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CHARACTERIZATION MEASUREMENTS ON NEW NICKEL/CADMIUM AIRCRAFT BA--ETC(U)  
OCT 79 K FELDMAN , & VERVILLE  
DREO-TN-79-22

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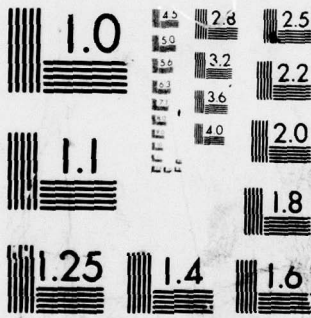
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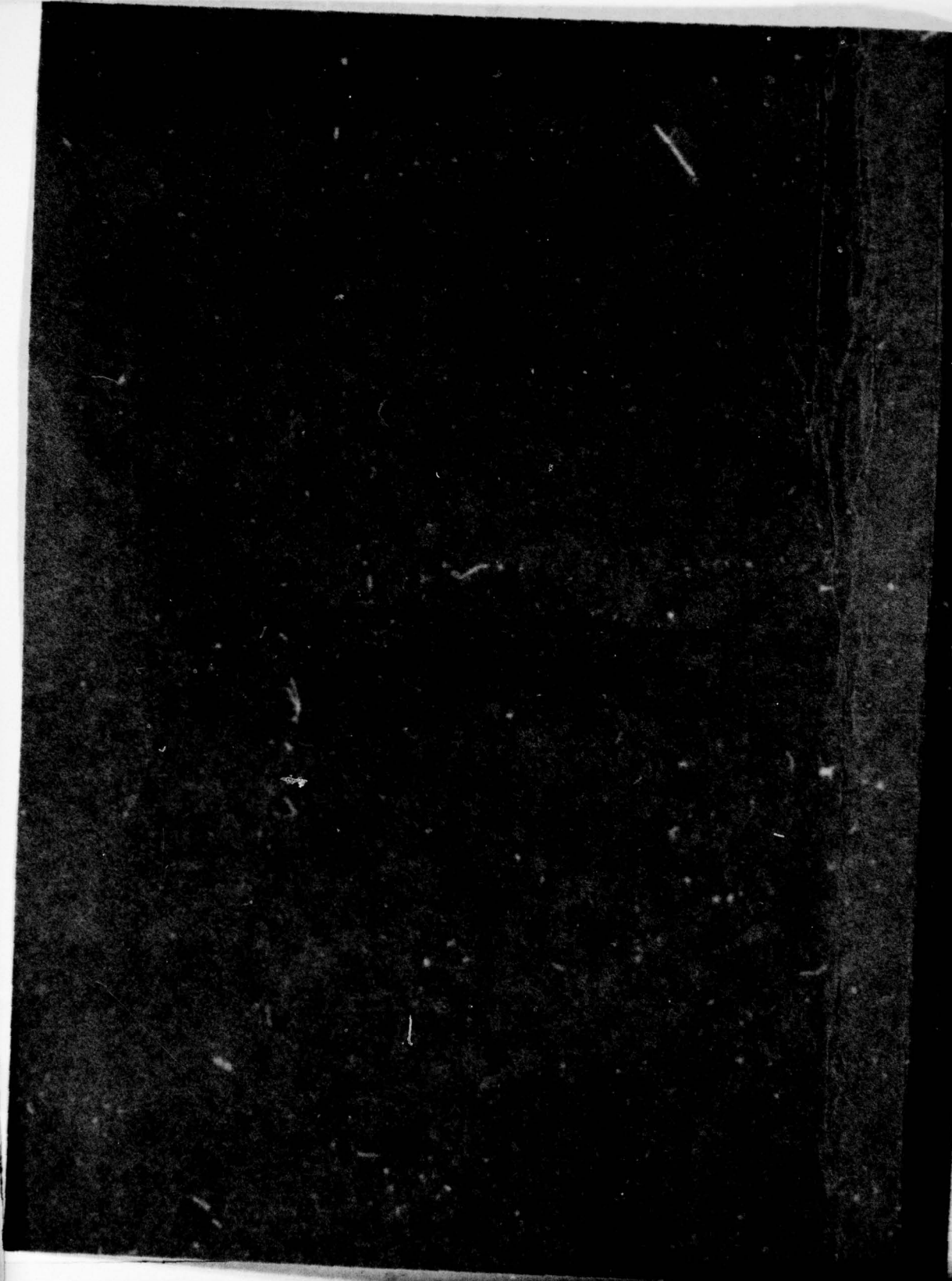
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It should also be noted that the actual capacities considerably exceed the nominal values. The "22Ah" Marathon cells, on the average, show capacities of 29.7Ah, an excess of 35%. Similarly, the "36Ah" cells exceed their nominal capacities by about 33%. This means that in attempting to fully charge these batteries from their discharged state, considerably more charge

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CANADA

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

9 TECHNICAL NOTE NO. 79-22

14 DREO-TN-79-22

6 CHARACTERIZATION MEASUREMENTS ON  
NEW NICKEL/CADMIUM AIRCRAFT BATTERIES  
MANUFACTURED BY MARATHON AND SAFT.

by Saston  
100 Keiva ~~and~~ Feldman ~~and~~ Nerville  
Energy Conversion Division

PROJECT NO.  
25A00

\* On contract from Computing Devices Company.

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ABSTRACT

A set of measurements has been found useful in the laboratory at DREO for characterizing nickel/cadmium aircraft cells. It is thought such measurements would also be useful in the battery shop to aid in the making of decisions on the need for reconditioning or for discarding cells which are no longer safe or satisfactory.

Most of the experience at DREO has, however, dealt with old or rebuilt batteries. Recently one new 22Ah battery from Marathon and two new 36Ah batteries from SAFT were obtained. Results of the measurements on these are therefore of special interest.

This paper briefly outlines the measurements and presents the data obtained.

RÉSUMÉ

Un ensemble de mesures effectuées en laboratoire s'est avéré très utile pour évaluer les accumulateurs d'avion au nickel/cadmium. Nous croyons que ces mesures peuvent être appliquées dans les ateliers de service afin de déterminer si un accumulateur doit être reconditionné ou mis hors de service.

Les mesures indiquées ont surtout été effectuées sur des accumulateurs usagés ou reconstruits. Récemment nous avons obtenu une batterie neuve de 22 Ah de Marathon et deux batteries neuves de 36Ah de SAFT. Les données obtenues sur ces batteries peuvent servir de données de référence.

Une description sommaire des mesures et les données obtenues sont présentées dans cette note technique.

INTRODUCTION

Nickel/cadmium aircraft batteries are regularly returned to the battery shop for servicing and assessment. Personnel there must determine that each cell is in satisfactory condition. This is complicated by individual differences between cells which are nominally identical. The variations may be due to intended or accidental differences in manufacture and subsequent use. The battery shop must nevertheless decide whether each cell is in a satisfactory state, whether it requires further reconditioning, or whether it is unable to perform its task and may perhaps become hazardous so should be removed from the battery.

A set of characterizing tests in use in the laboratory at DREO may be useful in making the required decisions. Measurements are made to determine the condition of the electrolyte, cell gassing characteristics, discharge characteristics and high rate capability. However, acceptable tolerances must be set before the results can be used as a guide to the required decisions. The tolerances should be set as a result of experience with batteries in the field rather than in the laboratory. However, laboratory experience can provide a useful starting point, and in particular, the measurements on new batteries should be of interest. Some of these are available and are presented in this paper.

THE MEASUREMENTS

Discussions of the measurements involved have been published previously (1)(2)(3) and only a brief review is given here. Some of the measurements are normal in shop practice and some involve extensions of normal procedures. Others may require additional equipment. However, an understanding of the facts relating to those measurements may be useful even if they cannot be carried out as described.

ELECTROLYTE CONDITION

Both the electrolyte composition and its level in the cell are important in battery performance. Two aspects of this are significant here. First, the electrolyte condition after service in the aircraft may indicate the state of health of the cell. For example, if, the electrolyte in all cells of a battery were "topped up" to approximately the same level at the previous maintenance period, but the level in one cell is now significantly higher than in the rest, the cell should be investigated. One possibility is that during overcharge very little gas is actually emitted. This means that the cell will heat up as a result of the oxygen-cadmium recombination. Another possibility is that the cell is self-discharging sufficiently during inactive periods so that it does not recharge during an ordinary flight to get to the gassing stage. Both of these situations are of course, unsatisfactory.

The second aspect of importance here is that unsatisfactory electrolyte level and/or condition may affect the results in the remaining tests.

Electrolyte analysis can be carried out in the normal way (4). If this is not possible, it should nevertheless be ensured that the electrolyte level is within the specified limits. If necessary, distilled water should be added. Potassium hydroxide (KOH) solution should not be added unless there is evidence that the concentration is too low. If carbonate ( $K_2CO_3$ ), concentration is too high, normal exchange procedures (4)(5) should be followed. High carbonate levels cause poor high rate service, particularly at low temperature.

The electrolyte in each cell should also be inspected for turbidity once or twice a year. Samples of electrolyte may be taken with a syringe while the battery is in overcharge and is gassing vigorously. The samples are placed in test tubes for observation. Figure 1 shows examples of electrolyte from cells which had seen extensive use. They are arranged to show the wide range of turbidity which may be found. The two test tubes shown at the right hand end contain pure electrolyte for reference purposes. The two samples at the left are extremely "muddy". It is likely that cells with such large quantities of material in the electrolyte, and by inference, in the separator materials, would develop short circuits in the near future and should perhaps be removed from service.

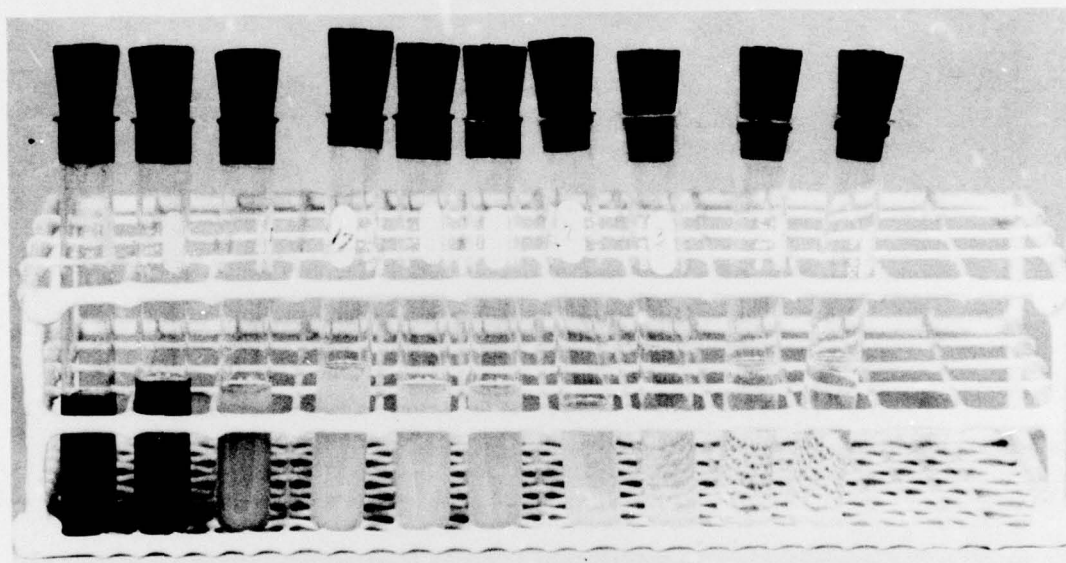


Fig. 1: Examples of turbidity in cell electrolyte.

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## GASSING MEASUREMENTS

If suitable equipment is available (6) two kinds of measurements on gassing can be made. One of these determines the maximum gassing rate of each cell when it is charged after all active material has been converted to the charged form. If this rate for any cell is significantly below the theoretical value (2) the cause is either excessive oxygen-cadmium recombination or some other self-discharge mechanism. In either case excessive heating and possibly other problems may be expected, and such cells should be removed.

A second measurements may be made as follows. The battery is fully charged (to maximum gassing rate) and allowed to stand on open circuit overnight or longer. Charging is then resumed at a constant current and the length of time required for each cell to start gassing is observed. Excessively long periods indicate abnormal self-discharge rates, probably caused by the early stages of short-circuit formation.

## DISCHARGE CHARACTERISTICS

Active materials in the plates of a cell may undergo undesirable changes, such as large crystal formation, which result in deteriorated performance. Such changes usually may be reversed by deep cycling in the battery shop. The need for doing so, possibly more than once, may be determined as follows.

The charged battery is discharged. Records are made of the number of ampere-hours obtained from each cell to both the one-volt end point and to zero volts (each cell is short circuited when it reaches zero volts to prevent reverse charging). Differences in capacity between the two end-points which are significantly larger than normal (one or two ampere-hours) indicate the need for deep cycling (1).

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## HIGH RATE CAPABILITY

The satisfactory performance of a battery in high rate applications, such as engine cranking, depends largely on low battery resistance. While, in part, this depends on the battery design, factors under control of the battery shop may play a part. Also manufacturing defects or cell deterioration may render a cell unsatisfactory for high rate use when it still seems satisfactory at low rates. When measurements attract attention to such cells, the battery shop can readily determine whether the condition can be corrected (low electrolyte, faulty interconnections etc.) or whether replacement is necessary.

Resistance may be measured directly if a suitable milliohmmeter is available or it may be calculated from instantaneous changes in current and voltage when brief high rate discharges are started or terminated (3). Excessive gas entrapment may also cause excessive resistance in some circumstances. This may be determined as follows. The battery is charged until it gasses vigorously. It is then left on open circuit for several hours. Resistances are then measured before and after applying a vacuum for few seconds to the vent of each cell. A significant drop in resistance caused by the vacuum application indicates excessive gas entrapment.

MEASUREMENTS ON THE THREE NEW BATTERIES

Measurements such as the ones described above were made on the three new batteries referred to earlier. The results obtained are given here as examples of new battery conditions. The batteries used were as follows:

- (a) Marathon, 22Ah, 19 cell battery using cell type 24M220, with Celgard 3400 barrier layer in the separators.
- (b) SAFT, 36Ah, 20 cell battery using cell type VP400KH with Celgard 3400 barrier layer in the separators.
- (c) SAFT, 36Ah, 20 cell battery using cell type VP400KH with cellophane barrier layer in the separators.

After the first few charge discharge cycles and minor level adjustments where necessary, the electrolyte was analyzed by the usual titration method. The results are shown in Table 1.

TABLE 1  
KOH and  $K_2CO_3$  Concentrations

Cell	Celgard-Marathon		Celgard-SAFT		Cellophane-SAFT	
	KOH	$K_2CO_3$	KOH	$K_2CO_3$	KOH	$K_2CO_3$
1	29.7%	4.9%	27.5%	1.6%	27.1%	4.7%
2	31.5	2.9	29.3	1.6	27.2	4.0
3	30.8	3.8	28.2	1.3	27.6	4.2
4	29.4	4.7	28.2	1.1	27.3	4.7
5	31.2	4.2	26.5	1.8	27.2	4.5
6	30.1	3.8	27.8	1.3	28.0	4.2
7	30.3	4.2	27.1	1.6	28.6	3.8
8	30.9	4.0	28.4	1.3	28.4	3.2
9	31.3	2.4	26.2	1.6	25.8	4.5
10	29.0	5.8	29.3	1.6	27.6	4.0
11	30.7	4.0	26.0	1.6	27.8	4.5
12	30.4	3.8	27.5	1.6	28.0	3.4
13	26.9	5.8	28.1	1.3	27.5	4.2
14	29.5	3.8	29.0	1.6	26.5	4.7
15	29.6	5.1	26.4	1.3	28.2	4.2
16	30.7	2.4	28.0	1.1	28.4	3.8
17	30.2	3.8	27.2	1.6	27.9	3.8
18	31.3	3.2	27.6	1.6	26.6	3.8
19	31.0	3.6	29.2	1.3	27.9	4.5
20	--	---	28.8	1.3	26.6	5.6

Average:    30.2       4.0       27.8       1.5       27.5       4.2

For test purposes these concentrations were considered adequate and were not altered. However, it is interesting to note the following:

(1) The carbonate concentration in the battery with cellophane is nearly three times as high as in the SAFT battery with Celgard. It is understood that these two batteries were made with plates from the same manufacturing batches. One would expect therefore that initial carbonate contaminations would have been similar. Presumably the increase in the one battery has resulted from the gradual deterioration of the cellophane between the time of manufacture and the time of the above measurements.

(2) The total alkalinity (i.e. of the KOH plus the carbonate) in the Celgard batteries average 29.3% for SAFT and 34.2% for Marathon. In use, water loss during overcharge would increase these concentrations further. The latter concentration at least, would then be too high for optimum high rate operation at low temperatures (7).

(3) No cells showed any evidence of turbidity.

#### GASSING MEASUREMENTS

After a few conditioning cycles, the batteries were charged at 10A constant current until maximum gassing rates were achieved. The rates given in Table II were obtained.

TABLE II

Maximum Gassing Rates\*

Cell	Celgard-Marathon	Celgard-SAFT	Cellophane-SAFT
1	94%	92%	90%
2	90	94	86
3	98	92	92
4	94	95	91
5	98	93	90
6	95	85	93
7	95	86	90
8	99	95	94
9	96	80	93
10	87	96	82
11	96	83	88
12	94	82	91
13	95	96	94
14	100	98	94
15	100	81	86
16	97	88	92
17	94	95	92
18	99	88	98
19	96	94	91
20	--	96	94

\* Rates are given in per cent of theoretical maximum.

The accuracy of the gassing rate measurements is probably not above + 10%. Aside from inherent channel to channel variations in sensitivity of the equipment, it is difficult to ensure gas tight connections to the cells on a routine basis. Leakages, of course, lower the readings obtained. In particular, the vent cap design on the SAFT batteries above is different from that for which the apparatus fittings were designed and a temporary scheme was used to obtain these measurements. However, the results shown in the table are regarded as being adequately high for practical purposes.

The second set of gassing measurements, to determine whether there were any excessive self-discharging rates in any of the cells, was made as follows. Each battery was charged until maximum gassing rates were achieved (more than twice the nominal capacity was required; note the actual capacities given in a later section). Each battery was then left on open circuit for 20 hours. Charging was then resumed at a constant current of 5A. The time required for each cell to start gassing again is given in Table III.

Since these batteries were new presumably no "short circuit" paths had yet started to form. The observed times are therefore assumed to represent "Normal" discharge mechanisms. It may be noted that for the 22Ah (Marathon) battery the times to start gassing varied from 1:45 (minutes and seconds) to 3:50. For the 36Ah Cellophane (SAFT) battery the times varied from 1:35 to 4:28. The average times for the two batteries were 2:44 and 3:00 respectively. Since the same current was used for both sizes of battery, and since presumably at least some of the self-discharge mechanisms operate on an "Area" basis, it might be expected that somewhat longer times would be required by the larger cells.

The results obtained with the Celgard-SAFT are not fully understood. Due to accidental circumstances the original measurements for this battery do not reliably indicate the times for the individual cells, and were made at a higher charge rate than is normally used for this test. It is calculated that converted to the standard rate, the times would have ranged between 4:13 and 7:42. Because of the above situation measurements were repeated after the battery had been subjected to a number of other experiments. These results are given in Table III. They range from 5:10 to 7:23, and thus seem to correspond to the original results. Why they are considerably higher than the results for the other SAFT battery is not known.

#### DISCHARGE CHARACTERISTICS

After several conditioning cycles, the batteries were charged fully and left on open circuit overnight. They were then discharged at a constant current of 10A. The capacities obtained are shown in Table V. The differences between the capacities to the one volt and zero volt end points are also shown. It may be noted that in nearly all cases, these differences are less than 3Ah. Considerably larger differences are typical of cells in a poor state of health (1).

TABLE III

Times\* Required for Cells to Resume Cassing at 5A

Cell	Celgard-Marathon	Cellgard-Soft	Cellophane-SAFT
1	3:00	5:10	3:20
2	2:10	5:37	4:28
3	2:00	6:20	3:58
4	2:35	5:30	3:14
5	2:25	5:40	2:40
6	3:16	5:30	2:47
7	2:40	5:35	2:55
8	3:40	5:25	3:55
9	2:25	6:45	3:47
10	2:10	5:20	2:45
11	3:00	6:40	3:44
12	2:00	7:23	2:00
13	1:45	5:25	1:35
14	3:10	5:07	3:45
15	3:10	7:07	2:26
16	3:50	6:00	2:30
17	2:25	5:25	2:45
18	3:15	5:32	2:42
19	3:10	5:15	2:12
20	----	5:10	2:35
Average	2:44	5:08	3:00

\* Times are given in Minutes and Seconds.

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TABLE IV  
Capacities of the Cells in the Batteries

Cell	Celgard-Marathon		Celgard-SAFT		Cellophane-SAFT	
	to IV.	to OV. Difference	to IV.	to OV. Difference	to IV.	to OV. Difference
1	30.1Ah	32.0Ah 1.9Ah	49.5Ah	50.8Ah 1.3Ah	47.8Ah	48.2Ah 0.4Ah
2	30.3	32.9 2.6	50.2	51.2 1.0	48.9	50.7 1.8
3	29.9	33.3 3.4	49.3	50.6 1.3	48.9	51.0 2.1
4	27.1	28.5 1.4	49.2	50.5 1.3	48.5	49.9 1.4
5	29.5	30.3 0.8	49.0	50.5 1.5	48.4	50.8 2.4
6	29.5	30.8 1.3	49.4	51.1 1.7	48.9	50.9 2.0
7	28.4	29.9 1.5	49.9	51.8 1.9	48.1	50.0 1.9
8	27.5	28.1 0.6	49.7	51.5 1.8	48.6	51.3 2.7
9	29.2	29.9 0.7	49.7	52.1 2.4	48.2	50.9 2.7
10	30.1	32.1 2.0	50.1	51.3 1.2	48.4	50.5 2.1
11	28.8	29.8 1.0	49.5	51.4 1.9	48.8	50.6 1.8
12	31.0	33.4 2.4	49.9	52.0 2.1	48.8	50.2 1.4
13	32.6	35.7 3.1	49.6	51.3 1.7	48.8	51.0 2.2
14	29.3	31.1 1.8	49.7	51.4 1.7	47.9	49.8 1.9
15	30.9	33.8 2.9	49.1	50.7 1.6	48.1	49.8 1.7
16	30.2	31.8 1.6	50.0	51.5 1.5	48.9	50.1 1.2
17	31.9	34.8 2.9	48.7	50.3 1.6	48.9	51.0 2.1
18	29.4	30.2 0.8	49.4	51.0 1.6	48.0	50.3 2.3
19	28.6	29.7 1.1	49.3	50.4 1.1	48.3	50.7 2.4
20	----	----	48.9	50.4 1.5	48.7	51.3 2.6
Average	29.7	31.5 1.8	49.5	51.1 1.7	48.5	50.5 2.0

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It should also be noted that the actual capacities considerably exceed the nominal values. The "22Ah" Marathon cells, on the average, show capacities of 29.7Ah, an excess of 35%. Similarly, the "36Ah" cells exceed their nominal capacities by about 33%. This means that in attempting to fully charge these batteries from their discharged state, considerably more charge is required than that based on the nominal values. Furthermore, for cell balance purposes, the capacity extremes are more significant than the average. As an example, Marathon Cell 13 has a capacity of 32.6Ah, nearly 50% over the nominal value.

Resistance measurements are given in Table V. These were made at room temperature with a Hewlett Packard Model 4328A milliohmmeter (3) after the batteries had been charged and left on open circuit overnight. To assess gas entrapment the measurements were made twice. Between the two measurements a vacuum was applied for a few seconds to the vent of each cell. The resulting average reduction in resistance was only a few percent so gas entrapment at room temperature is not a serious problem in any of these batteries.

It may be seen that a few cells show a resistance that is approximately 10% higher than the average for the particular battery. Any higher variation would be cause for further investigation.

It should be noted that, since the significance of some of the factors involved in cell resistance changes completely at low temperatures, if low temperature operation is involved, measurements should also be made at low temperatures.

#### CONCLUSION

The data presented in this paper gives the results obtained in characterization measurements on three new nickel/cadmium aircraft batteries. When account is taken of the differences in capacity and resistance between the two battery sizes, the data illustrate the values to be expected of batteries in good condition. There is some question regarding the self-discharge rate of the 36Ah SAFT Celgard battery. However, experience with this size is too limited for judgement as to whether the observed values are anomalous.

TABLE V

Resistance Measurements by Milliohmmeter at Room Temperature

Cell	Celgard-Marathon			Celgard-SAFT			Cellophane-SAFT		
	(N)*	(V)*	Diff.	(N)	(V)	Diff.	(N)	(V)	Diff.
1	1.36m $\Omega$	1.31m $\Omega$	0.05m $\Omega$	0.61m $\Omega$	0.60m $\Omega$	0.01m $\Omega$	0.59m $\Omega$	0.57m $\Omega$	0.02m $\Omega$
2	1.44	1.35	0.09	0.60	0.59	0.01	0.58	0.56	0.02
3	1.41	1.34	0.07	0.53	0.53	0.00	0.53	0.52	0.01
4	1.51	1.47	0.04	0.53	0.52	0.01	0.53	0.51	0.02
5	1.30	1.28	0.02	0.57	0.57	0.00	0.59	0.59	0.00
6	1.31	1.30	0.04	0.61	0.61	0.00	0.58	0.54	0.04
7	1.33	1.30	0.03	0.57	0.57	0.00	0.53	0.52	0.01
8	1.29	1.25	0.04	0.55	0.55	0.00	0.53	0.52	0.01
9	1.37	1.30	0.07	0.56	0.56	0.00	0.52	0.51	0.01
10	1.34	1.26	0.08	0.55	0.54	0.01	0.54	0.52	0.02
11	1.34	1.29	0.05	0.55	0.55	0.00	0.53	0.52	0.01
12	1.35	1.27	0.08	0.57	0.57	0.00	0.55	0.54	0.01
13	1.33	1.28	0.05	0.57	0.56	0.01	0.53	0.52	0.01
14	1.35	1.31	0.04	0.60	0.60	0.00	0.56	0.56	0.00
15	1.35	1.29	0.06	0.62	0.62	0.00	0.54	0.54	0.00
16	1.30	1.28	0.02	0.56	0.56	0.00	0.55	0.53	0.02
17	1.40	1.36	0.04	0.56	0.56	0.00	0.53	0.52	0.01
18	1.45	1.39	0.06	0.53	0.53	0.00	0.52	0.51	0.01
19	1.36	1.33	0.03	0.54	0.54	0.00	0.53	0.52	0.01
20	--	--	--	0.55	0.55	0.00	0.56	0.55	0.01

Average 1.36 1.31 0.05 0.57 0.56 0.01- 0.55 0.53 0.01+

\* (N): First Value, (V): Value after Vacuum application.

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## KEY WORDS

**BATTERY CHARACTERIZATION**

**NICKEL/CADMIUM BATTERIES**

**AIRCRAFT BATTERIES, CHARACTERIZATION**

**NEW BATTERY CHARACTERIZATION**

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