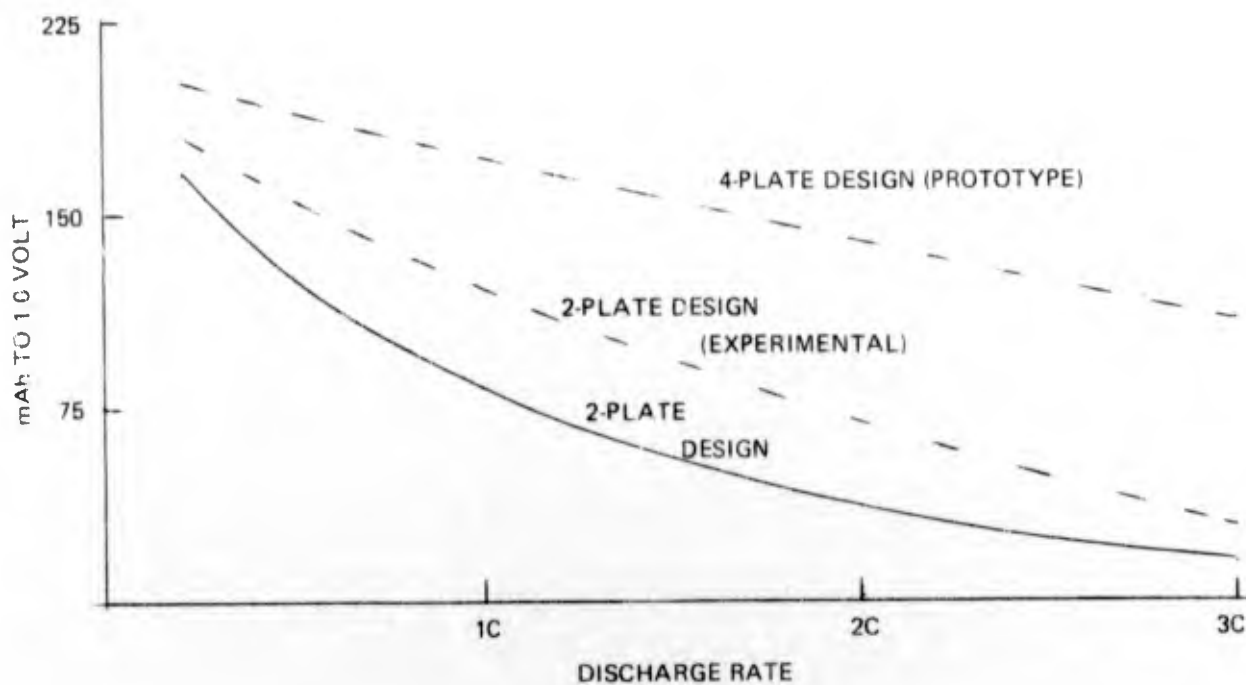


FIGURE II-15. CAPACITIES OF BB-685()/U AND COMMERCIAL CELLS AT VARIOUS DISCHARGE RATES

----- BB-685()/U (SINTERED ELECTRODES)
 _____ GOULD TYPE 150B (PRESSED ELECTRODES)

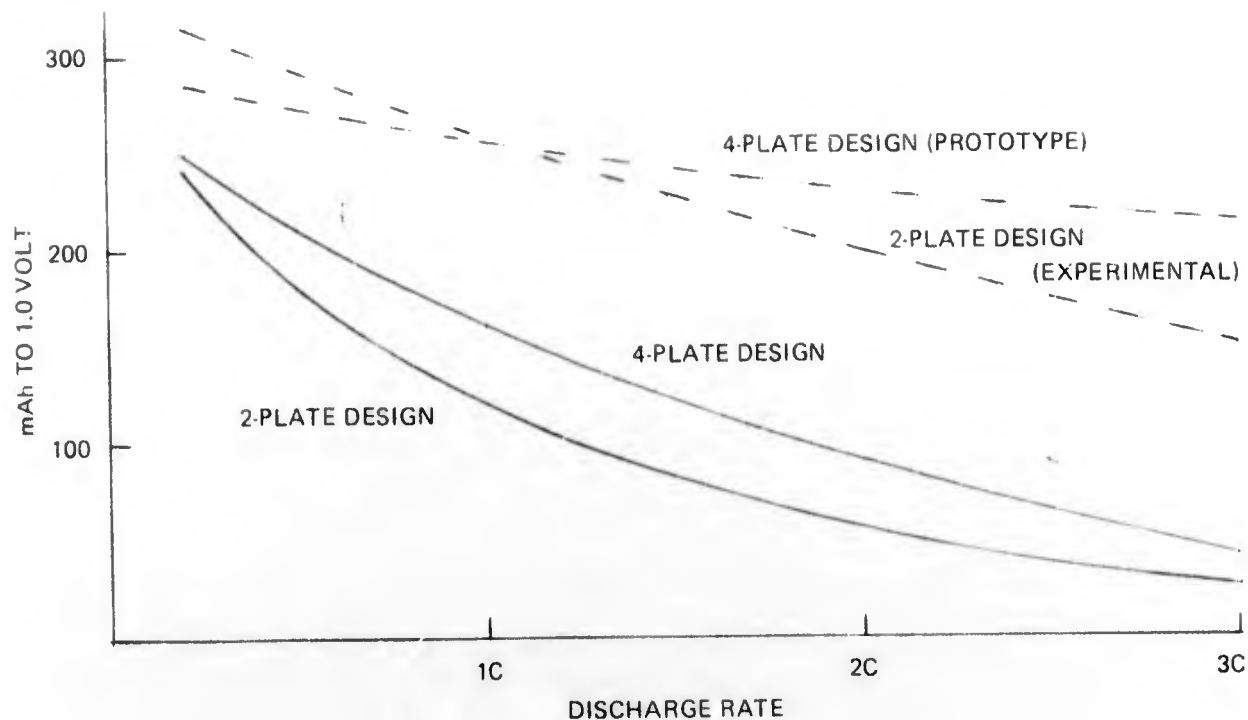


FIGURE II-16. CAPACITIES OF BB-686()/U AND COMMERCIAL CELLS AT VARIOUS DISCHARGE RATES

----- BB-686()/U (SINTERED ELECTRODES)
 ——— GOULD TYPE 225B & 225BH (PRESSED ELECTRODES)

III. CONCLUSIONS

- The designs of the four prototype batteries developed have been shown to meet all the requirements except for the long cycle life tests (420 cycles) which are still in progress. The batteries have generally exceeded the minimum performances specified.
- Two basic designs were investigated: one contained two plates (one positive, one negative), the other four plates (two positives, two negatives). The 4-plate design was used in the prototype batteries BB-684, BB-685, and BB-686. The 50 mAh size (BB-683) is the 2-plate design. No real advantages would be offered in a 4-plate design of the 50 mAh size. In fact, lower capacity would result in the same height cell due to the additional separators that would be required.
- In the design parameters study the emphasis was placed on designs capable of delivering the best performances at the high-rate discharges.

IV. RECOMMENDATIONS

Although the program for the development of a family of miniature nickel-cadmium sealed cells has been successfully accomplished the study pointed out some areas which could contribute further to the advancement of these products. These can be broken down into two general categories. The work areas include but are not necessarily limited to the following:

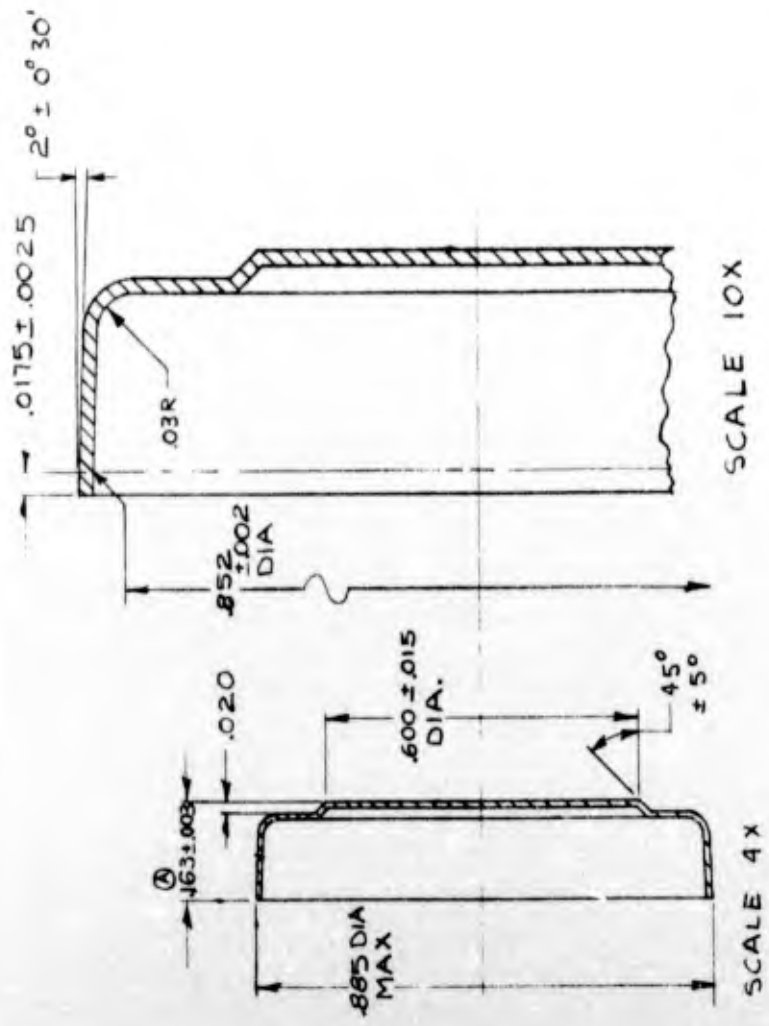
A. Present Design Improvements

- Parametric studies; e.g., continue the optimization of the negative/positive capacity ratio, electrolyte and separator material to further improve overall performance (cycle life, low and high temperature, etc.). Although these studies were conducted the extensive test results indicate that further design improvements could possibly be achieved.
- Faster charge capability; e.g., 0.2 C to 0.3 C rates as contrasted to 0.1 C rate for the present requirements.

B. Advanced Designs

- Simplified designs for BB-684 (100 mAh), BB-685 (150 mAh), and BB-686 (250 mAh) to reduce cost; i.e., 2 and 3-plate designs for these sizes (may require specification changes in the weights and/or cell diameters); optimization of the designs would be aimed toward equivalent performance.

APPENDIX A
CELL COMPONENT DRAWINGS



MAT'L: 1002 or 1010 C.R.S. ALUMINUM KILLED
 NON SCALLOPING #5 TEMPER. NICKEL
 PLATE .00010 TO .00015 PER SIDE. NO
 INTERMEDIATE STRIKE PERMITTED. MAY BE
 MADE FROM GOULD INC. P/N 101449

ET 119
 Rev A - 4/18/72

TITLE
 Can For BB-683()/U

GOULD LABORATORIES
 ENERGY TECHNOLOGY
 ST. PAUL, MINNESOTA

GOULD INC.

Technical drawing of a mechanical part, likely a piston pin, showing dimensions and tolerances. The part is a long, thin cylinder with a central hole. Dimensions include overall length 2.0 ± 0.30 , outer diameter $.867 \text{ DIA}$, inner diameter $.600 \text{ DIA}$, and various fillet and chamfer radii. A note indicates $.011 \text{ THICK MAT'L}$.

Key dimensions and features:

- Overall length: 2.0 ± 0.30
- Outer diameter: $.867 \text{ DIA}$
- Inner diameter: $.600 \text{ DIA}$
- Chamfer: $45^\circ \pm .15$
- Fillet radius: $.03 R$
- End face thickness: $.12 \triangle$
- End face hole diameter: $.852 \text{ DIA} \pm .002 \triangle$
- End face hole position: $.228$
- End face hole diameter tolerance: $\pm .003 \text{ (A)}$
- Material thickness: $.011 \text{ THICK MAT'L}$

MAT'L: 1002 OR 1010 C.R.S
ALUMINUM KILLED NON
SCALLOPING #5 TEMPER
NICKEL PLATE .00010to
.00015 INCH PER SIDE.
NO INTERMEDIATE
STRIKE PERMITTED
MAY BE MADE FROM
(A) GOULD INC P/N 101449

**GOULD LABORATORIES
ENERGY TECHNOLOGY
ST. PAUL, MINNESOTA**

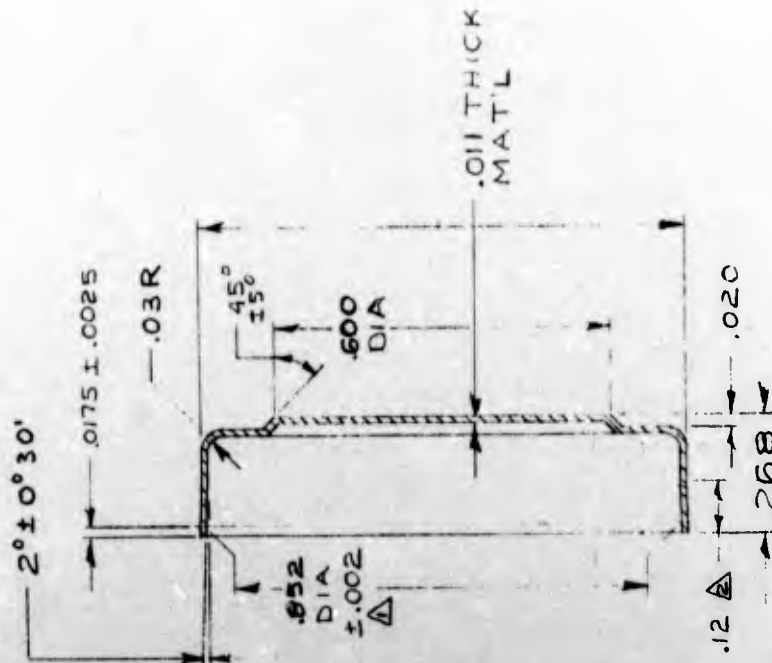
GOULD

TITLE

Can For BB-684()/U

ET 121
Rev A - 4/19/72

△ TO BE MEASURED AS INDICATED
 △ MAX FLARED AREA



NO SCALE

MAT'L: 1002 OR 1010 C.R.S
 ALUMINUM KILLED NON
 SCALLOPING #5 TEMPER
 NICKEL PLATE .00010
 .00015 INCH PER SIDE.
NO INTERMEDIATE
 STRIKE PERMITTED
 MAY BE MADE FROM
 ⑧ GOULD INC, PN 101449

TITLE

GOULD LABORATORIES
 ENERGY TECHNOLOGY
 ST. PAUL, MINNESOTA

Can For BB-685(1)/U

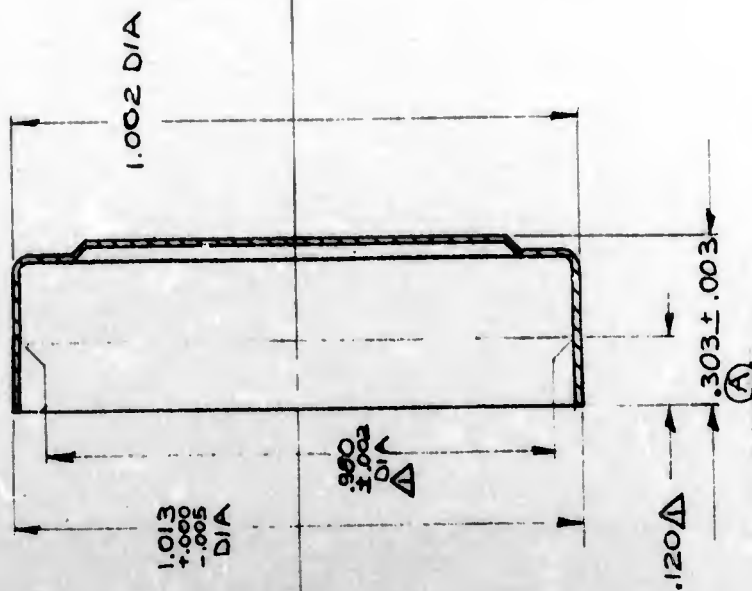
ET 122

Rev A - 11/11/71

Rev B - 4/19/72

GOULD INC.

Δ MEASURED AT POINT SHOWN.



MAT'L: USE GOULD INC
P/N 102124 OR
EQUIVALENT.

TITLE

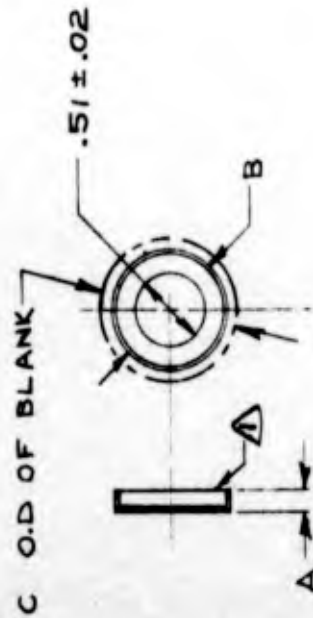
GOULD LABORATORIES
ENERGY TECHNOLOGY
INC. ST. PAUL, MINNESOTA

ET 140
Rev A - 4/19/72

Can For BB-686()/U

GOULD

PART N ^o	A	B	C
ET186	-1.065	.83	.960
	-2.116	.83	1.063
	-3.150	.83	1.125
ET186	-4.213	.97	1.400



Δ. ROUGH EDGE PERMISSIBLE
 2. MAT'L: .004 ± .001 POLYESTER
 FILM, HEAT SEALABLE.

ET 186

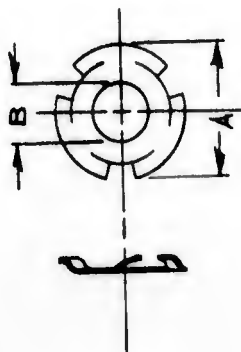
TITLE

Insulator

GOULD LABORATORIES
 ENERGY TECHNOLOGY
 ST. PAUL, MINNESOTA

GOULD INC.

ET PART N ^o	VENDOR	VENDOR P/N	A	B
ET187 -1	Δ	F0595-010	.595	.312
ET187 -2	Δ	F0728-006	.728	.344
ET187 -3	Δ	F0926-007	.926	.453



Δ ASSOCIATED SPRING CORP.
BRISTOL, CONN.

GOULD INC.

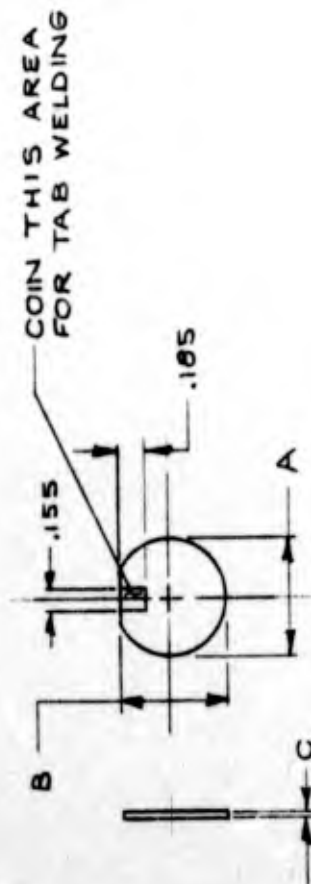
GOULD LABORATORIES
ENERGY TECHNOLOGY
ST. PAUL, MINNESOTA

TITLE

Spring

ET 187

PART NO	A	B	C	USE
-1	.788 ±.010	.788 ±.010	.023	BB683 POS
-2	.788 ±.010	.738 ±.010	.017	BB684 POS
-3	.788 ±.010	.738 ±.010	.028	BB685 POS
-4	.930 ±.010	.880 ±.010	.034	BB686 POS
-5	.788 ±.010	.788 ±.010	.017	BB683 NEG
-6	.788 ±.010	.738 ±.010	.014	BB684 NEG
-7	.788 ±.010	.738 ±.010	.017	BB685 NEG
-8	.930 ±.010	.880 ±.010	.024	BB686 NEG



1. DIMENSIONS SHOWN ARE AFTER SINTERING. SLIGHT PRESSING TO FLATTEN AFTER SINTERING TO SET DIMENSION C.

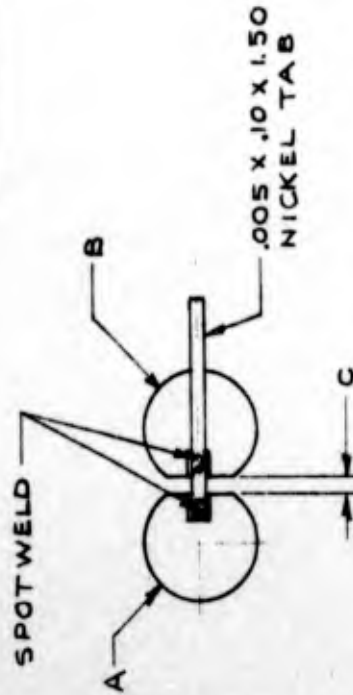
GOULD

GOULD LABORATORIES
ENERGY TECHNOLOGY
ST. PAUL, MINNESOTA

TITLE

Sintered Nickel Electrode Substrate

ET 188



1. ELECTRODES TO BE PROCESSED
PER GOULD PROPRIETARY METHODS
FOR POSITIVE AND NEGATIVE
ELECTRODE PREPARATION.

PART NO	A	B	C	USE
ET189-1	NONE	ET188-1	—	BB863 POS
-2	ET188-2	ET188-2	.120	864
-3	ET188-3	ET188-3	.130	865
-4	ET188-4	ET188-4	.140	866
-5	NONE	ET188-5	—	863 NEG
-6	ET188-6	ET188-6	.130	864
-7	ET188-7	ET188-7	.140	865
-8	ET188-8	ET188-8	.150	866

GOULD INC. GOULD LABORATORIES
ENERGY TECHNOLOGY
ST. PAUL, MINNESOTA

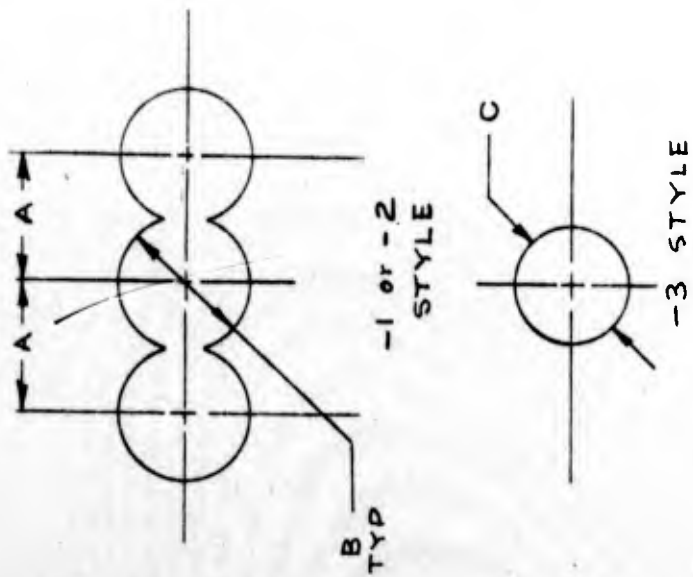
TITLE

Two-Plate Electrode Substrate Assembly

ET 189

GOULD

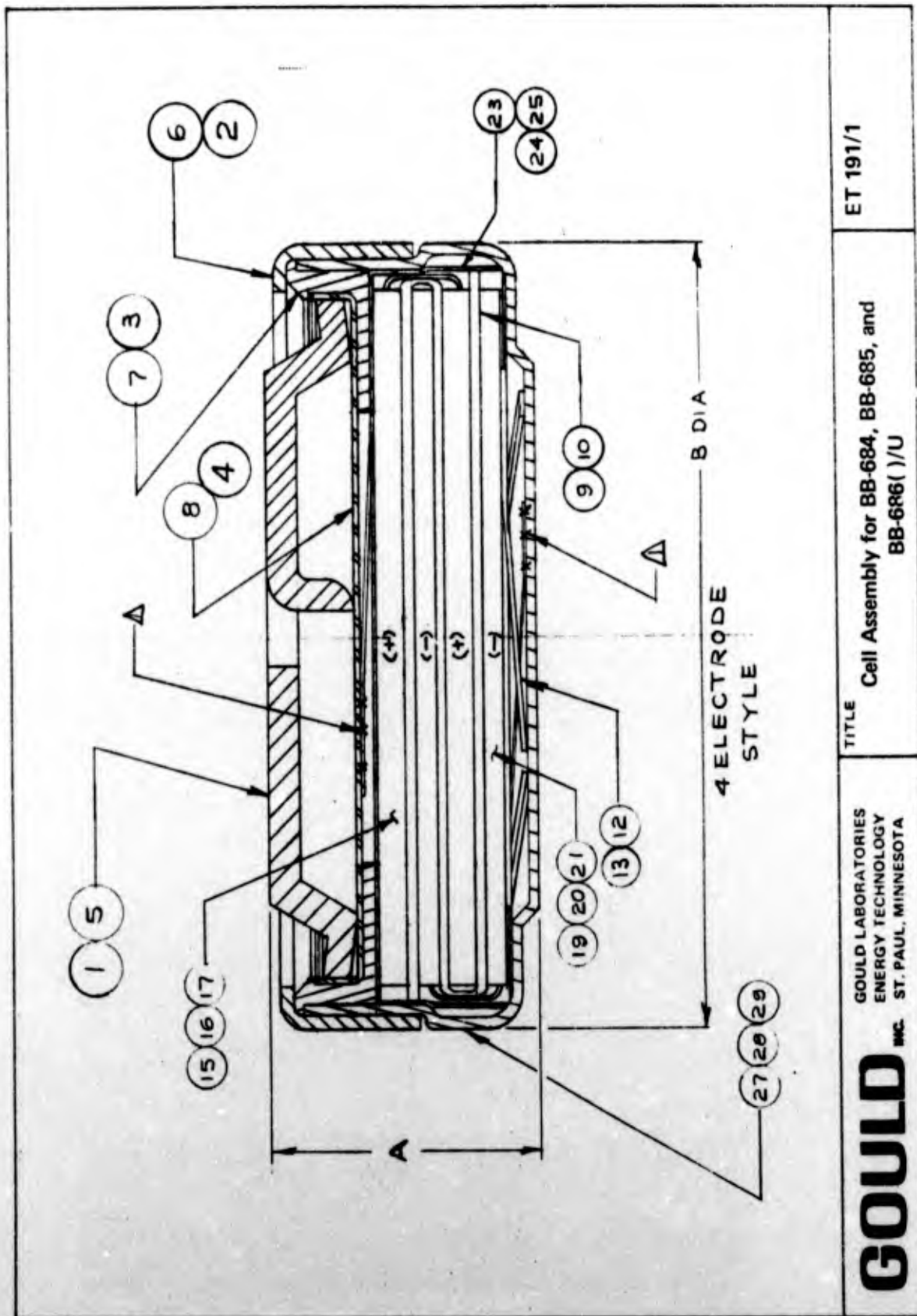
PART NO	A	B	C	MAT'L
-1	.825	.900	—	2504 PELLON
-2	.850	1.000	—	2504 PELLON
-3	—	—	.825	2506 PELLON

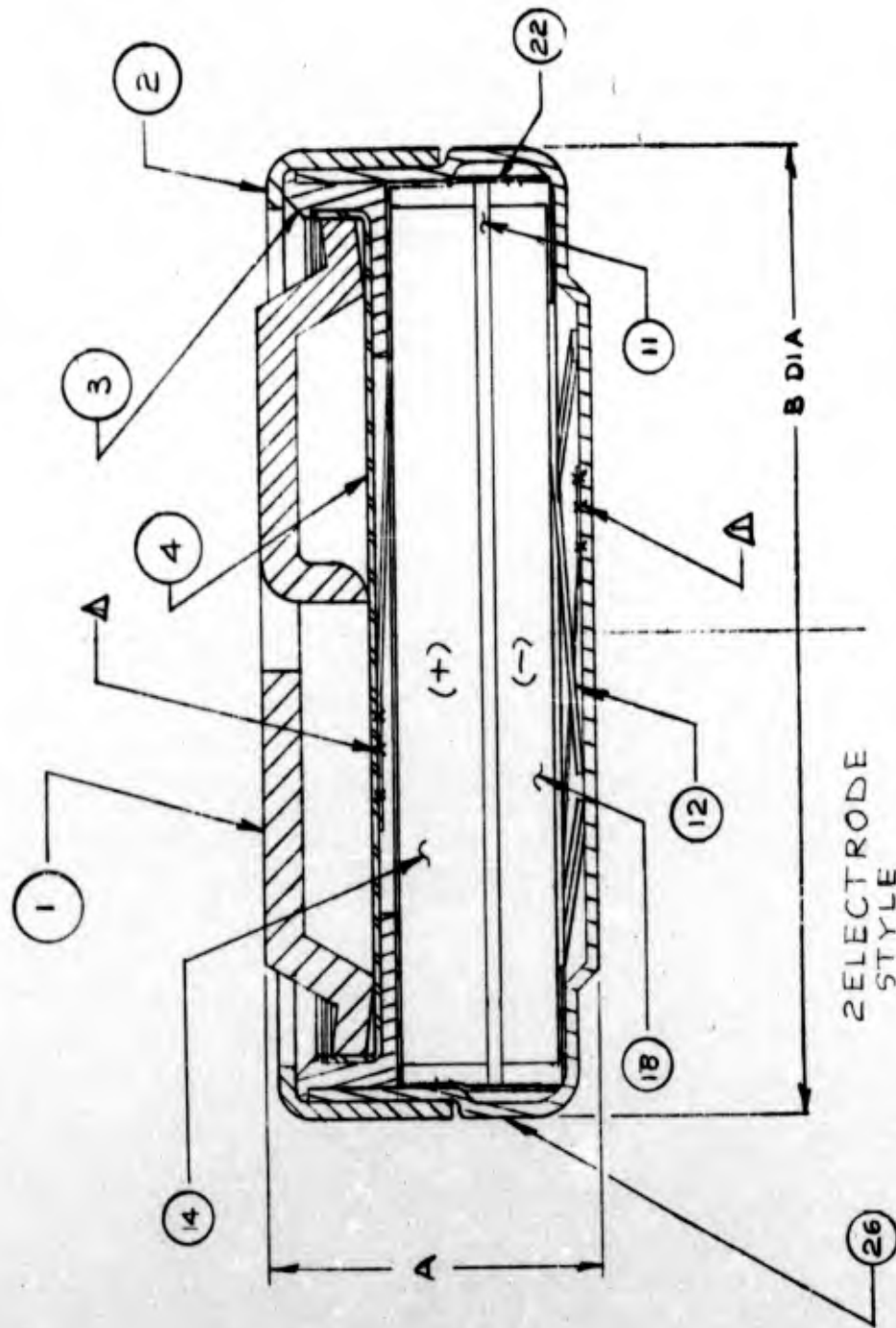


GOULD INC. GOULD LABORATORIES
ENERGY TECHNOLOGY
ST. PAUL, MINNESOTA

TITLE
Separator

ET 190





ET 191/2

TITLE
Cell Assembly for BB-683()/U

GOULD INC. GOULD LABORATORIES
ENERGY TECHNOLOGY
ST. PAUL, MINNESOTA

GOULD

ET 191 PART N ^o	QUANTITY USED				ITEM	PART N ^o	NAME	REMARKS
	-4	-3	-2	-1				
					29	ET 140	CAN	A ↔ A
					28	ET 122	CAN	
					27	ET 121	CAN	
					26	ET 119	CAN	
					25	ET 186-4	INSULATOR	A ↔ A
					24	-3		
					23	-2		
					22	ET 186-1	INSULATOR	
					21	ET 189-8	ELECTRODE	A ↔ A
					20	-7		
					19	-6		
					18	-5		
					17	-4		A ↔ A
					16	-3		
					15	-2		
					14	ET 189-J	ELECTRODE	
					13	ET 187-2	SPRING	A ↔ A
					12	ET 187-1	SPRING	
					11	ET 190-3	SEPARATOR	
					10	ET 190-2	SEPARATOR	
					9	ET 180-1	SEPARATOR	A ↔ A
					8	102126	DIAPHRAM	
					7	100639	GASKET	
					6	102127	SEAL RING	
					5	102125	COVER	A ↔ A
					4	101446	DIAPHRAM	
					3	101412	GASKET	
					2	101448	SEAL RING	
					1	101436	COVER	A ↔ A

ET 191/3

Bill of Material

TITLE

GOULD LABORATORIES
ENERGY TECHNOLOGY
ST. PAUL, MINNESOTA

GOULD INC.

NOTES:

⚠ SPOT WELD TAB TO DIAPHRAM OR CAN
AS SHOWN

2 ET191-1 15 BB683
↓
-2 15 BB684
↓
-3 15 BB685
ET191-4 15 BB686

3 DIMENSIONS:

PART N ^o	A	B
ET191 -1	.220	.873
↓	-2	.270 .873
↓	-3	.295 .873
ET191 -4	.335	1.008

⚠ GOULD COMMERCIAL PARTS.

⚠ MADE FROM GOULD COMMERCIAL PARTS

GOULD INC. GOULD LABORATORIES
ENERGY TECHNOLOGY
ST. PAUL, MINNESOTA

TITLE

Notes

ET 191/4

DOCUMENT CONTROL DATA - R & D

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13. ABSTRACT The purpose of this program has been to design, develop, fabricate, and test miniature high-rate sealed nickel-cadmium batteries of the button cell construction. The battery types are BB-683()/U (50 mAh), BB-684()/U (100 mAh), BB-685()/U (150 mAh), and BB-686()/U (250 mAh). The program was carried out as follows: design parameter study to select prototype models, qualification tests on the prototype batteries in accordance with the specification SCL-6899A, fabrication, and delivery of 100 cells and 20 12-volt batteries of each type. Within the cell dimension and weight limits imposed, the selection of the prototype batteries included investigations on two basic design assemblies; i.e., a 2-plate design and a 4-plate design. The prototype design for the 50 mAh battery is the 2-plate construction; i.e., one positive and one negative. The other three types are of the 4-plate construction; i.e., two positives and two negatives. The four prototype designs met all the requirements (dimensions, weights, electrical, and other environmental tests). The weights of the three 4-plate batteries (100, 150, and 250 mAh sizes) were 8.3, 10.3, and 14.3 g compared to the requirements of 11.34, 12.76, and 17.01 g maximum. In general the minimum capacity requirements were easily exceeded. Batteries of each type are on long life cycle test. The batteries have passed the minimum 56 cycles that was required before the fabrication of the delivery items. The qualification test results show that the program was successfully accomplished.			

KEY WORDS

Battery BB-683()/U
Battery BB-684()/U
Battery BB-685()/U
Battery BB-686()/U
Ni-Cd Secondary
Sealed Ni-Cd

LINK A

LINK B

LINK C

ROLE

WT

ROLE

WT

ROLE

WT

Unclassified
Security Classification