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NAVAL WEAPONS SUPPORT CENTER CRANE IND WEAPONS QUALI--ETC F/G 10/3
ENGINEERING EVALUATION TESTS OF 3-4 AMPERE-HOUR SEALED LEAD-ACI--ETC(U)
DEC 77 A W GOODMAN
WQEC/C-77-395

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WEAPONS QUALITY ENGINEERING CENTER
NAVAL WEAPONS SUPPORT CENTER
CRANE, IN 47522

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ENGINEERING EVALUATION TESTS
OF
3-4 AMPERE-HOUR SEALED LEAD-ACID BATTERIES
ELPOWER, ESB, EAGLE-PICHER, GLOBE UNION AND GATES

HW NO.

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TABLE OF CONTENTS

PARAGRAPH		PAGE
	REPORT BRIEF	1
I.	INTRODUCTION	1
II.	TEST CONDITIONS	1
III.	BATTERY DESCRIPTION	1
IV.	TEST PROCEDURES AND RESULTS	2-10
	A. Initial Capacity Test	2
	B. Life Cycling Test	3
	C. Discharge Time Versus Discharge Rate	5
	D. Temperature Versus Discharge Capacity	6
	E. Constant Potential Charging	9
	F. Temperature Rise and Float Test	9

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REPORT BRIEF

ENGINEERING EVALUATION TESTS
OF

3-4 AMPERE-HOUR SEALED LEAD-ACID BATTERIES
MANUFACTURED BY ELPOWER, ESB, EAGLE-PICHER, GLOBE UNION AND GATES

Ref: (a) Work Unit NWSC 4P7-117/27
(b) MIL-B-83769B of 20 May 1975
(c) MIL-B-8565H(AS) of 26 Aug 1977

I: TEST ASSIGNMENT

A. In compliance with reference (a), evaluation tests were conducted on sealed lead-acid batteries manufactured by Elpower Corporation, ESB Incorporated, Eagle-Picher Industries, Globe Union, Inc. and Gates Energy Products, Inc.

B. ✓ The program objective was to evaluate and determine:

- (1) High rate capability,
- (2) Low temperature performance,
- (3) A plot of discharge time versus various discharge rates,
- (4) Life cycle capability, and
- (5) Charging requirements. ↑

C. A total of 50 batteries were received for evaluation, 10 from each manufacturer.

EVALUATION TESTS CONDUCTED

REPORT PARAGRAPH	TEST
IV.A	Initial Capacity Test
IV.B	Life Cycling Test
IV.C	Discharge Time Versus Discharge Rate
IV.D	Temperature Versus Discharge Capacity
IV.E	Constant Potential Charging
IV.F	Temperature Rise and Float Test

II. BATTERY DESCRIPTION

A. The 50 batteries are 12-volt, secondary sealed lead-acid storage batteries in the 3-4 ampere-hour capacity range.

B. Each battery is sealed with a lifetime supply of electrolyte, eliminating watering. The batteries use either the starved electrolyte system or gelled electrolyte system. Lead-calcium grids are used instead of lead-antimony grids to reduce the self-discharge rate and the high gassing rate during charging associated with lead-antimony grids.

C. Before testing, sample numbers were assigned to the 50 batteries. The 10 Elpower batteries were numbered EL1 through EL10 inclusive, 10 ESB batteries ES1 through ES10 inclusive, 10 Eagle-Picher batteries EP1 through EP10 inclusive, 10 Globe Union batteries GL1 through GL10 inclusive, and 10 Gates batteries G1 through G10 inclusive.

III. SUMMARY OF RESULTS

A. The Gates batteries exhibited superior life cycling performance (600 cycles) compared to standard lead-acid or the other sealed lead-acid batteries tested. Life cycles completed by the manufacturers were:

- (1) Gates - 600 cycles
- (2) Elpower - 312 cycles
- (3) ESB - 151 cycles
- (4) Eagle-Picher - 108 cycles
- (5) Globe Union - 76 cycles

B. The ESB and Globe Union batteries lacked the high rate capability compared to the other batteries under test.

C. The Elpower (EL2 and EL3) and Gates (G7 and G8) batteries passed the -18°C capacity performance requirement (6.0 C rate, 7.2 volt cutoff) of reference (b) while the ESB, Eagle-Picher and Globe Union batteries failed to meet the minimum time requirement of 3.3 minutes.

D. All batteries except the Gates failed the three minute heavy duty, low rate discharge of reference (c). Gates batteries (G7 and G8) passed with times of 3.20 and 3.0 minutes respectively.

E. Batteries EL2, EL3, EP1, EP2, G7 and G8 all passed the 6 second heavy duty, high rate discharge of reference (c).

F. Batteries EL2, EL3, EP1, EP2, G7 and G8 all failed the one hour, .8 C rate discharge at -30°C ; which is associated with heavy duty, high rate nickel-cadmium batteries. The time to reach cutoff voltage was:

<u>SAMPLE NUMBER</u>	<u>TIME (MINUTES)</u>
EL2, EL3	48, 36
EP1, EP2	26, 26
G7, G8	52, 52

G. A Gates battery was subjected to a special life cycling test using a constant potential charge and completed 100 life cycles without any noticeable loss in capacity or needed maintenance.

H. The temperature rise and float test in MIL-B-81757 was performed on a Gates battery. The battery passed the test with a maximum temperature of 64°C and no increase in current.

I. The sealed lead-acid batteries did not need the maintenance that is essential for the performance of vented lead-acid or nickel-cadmium batteries.

IV. RECOMMENDATION

A. It is recommended that a program to build a sealed 18ah or 31ah military battery be initiated.

RESULTS OF ENGINEERING EVALUATION TEST
OF
3-4 AMPERE-HOUR SEALED LEAD-ACID BATTERIES MANUFACTURED BY
ELPOWER, ESB, EAGLE-PICHER, GLOBE UNION AND GATES

I. INTRODUCTION

A. The evaluation testing of 3-4ah sealed lead-acid batteries was conducted between June 1976 and July 1977. Test results are contained herein.

II. TEST CONDITIONS

A. Each test was conducted at existing relative humidity, atmospheric pressure and room ambient temperature ($21 \pm 5^{\circ}\text{C}$) unless otherwise indicated.

III. DESCRIPTION OF BATTERIES

A. The Elpower Corporation Battery, part number EP1245A, is a 12-volt, maintenance free, solid-gel electrolyte, sealed lead-acid battery having a rated capacity of 4.5ah at the 20-hour rate. The battery's physical dimensions in inches are 5.96 L X 2.66 W X 3.94 H and weighs 5.0 pounds.

B. The ESB Incorporated Cell, part number PB-F is a 2-volt, maintenance free, starved electrolyte, cylindrical sealed lead-acid cell having a rated capacity of 4.0ah at the 10-hour rate. The cell's physical dimensions in inches are 3.55L X 1.43W X 1.43H and weighs .62 pounds. Six cells were connected in series to form a 12-volt battery pack.

C. The Eagle-Picher Industries, Inc. Battery, battery number CF12V5, is a 12-volt maintenance free, starved electrolyte, sealed lead-acid battery having a rated capacity of 5.0ah at the 20-hour rate. The battery's physical dimensions in inches are 4.62L X 3.18W X 3.90H and weighs 4.7 pounds.

D. The Globe Union Inc. Battery, part number GC1245-1, is a 12-volt, maintenance free, solid-gel electrolyte, sealed lead-acid battery having a rated capacity of 4.5ah at the 20-hour rate. The battery's physical dimensions in inches are 5.95 L X 2.52 W X 3.74 H and weighs 4.5 pounds.

E. The Gates Energy Products, Inc. Battery, part number 0800-0008, is a 12-volt, maintenance free, starved electrolyte, sealed lead-acid battery with cylindrical cells having a rated capacity of 5.2ah at the 20-hour rate. The battery's physical dimensions in inches are 5.41 L X 3.66 W X 3.12 H and weighs 5.1 pounds.

F. Each battery was marked with a code to distinguish manufacturer and sample number. The codes are listed below:

10 Elpower Batteries	EL1 through EL10
10 ESB Batteries	ES1 through ES10
10 Eagle-Picher Batteries	EP1 through EP10
10 Globe Union Batteries	GL1 through GL10
10 Gates Batteries	G1 through G10

IV. EVALUATION TEST PROCEDURES AND RESULTS

A. Initial Capacity Test

1. All batteries were charged at a constant-potential voltage of 14.5 volts for 5 hours. The batteries were then discharged at the 1-C rate to a cutoff voltage of 9.0 volts. The 1-C rate chosen for each battery manufacturer was:

	<u>1-C RATE</u>
(a) Elpower	2.25 Amperes
(b) ESB	2.00 Amperes
(c) Eagle-Picher	2.50 Amperes
(d) Globe Union	2.25 Amperes
(e) Gates	2.50 Amperes

a. The ampere-hour capacities at the 1-C rates are shown below:

<u>SAMPLE NO.</u>	<u>AMPERE-HOURS DELIVERED</u>	<u>SAMPLE NO.</u>	<u>AMPERE-HOURS DELIVERED</u>
EL1	3.15	GL1	2.36
EL2	3.52	GL2	2.25
EL3	3.50	GL3	2.51
EL4	3.97	GL4	2.62
EL5	3.37	GL5	2.65
EL6	3.52	GL6	2.54
ES1	2.86	G1	3.79
ES2	2.77	G2	3.67
ES3	2.44	G3	3.75
ES4	2.64	G4	3.50
ES5	2.94	G5	3.83
ES6	2.84	G6	3.79

<u>SAMPLE NO.</u>	<u>AMPERE-HOURS DELIVERED</u>	<u>SAMPLE NO.</u>	<u>AMPRER-HOURS DELIVERED</u>
EP1	3.95		
EP2	4.00		
EP3	3.88		
EP4	3.83		
EP5	3.84		
EP6	3.73		

B. Life Cycling Tests

1. Batteries EL5, EL6, ES7, ES8, EP3, EP4, GL4, GL5, G1 and G2 were life cycled at the 1-hour discharge rate and a 110 percent recharge.

2. Each cycle consisted of a discharge period of one hour at the 1-C discharge rate or until the battery's terminal voltage dropped below 9.0 volts. Following the discharge each battery was rested on open circuit for one hour prior to recharge. Each battery was given a constant-current 5-hour charge to effect a 10 percent overcharge. Following the charge, each battery was rested on open circuit for one hour prior to the next cycle.

a. The life cycling data is shown below:

CHARGE - 110 PERCENT, .50 AMPERE FOR 5 HOURS
DISCHARGE - 2.25 AMPERES FOR 1 HOUR

<u>SAMPLE NO.</u>	<u>CYCLE NO</u>	<u>EOC VOLTAGE</u>	<u>EOD VOLTAGE</u>
EL5, EL6	1	16.37, 16.17	11.71, 11.73
EL5, EL6	20	17.07, 16.89	11.72, 11.76
EL5, EL6	40	17.12, 16.90	11.73, 11.75
EL5, EL6	80	17.02, 16.76	11.70, 11.69
EL5, EL6	100	16.93, 16.69	11.65, 11.57
EL5, EL6	150	15.19, 15.48	11.66, 9.51
EL5, EL6	200	16.62, 16.07	11.72, 9.00
EL5	250	15.16	11.60, EL6 Failed at Cycle #200
EL5	300	16.56	11.47
EL5	350	16.58	9.42
EL5	400	16.24	9.23
EL5	425	16.30	9.00 Stopped Cycling

CHARGE - 110 PERCENT, .44 AMPERE FOR 5 HOURS
DISCHARGE - 2.00 AMPERES FOR 1 HOUR

SAMPLE NO.	CYCLE NO.	EOC VOLTAGE	EOD VOLTAGE
ES7, ES8	1	14.86, 15.47	11.28, 11.34
ES7, ES8	20	16.80, 16.82	11.56, 11.63
ES7, ES8	40	16.98, 16.96	11.61, 11.66
ES7, ES8	60	16.98, 16.96	11.67, 11.72
ES7, ES8	80	17.09, 17.05	11.52, 11.55
ES7, ES8	100	17.04, 16.99	11.33, 11.40
ES7, ES8	125	17.05, 17.03	10.09, 10.62
ES7, ES8	142	16.96, 16.87	9.00, 9.54
ES8	160	17.10	9.00

ES7 Failed, 9.00 Stopped
at Cycle #142 Cycling

CHARGE - 110 PERCENT, .55 AMPERE FOR 5 HOUR
DISCHARGE - 2.50 AMPERES FOR 1 HOUR

SAMPLE NO.	CYCLE NO.	EOC VOLTAGE	EOD VOLTAGE
EP3, EP4	1	17.07, 17.02	11.38, 11.39
EP3, EP4	20	17.00, 17.00	10.95, 10.89
EP3, EP4	40	17.10, 17.11	10.70, 10.61
EP3, EP4	60	16.88, 16.89	10.33, 10.15
EP3, EP4	80	17.13, 17.12	9.92, 9.81
EP3, EP4	100	16.92, 16.92	9.46, 9.53
EP3, EP4	108	16.94, 16.94	9.00, 9.00

Stopped Cycling

CHARGE - 110 PERCENT, .44 AMPERE FOR 5 HOURS
DISCHARGE - 2.00 AMPERES FOR 1 HOUR

SAMPLE NO.	CYCLE NO.	EOC VOLTAGE	EOD VOLTAGE
GL4, GL5	1	17.11, 17.17	11.16, 10.84
GL4, GL5	20	16.79, 16.31	10.84, 10.60
GL4, GL5	40	16.76, 16.16	11.09, 9.00
GL4	60	16.60	10.98,
GL4	80	16.66	10.69,
GL4	100	16.41	9.52,
GL4	113	16.16	9.00 Stopped Cycling

GL4 Failed at Cycle #40

CHARGE - 110 PERCENT, .55 AMPERES FOR 5 HOURS
DISCHARGE - 2.50 AMPERES FOR 1 HOUR

G1, G2	1	16.80, 16.80	11.74, 11.72
G1, G2	20	14.41, 14.39	11.59, 11.58
GL, G2	40	14.38, 14.38	11.40, 11.41
GL, G2	60	14.37, 14.42	11.42, 11.46
G1, G2	80	14.41, 14.43	11.26, 11.34
G1, G2	100	14.40, 14.43	11.19, 11.28
G1, G2	150	14.34, 14.40	11.15, 11.24
G1, G2	200	14.27, 14.33	11.15, 11.25
G1, G2	250	14.31, 14.36	10.85, 11.02
G1, G2	300	14.33, 14.34	10.86, 10.98
G1, G2	350	14.33, 14.35	10.72, 10.85
G1, G2	400	14.36, 14.38	10.57, 10.69
G1, G2	450	14.36, 14.37	10.21, 10.25
G1, G2	500	14.38, 14.38	9.67, 9.83
G1, G2	550	14.21, 14.22	10.47, 10.53
G1, G2	600	14.41, 14.39	9.30, 9.00 Stopped Cycling

b. The average number of life cycles completed by each manufacturer was:

- (1) Elpower 312 Cycles
- (2) ESB 151 Cycles
- (3) Eagle-Picher 108 Cycles
- (4) Globe Union 76 Cycles
- (5) Gates 600 Cycles

C. Discharge Time Versus Discharge Rate

1. Batteries EL1, EL2, ES5, ES6, EP5, EP6, GL1, GL2, G3, and G4 were given a 12-hour constant current charge at the C/10 rate prior to each of the following discharges. Each battery was subjected to 2-C, 3-C, 5-C and 6.5-C rate constant current discharges to a cutoff voltage. Higher rates were not performed since the battery intercell connectors were not designed for such discharges.

a. The discharge data for the various discharges is shown below:

<u>SAMPLE NO.</u>	<u>DISCHARGE RATE</u>	<u>TIME (HOURS) TO CUTOFF VOLTAGE</u>	<u>AMPERE-HOURS DELIVERED</u>
EL1, EL2	4.50 A to 9.0 V	.667, .716	3.00, 3.22
EL1, EL2	6.75 A to 9.0 V	.383, .433	2.59, 2.92
EL1, EL2	11.25 A to 8.0 V	.174, .217	1.95, 2.44
EL1, EL2	14.62 A to 7.2 V	.161, .169	2.36, 2.47
ES5, ES6	4.00 A to 9.0 V	.330, .467	1.32, 1.86
ES5, ES6	6.00 A to 9.0 V	.200, .288	1.20, 1.70
ES5, ES6	10.00 A to 8.0 V	.068, .075	.68, .75
ES5, ES6	13.00 A to 7.2 V	.024, 0.73	.31, .95
EP5, EP6	5.00 A to 9.0 V	.517, .500	2.58, 2.50
EP5, EP6	7.50 A to 9.0 V	.300, .300	2.25, 2.25
EP5, EP6	12.50 A to 8.0 V	.150, .135	1.87, 1.68
EP5, EP6	16.25 A to 7.2 V	.095, .093	1.54, 1.51
GL1, GL2	4.00 A to 9.0 V	.417, .350	1.67, 1.40
GL1, GL2	6.00 A to 9.0 V	.250, .217	1.50, 1.30
GL1, GL2	10.00 A to 8.2 V	.108, .100	1.08, 1.00
GL1, GL2	13.00 A to 7.2 V	.064, .052	.83, .67
G3, G4	5.00 A to 9.0 V	.667, .633	3.33, 3.17
G3, G4	7.50 A to 9.0 V	.383, .367	2.87, 2.75
G3, G4	12.50 A to 8.0 V	.208, .189	2.60, 2.36
G3, G4	16.25 A to 7.2 V	.147, 1.43	2.39, 2.32 ...2

D. Temperature Versus Discharge Capacity

1. Batteries EL2, EL3, ES3, ES4, EP1, EP2, GL6, GL7, G7 and G8 were given a (125 percent of previous discharge) constant-current recharge prior to each of the following discharges.

2. Each battery was discharged at the 1-C rate to 9.0 volts cutoff at 25°C, 0°C and -18°C.

a. The discharge data for the 1-C rate discharges at 25°C, 0°C and -18°C is shown below:

<u>SAMPLE NO.</u>	<u>DISCHARGE RATE</u>	<u>TEMPERATURE</u>	<u>AMPERE-HOURS DELIVERED</u>
EL2, EL3	2.25 A to 9.0 V	25°C	2.85, 2.81
EL2, EL3	2.25 A to 9.0 V	0°C	2.77, 2.25
EL2, EL3	2.25 A to 9.0 V	-18°C	1.58, 1.01
ES3, ES4	2.00 A to 9.0 V	25°C	1.60, 1.53
ES3, ES4	2.00 A to 9.0 V	0°C	1.30, 1.33
ES3, ES4	2.00 A to 9.0 V	-18°C	.77, .53
EP1, EP2	2.50 A to 9.0 V	25°C	3.42, 3.29
EP1, EP2	2.50 A to 9.0 V	0°C	2.85, 2.71
EP1, EP2	2.50 A to 9.0 V	-18°C	1.50, 1.42
GL6, GL7	2.00 A to 9.0 V	25°C	2.07, 2.10
GL6, GL7	2.00 A to 9.0 V	0°C	1.20, 1.37
GL6, GL7	2.00 A to 9.0 V	-18°C	.57, .73
G7, G8	2.50 A to 9.0 V	25°C	3.83, 3.79
G7, G8	2.50 A to 9.0 V	0°C	3.38, 3.42
G7, G8	2.50 A to 9.0 V	-18°C	2.46, 2.38

3. The -18°C capacity performance requirement (6.0 C rate, 7.2 volt cutoff, -18°C) of reference (b) was performed on each battery. Minimum time to cutoff voltage as specified is 3.3 minutes.

a. The discharge data for the 6.0-C rate, -18°C discharge is shown below:

<u>SAMPLE NO.</u>	<u>DISCHARGE 6.0-C RATE</u>	<u>TIME (MINUTES) TO CUTOFF VOLTAGE</u>	<u>AMPERE-HOURS DELIVERED</u>
EL2, EL3	13.50 A to 7.2 V	4.57, 3.12	1.03, 0.70
ES3, ES4	12.00 A to 7.2 V	Battery Voltage Went Negative at Start of 12.0 A Discharge	0.00, 0.00
EP1, EP2	15.00A to 7.2 V	2.17, 2.08	0.54, 0.54
GL6, GL7	12.00 A to 7.2 V	Battery Voltage 4.7 V and 4.8 V after 5 seconds	0.00, 0.00
G7, G8	15.00 A to 7.2 V	4.40, 4.13	1.10, 1.04

b. Gates and Elpower passed the 3.3 minute time requirement compared to the Eagle Picher batteries failing by more than 1 minute. The ESB and Globe Union batteries demonstrated a lack of any high rate, low temperature capability.

4.. Batteries EL2, EL3, EP1, EP2, G7 and G8 were subjected to the 3 minute heavy duty, low rate discharge battery requirement of reference (c). The test conditions were a 6.0-C rate discharge to 7.2 volts at -23.3°C. Minimum time to cutoff voltage as specified is three minutes. Batteries ES3, ES4, GL6 and GL7 were not subjected to the discharge since they failed the previous discharge at -18°C.

a. The discharge data for the 6.0-C rate, -23.3°C discharge is shown below:

<u>SAMPLE NO.</u>	<u>DISCHARGE 6.0-RATE</u>	<u>CUTOFF VOLTAGE (7.2V)</u>	<u>AMPERE-HOURS DELIVERED</u>
EL2, EL3	13.50 A to 7.2V	2.95, 1.80	.66, .41
EP1, EP2	15.00 A to 7.2 V	1.33, 1.33	.33, .33
G7, G8	15.00 A to 7.2 V	3.20, 3.00	.80, .75

b. G7 and G8 passed the three minute requirement at the 6.0-C rate and -23.3°C temperature while EL2, EL3, EP1 and EP2 failed to complete the three minute discharge.

5. Batteries EL2, EL3, EP1, EP2, G7 and G8 were subjected to the six seconds, heavy duty, high rate discharge battery requirement of reference (c). The test conditions were a 4.1C rate discharge to 9.0 volts at -30°C. Minimum time to cutoff voltage as specified is six seconds.

a. The discharge data for the 4.1-C rate, -30°C discharge is shown below:

<u>SAMPLE NO.</u>	<u>DISCHARGE 4.1-C RATE</u>	<u>TIME (SECONDS) TO CUTOFF VOLTAGE</u>	<u>AMPERE-HOUR DELIVERED</u>
EL2, EL3	9.22 A to 9.0 V	225, 78	.576, .200
EP1, EP2	10.25 A to 9.0 V	15, 42	.043, .120
G7, G8	10.25 A to 9.0 V	282, 267	.803, .760

b. EL2, EL3, EP1, EP2, G7 and G8 all passed the six second minimum time requirement.

6. Batteries EL2, EL3, EP1, EP2, G7 and G8 were subjected to the one-hour discharge at -30°C specified in reference (c). The test conditions were a .8C rate discharge to 9.0 volts at -30°C. Minimum time to cutoff voltage as specified is one hour.

a. The discharge data for the .8C rate, -30°C discharge is shown below:

<u>SAMPLE NO.</u>	<u>DISCHARGE .8-C RATE</u>	<u>TIME (MINUTES) TO CUTOFF VOLTAGE</u>	<u>AMPERE-HOURS DELIVERED</u>
EL2, EL3	1.80 A to 9.0 V	48, 36	1.44, 1.08
EP1, EP2	2.00 A to 9.0 V	26, 26,	.87, .87
G7, G8	2.00 A to 9.0 V	52, 52	1.73, 1.73

b. All batteries failed the discharge requirement associated with nickel-cadmium batteries.

E. Constant Potential Charging

1. G5 and G6 were series together to form a 24 volt battery. The battery was life cycled using a 5-hour constant potential charge instead of a 5-hour constant current charge for 100 life cycles.

2. Each cycle consisted of a discharge period of one hour at a 3.0 ampere discharge rate or until the battery's terminal voltage dropped below 18.0 volts. Following the discharge, the battery was rested on open circuit for one hour prior to recharge and then given a 5-hour constant potential charge (with a 3.0 ampere current limit) at 28.50 volts. Following the charge, the battery was rested on open circuit for one hour prior to the next cycle.

a. The life cycling data is shown below for the 24 volt battery (G5 in series with G6).

<u>CYCLE NO.</u>	<u>EOC VOLTAGE</u>
1	22.65
5	22.20
10	22.40
20	22.48
30	22.54
40	22.59
50	22.65
60	22.96
70	22.60
80	22.53
90	22.57
100	22.40

b. The battery did not reach maximum capacity until cycle number 60 and completed 100 cycles without any noticeable loss in capacity.

F. Temperature Rise and Float Test

1. Batteries G2 and G9 were series together to form a 24 volt battery. G2 had been life cycled for 600 cycles and G9 was a new battery pack. This was done to set up a worse case condition (old cells mixed with new cells).

2. The temperature rise and float test specified in paragraph 4.6.20 of MIL-B-81757 was performed. The battery was placed in a temperature chamber at $49^{\circ} + 3^{\circ}\text{C}$ for 16 hours. At this temperature the battery was discharged at the 9C (22.5 amperes) rate for five minutes. Immediately following this discharge, with the battery still in the chamber at 49°C , a constant potential charge of 27.9 volts was conducted for 10 hours. The battery was then stabilized at room ambient and discharged at the 1-C rate to 18.0 volts.

a. The temperature rise and float test data is shown below:

49°C DISCHARGE 9-C Rate

<u>INTERVAL (MINUTES)</u>	<u>VOLTS</u>	<u>CURRENT (AMPERES)</u>	<u>TEMPERATURE (°C)</u>
OCV	25.35	0.0	49.4
01	21.64	22.5	49.4
02	21.05	22.5	49.4
03	20.20	22.5	49.4
04	18.10	22.5	50.0
04 Min 30 Sec	14.40	22.5	50.0

27.90 VOLTS CHARGE

OCV	23.88	0.0	51.1
15 Min.	27.90	1.43	57.8 57.8
30 Min.	27.90	.50	58.9
1 Hour	27.90	.50	61.1
2	27.90	.45	64.0
3	27.90	.41	64.0
4	27.90	.38	63.3
5	27.90	.32	62.2
7	27.90	.26	60.0
10 Hours	27.90	.21	55.6

DISCHARGE 1-C RATE, ROOM AMBIENT

OCV	25.60	0.0	19.4
01	24.04	2.50	19.0
05	24.11	2.50	19.0
10	24.02	2.50	18.3
30	23.47	2.50	20.6
1 Hour	19.24	2.50	22.2
01	18.00	2.50	22.2

b. The battery passed all requirements; the current did not increase, the battery temperature stayed below 71°C and the battery exceeded the one hour required on discharge.

DISTRIBUTION LIST

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