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Performance Characteristics of the Sealed Lead/Acid BB-490/U Battery

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August 1991

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13. ABSTRACT *(Maximum 200 words)*

Performance characterization of a sealed lead/acid battery (BB-490/U) as a replacement for the lithium/sulfur dioxide battery (BA-5590/U) was undertaken. The effects of discharge rate and temperature upon battery performance were studied. Results were compared to those of the BA-5590/U battery under identical test conditions. Delivered capacity of the BB-490/U is greatly dependent upon both the rate of discharge and temperature; whereas, BA-5590/U performance is highly stable throughout the various test conditions. Continuous BB-490/U performance is at least 3.5 times less than that of the BA-5590/U battery. Overall, definite cost savings are realized using BB-490/U, versus BA-5590/U.

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INTRODUCTION

In response to the additional battery needs of the Army during Operation Desert Storm alternate battery systems to the BA-5590/U were investigated. This report deals with an intense two-month in-house testing and evaluation of one possible replacement, a sealed lead/acid battery. Positive test results played an important role towards the purchase of over 20,000 units of the BB-490/U lead/acid battery for military applications.

APPROACH

The investigation was performed to characterize the lead/acid battery with respect to discharge conditions (rate and temperature) and charging conditions (duration and temperature). Battery performance was compared to the lithium BA-5590/U under identical discharge conditions.

The battery, manufactured by Magnum Power Systems, is designated the BB-490/U. It is a rechargeable, sealed lead/acid battery that consists of two 12-volt sections. Each section consists of 6 cells in a series connection. The battery can be utilized with the sections connected in either a series or parallel arrangement. Nominal battery voltage is either 12 volts (parallel connection) or 24 volts (series connection).

The battery, as noted above, consists of 12 cells. The cells, manufactured by Panasonic, are designated LCS-182P. Cell dimensions and weight are 2.27 x 1.64 x 0.64 inches and 0.24 pounds, respectively. The total battery weighs 3.5 pounds. Its dimensions are 4.40 x 2.45 x 5.00 inches.

The battery charging system consists of a charger, designated the MPS-AH-6, and a power supply, designated the MPS-CH2. The charger weighs 0.5 pound and its dimensions are 4.75 x 2.75 x 1.40 inches. The weight of the power supply is 1.9 pounds and its dimensions are 3.50 x 3.00 x 2.50 inches. The total weight of the charging system is 2.4 pounds. The charging system is designed to charge each 6-cell, nominal 12-volt section of the battery independently. Approximately 3-4 hours are required to completely charge a fully discharged battery. The power supply is a 15 volts AC, wall plug-in type with an output of 1.5 amperes at 16 volts DC.

EXPERIMENTAL PROCEDURE

Five BB-490/U batteries and five chargers and power supplies were obtained from Magnum for test and evaluation. Initially, the batteries were discharged at 350 mA at room temperature (70-75°F), charged for 4 hours, then discharged again at 350 mA and room temperature. This initial screening detected one of the five batteries to be defective. Test results (Table 1) found battery 1 to have delivered 32% less capacity than the remaining four. This deficient battery was removed from further investigation.

a. Discharge Characteristics: The effects of discharge rate and temperature on battery performance were investigated. Discharge rates ranged from 0.5 to 3.0 amperes. Discharge temperature varied from 0 to 130°F. Batteries were soaked for 8 hours at the appropriate temperature prior to discharge. At each temperature (0, 70, and 130°F) and discharge current (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 amperes) combination, only one battery was tested. Prior to analysis, the batteries were randomly chosen to assure that each BB-490/U was not always discharged at the same current. Following each experiment, the batteries were charged at 70-80°F (room temperature) for at least 4 hours. Prior to continued testing, the batteries were stored at room temperature for 2 hours. This rest between charge and discharge allowed the stability of both ion migration and battery voltage. Test results are shown in Table 2 and graphically in Figure 1.

b. Equipment Simulation: A major BA-5590/U application is the AN/PRC-119 SINCGARS radio. This radio, which operates at constant power, is energized by one BA-5590/U battery in the 15 volt mode (parallel connection). The characteristics of the lead/acid BB-490/U under AN/PRC-119 simulation were examined.

Testing scenario simulated typical usage of the radio. It consisted of 1 minute at 26.4 watts (transmit) followed by 9 minutes at 3.6 watts (receive). This cyclic regime was continued to a battery potential of 9 volts under the transmit mode. This test scenario was performed at 0, 40, 70, 110, and 160°F. All batteries were soaked for 8 hours at the appropriate temperature prior to discharge. Batteries were charged and conditioned in the identical method as described in Discharge Characteristics testing. Table 3 and Figure 3 illustrate BB-490/U test results.

c. Charging Characteristics: The charging system (charger and power supply) was also investigated. Effects of temperature and charging duration on battery performance were explored.

At 130°F and room temperature the charging profile was examined. One charger was altered so that both the charging current and battery potential could be monitored. Parameters were recorded for each electrical section individually.

DISCUSSION OF RESULTS

a. Discharge Characteristics: The effects of discharge rate and temperature on BB-490/U performance are shown in Figure 1. Battery capacity is inversely related to the discharge rate and directly related to the discharge temperature. At each discharge rate, Table 4 compares the delivered capacity at 70 and 0°F to that obtained at 130°F. Battery performance at rates and temperatures other than tested can be obtained via extrapolation (see Figure 1).

Figure 2 compares the BB-490/U performance to the performance of the lithium/sulfur dioxide BA-5590/U battery. Unlike the lead/acid BB490/U, performance of the lithium BA-5590/U battery is hardly affected by discharge temperature and rate. Throughout all test conditions, delivered capacity of the BA-5590/U was approximately 7.0 A-hr; whereas, the BB-490/U delivered less than 2.0 A-hr.

b. Equipment Simulation: Figure 3 graphically displays the effects of temperature on BB-490/U SINCGARS (AN/PRC-119) simulation. Battery performance is directly proportional to discharge temperature. Note the decreased capacity at 0°F.

A comparison of BB-490/U versus the BA-5590/U performance, under SINCGARS simulation, is shown in Figure 4. Across the various discharge temperatures, lithium BA-5590/U performance exceeded BB-490/U performance by at least a factor of 5.

c. Charging Characteristics: A typical BB-490/U charging profile is shown in Figure 5. Initially the potential (voltage) of both sections is approximately 12 volts. At this point the charging current is essentially 750-800 mA. As the battery is charged, the potential of both sections slowly rises to 14.5 volts (point A). At this point the current has declined to approximately 50 mA and the potential across both sections has dropped to approximately 13.5 volts. The battery is now fully charged. The charging system continued to maintain the potential of each section at 13.5 volts. Some batteries were charged in excess of 24 hours. No damage to either the battery or the charging system occurred.

During the charging process, the charger became hot. Initially it was warm-hot to the touch. As the process continued, the temperature of the charger was noticeably reduced.

OPERATING COSTS

Based on these test results, a SINCGARS operating battery cost analysis and a comparison between the two battery chemistries were performed. SINCGARS usage accounts for a large percentage of the BA-5590/U batteries employed every year. The cost comparison was based on the following:

BB-490/U		BA-5590/U
$280*	Unit Price	$45
200	Cycles Per Unit	1

*Includes charger and adapter.

Figure 6 shows the operating cost differential between the BB-490/U and the BA-5590/U. It clearly shows the significant cost savings that can be realized with BB-490/U usage.

Disadvantages of BB-490/U usage are related to the excess quantity and weight of batteries that would be required to furnish the same capacity (A-Hr) delivered by the BA-5590/U battery. Figure 7 clearly shows that the corresponding quantity of BB-490/U batteries is over 5. In other words, to power a SINCGARS radio for the same service that one BA-5590/U battery can provide, over five fully charged BB-490/U batteries would be required. From Figure 8 it can be seen that this translates to over 17 pounds of BB-490/U batteries versus 2.2 pounds for a single BA-5590/U battery.

CONCLUSIONS

Delivered capacity of the BB-490/U battery is dependent upon discharge rate and is strongly dependent upon temperature. BA-5590/U battery performance, on the other hand, is more stable throughout the various discharge conditions (rate and temperature). Constant current discharge capacity of the BB-490/U is at least 3.5 times less than that of the BA-5590 lithium battery. Overall, based on SINCGARS simulation testing, a definite cost savings can be realized with BB-490/U usage, versus BA-5590/U. Disadvantages of BB-490/U usage relate to the additional weight and quantity of batteries required.

RECOMMENDATIONS

Extensive BB-490/U testing is necessary to characterize battery performance versus the following parameters:

a. Cycle life
b. Shelf life
c. Cold temperature & high temperature charging
d. Environmental testing:
   1. Drop
   2. Mechanical shock
   3. Vibration

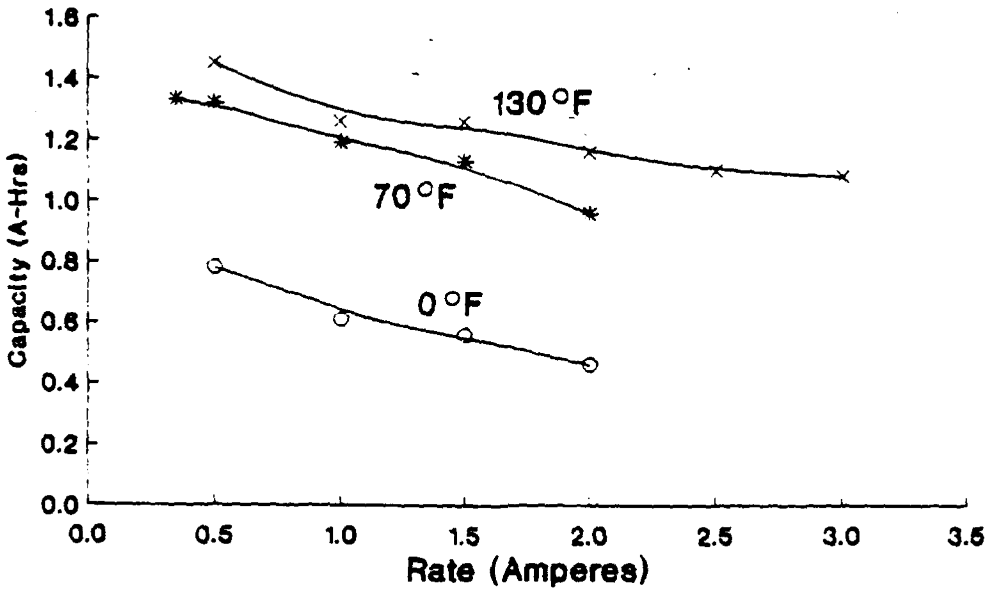

Figure 1. Effects of Discharge Rate and Temperature on BB-490/U Performance

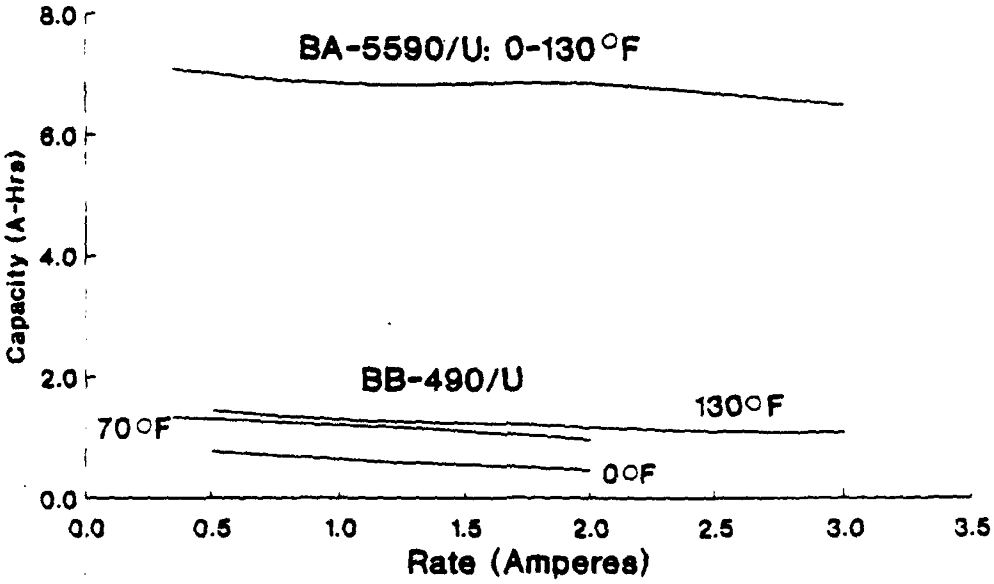

Figure 2. Effects of Discharge Rate and Temperature on Battery Performance.

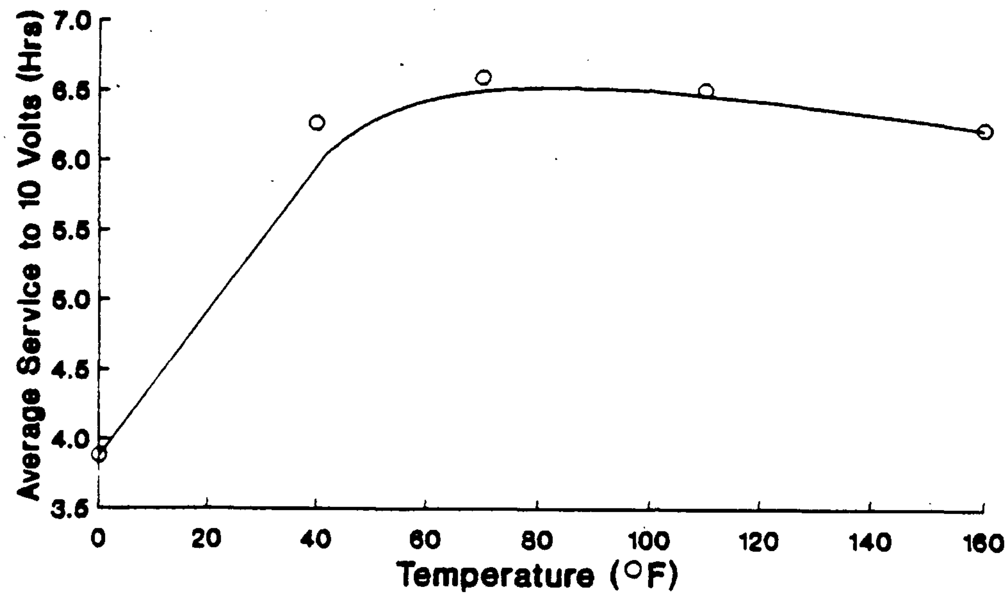

Figure 3. SINCGARS Simulation. Effects of Temperature Upon BB-490/U Performance.

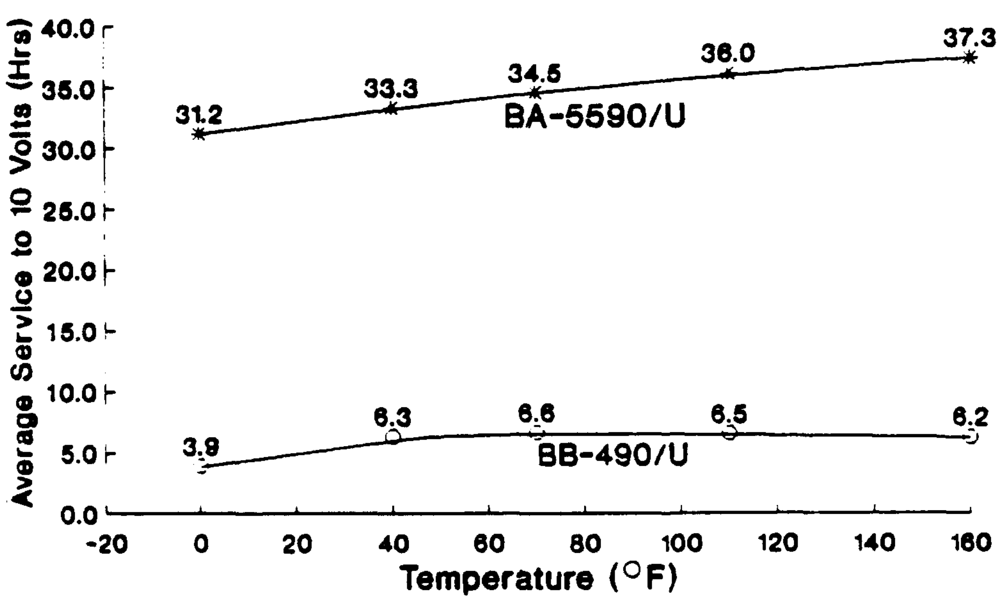

Figure 4. SINCGARS Simulation. Effects of Temperature on Battery Performance.

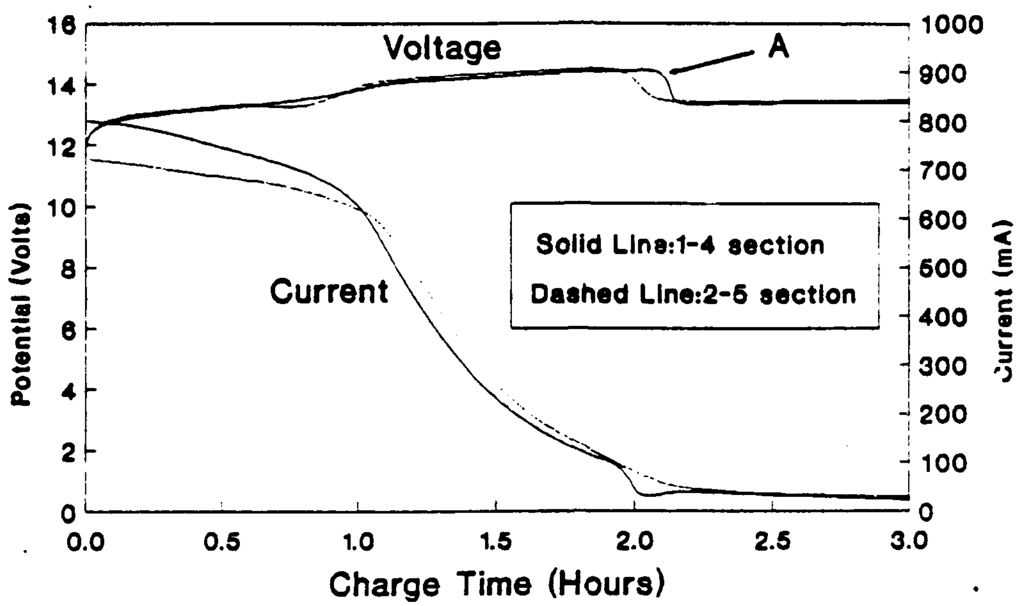

Figure 5. BB-490/U Charging Profile.

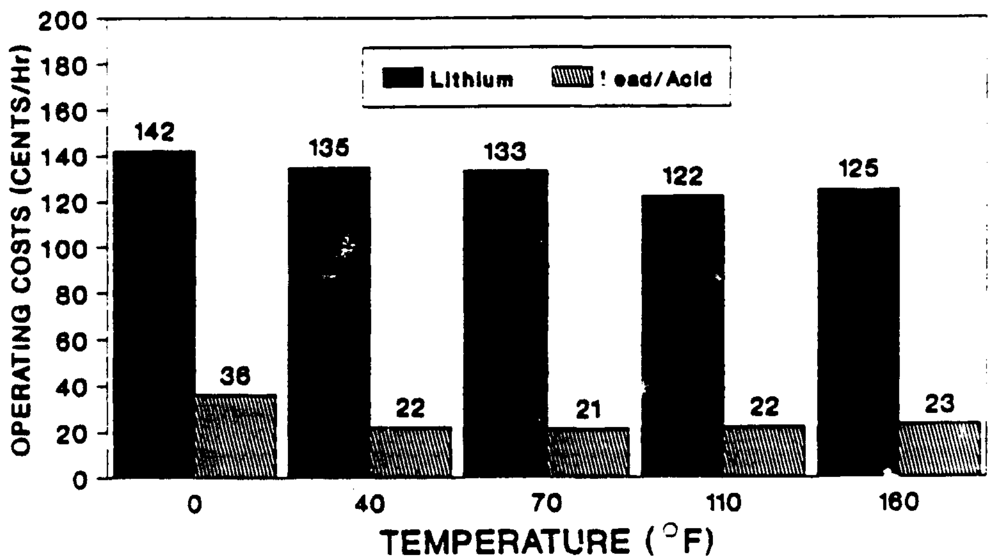

Figure 6. SINCGARS Simulation
Battery Operating Costs.

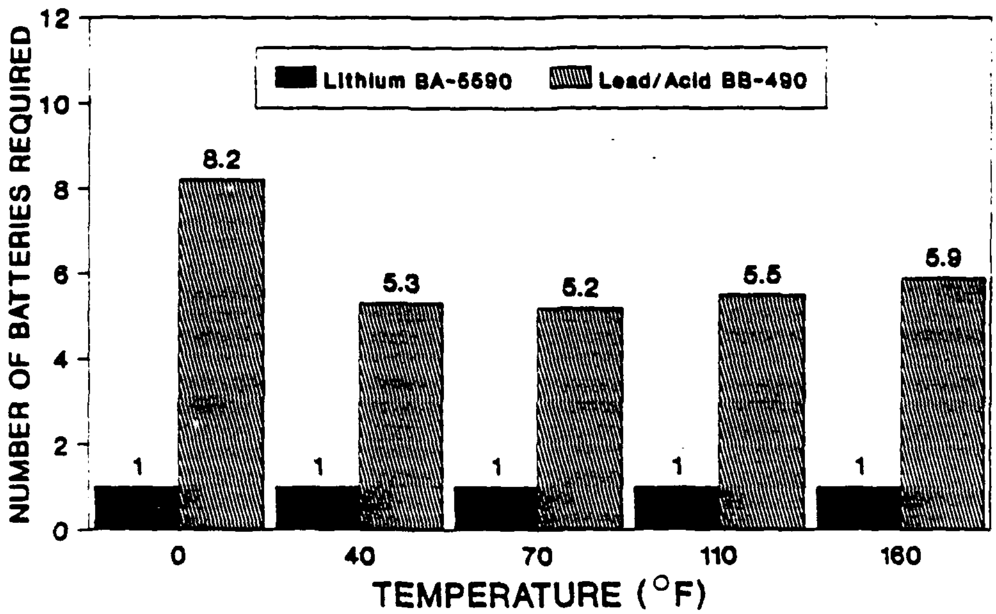

Figure 7. SINCGARS Simulation.
Quantity of Batteries Required.

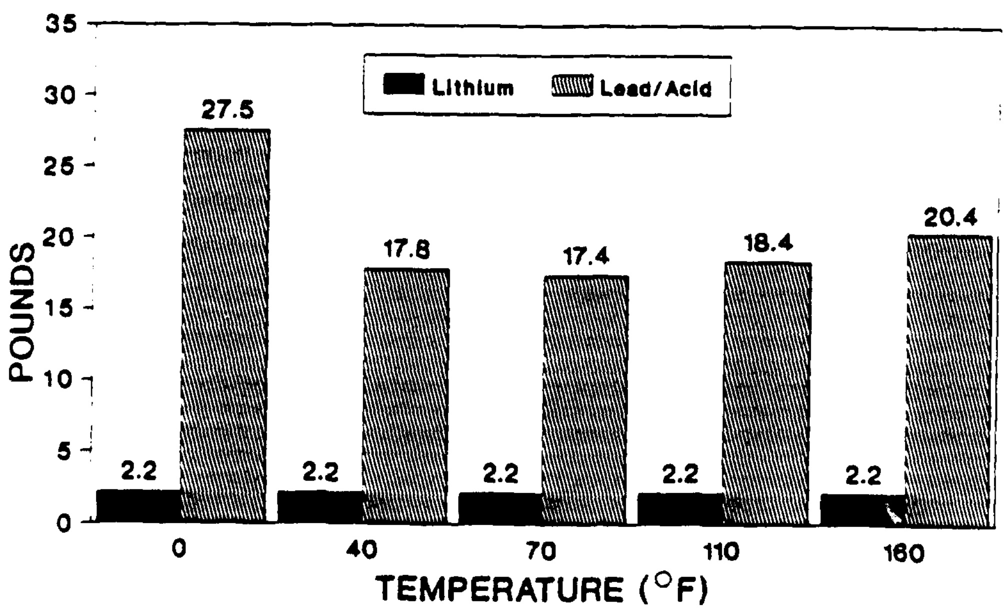

Figure 8. SINCGARS Simulation.
Weight of Batteries Required.

TABLE 1. INITIAL BATTERY SCREENING

Discharge Rate: 350 mA
Discharge Temperature: 70°F

Battery Number	Cycle Number	Service to 20 Volts (Hrs)	Capacity (A-Hr)
1	1	2.20*	0.77*
2	1	3.66	1.28
3	1	3.64	1.27
4	1	3.40	1.19
5	1	3.74	1.31
1	2	2.48*	0.87*
2	2	3.72	1.30
3	2	3.72	1.30
4	2	3.80	1.33
5	2	3.64	1.19

*Defective Battery

TABLE 2. EFFECTS OF DISCHARGE RATE AND TEMPERATURE ON BB-490/U PERFORMANCE

Battery Number	Discharge Rate (A)	Conditions Temperature (°F)	Service to 20 Volts (Hr)	Capacity (A-Hr)
4	2.0	0	0.23	0.46
2	1.5	0	0.37	0.56
5	1.0	0	0.61	0.61
3	0.5	0	1.57	0.78
2	2.0	70	0.48	0.96
3	1.5	70	0.75	1.13
4	1.0	70	1.19	1.19
5	0.5	70	2.64	1.32
3	3.0	130	0.36	1.08
5	2.5	130	0.44	1.10
4	2.0	130	0.58	1.16
2	1.5	130	0.84	1.26
5	1.0	130	1.26	1.26
3	0.5	130	2.90	1.45

TABLE 3. AN/PRC-119 SIMULATION. EFFECTS OF TEMPERATURE ON BB-490/U PERFORMANCE

Battery Number	Cycle Number	Temperature (°F)	Service to 10 Volts (Hrs)	Average Service (Hrs)
2	5	0	4.00	3.88
4	5	0	3.50	
5	5	0	4.00	
2	4	0	4.00	
5	2	40	6.18	6.26
2	2	40	6.33	
4	1	70	6.83	6.59
2	1	70	6.85	
5	1	70	6.35	
2	3	70	6.33	
5	3	110	6.67	6.50
4	3	110	6.67	
4	4	110	6.33	
5	4	110	6.33	
4	6	160	6.33	6.23
5	6	160	6.18	
4	7	160	6.17	

TABLE 4. BB-490/U CONSTANT CURRENT DISCHARGE PERFORMANCE COMPARISON

Rate (A)	SERVICE (A-HR) / PERCENTAGE LOST (%)		
	130°F	70°F	0°F
2.0	1.16	0.96/17.2%	0.46/60.3%
1.5	1.26	1.13/10.3%	0.56/55.6%
1.0	1.26	1.19/ 5.6%	0.61/51.6%
0.5	1.45	1.32/ 8.9%	0.78/46.2%

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