POCKET NICKEL CADMIUM CELL AND BATTERY EVALUATION

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The pocket NiCad battery has been around for a long time, and I wish to thank Floyd and Jerry for permitting me to present this at this workshop. Since this is a workshop, it is nice to present it.

The reason why I would like to present this paper is that we were looking at a military application that required a battery, not an aerospace-type battery, but a NiCad battery for a military application. Nife Corporation of Lincoln, Rhode Island and Sweden, loaned us 22 cells to test.

Since there is such a small data base on this particular battery and it had never been tested in a military application, I thought it was an excellent opportunity to test it and to present some of the results that I got during this testing.

(Figure 4-95)

The purpose of the test was to evaluate the 129-ampere hour cell to characterize the cell under controlled conditions. One test is missing there. It was an open-circuit stand test which I will talk about on the next chart.

(Figure 4-96)

Again, Nife loaned us 22 cells of which five modules were monoblocks, five and six-cell monoblocks, and we divided them up into various tests. We had five of them on charge characterization, which later on we went into ampere-hour efficiency tests.

We put five on discharge characterization; we had five on open circuit stand, and there were six that just sat open circuit with nothing going on.

(Figure 4-97)

This is a little bit of a description of the cell. You can see it is a big hummer, not a small guy. It is 15 inches tall and weighs roughly 15 pounds. The resistance you will notice I have scratched out there. Nife was nice enough to give me some updated information. It is 1.1 milliohms.

(Figure 4-98)

We have 27-cubic foot test chambers at Martin Marietta. You can see that's a five-cell monoblock, and you can see how much space it takes up in the cube itself. The total 22-cell battery weighed 330 pounds. I don't expect you to run out and put it in a spacecraft.

(Figure 4-99)

This is a drawing that was put together by myself and an illustrator at Martin showing the way a pocket NiCad plate is designed, put together or manufactured. At the top is a roll of metal steel which is 0.1 millimeters thick. It runs through a punch press that has needles that punches on either side of the plate, and you come out with a form plate that has got holes all perforated through it.

Previously, the method was to punch holes on one side. But now they are punching holes on both sides which gives them 30 percent more area for the electrolyte to flow through the plate.

Little briquets are then placed within the stamped plates. As you can see here, the edges are folded over and they interweave. When the plate is all put together, they are a nice, solid mesh plate. Both the positive and negative plates are made this way.

(Figure 4-100)

You will notice that the manufacturer recommended voltage limits on the right-hand column. This data was generated after we had already got into our tests, well along into our tests, and we had made some assumptions along the way that terminate the voltages at the selected voltages there. And we charge the cells at various rates; 5, 10, 15, and 25 amperes constant current until either a voltage limit cutoff or a time cutoff.

You will see later on that under the minus 10 condition, I have made an error in selecting the voltages. I did not know what the voltage cutoff was or recommended. I had arbitrarily picked a number.

(Figure 4-101)

Here is the result. You will see at the plus 40- and plus 25-degree state during the charge categorization test, that for the 5, 10 through the 25, we did get roughly 140 to 150 ampere-hours of capacity out of the cells.

But in the minus 10 condition, because I had made an error in judgment of picking too low, we did not get full state of charge. It is not the problem with the battery but was a problem with me. So, I didn't have anything to base my judgment on, and I just went ahead and picked a number.

(Figure 4-102)

This is some of the typical charge characteristic curves that I have got. These charges represent the capacity that I took out on a previous charge at the various temperatures. In other words, if you look at the 25-degree charge here, I took out roughly 130 ampere-hours of capacity out of the cell at the particular test, and that's what I put back in.

This is where I went into the gas evolution. You will notice I took out roughly 80 to 90 ampere-hours of capacity at that minus 10- and 40-degree test.

(Figure 4-103)

The discharge characterization is just a normal nice, smooth curve indicative of the nickel-cadmium system. I just wanted you to see what the curves looked like as I saw them during the tests.

(Figure 4-104)

Ampere-hours efficiency for the three charge conditions I was working with. It turned out I was operating somewhere between 55- and 95-percent ampere-hours efficiently through the charge characterization tests. It was a very excellent system for ground operations communications or terrestrial applications.

(Figure 4-105)

For open-circuit stand, we went actually 240 days, but I plotted out 200. We had six cells that we took. Periodically we would discharge them.

During the initial characterization test, we checked out the capacity, and we have got for the 22 cells, an average of 150.25 ampere-hours out of 129-ampere hour cells, which indicated we had like a 17-percent excess capacity above the nameplate capacity.

Again, the cells had never been tested to my knowledge, I don't think to Nife's knowledge, in this type of a regime. So they also were a little bit elated with some of the data that we got for them.

(Figure 4-106)

The five-cell was monoblock that I had for discharge characterization test. Nife and I do not see eye to eye on this (they are in the crowd, and they may expound on that later on), but when we did the characterization test, I left some of the cells sitting around in open-circuit charge. Five of the cells, (this particular monoblock), were low in electrolyte, and for some reason, the capacity was low when we went to test them. I do not have an explanation for it. Nife may offer some answer. I do not have an answer on that. I will let it go at that.

(Figure 4-107)

For terrestrial application, ground power communications, the system is excellent. It offers an excellent capacity over wide operating range and a large temperature range. Higher cutoff voltage was required, as I showed you. I had picked the wrong number. Since then Nife has come out and has come up with a set of limits that we can work with in a military-type application. Reasonable ampere-hour efficiency is afforded with this system.

Through the open-circuit stand time, we have only lost 3 percent a month. I think we only went down like 25 percent in 200 days. That's my results.

DISCUSSION

VOICE: How large was the pocket?

LEAR: How large was the pocket? 129 ampere-hours.

INTRODUCTION: TEST AND EVALUATION OF 129 Ahr POCKET PLATE NICKEL CADMIUM CELLS/BATTERY IN SUPPORT OF MILITARY APPLICATION.

OBJECTIVE: TO CHARACTERIZE THE ENERGY STORAGE SYSTEM UNDER CONTROLLED CONDITIONS.

SCOPE:

- o CHARGE CHARACTERIZATION
- o AMPERE HOUR EFFICIENCY
- o OPEN CIRCUIT STAND
- o DISCHARGE CHARACTERIZATION
- o CYCLE LIFE OPERATION

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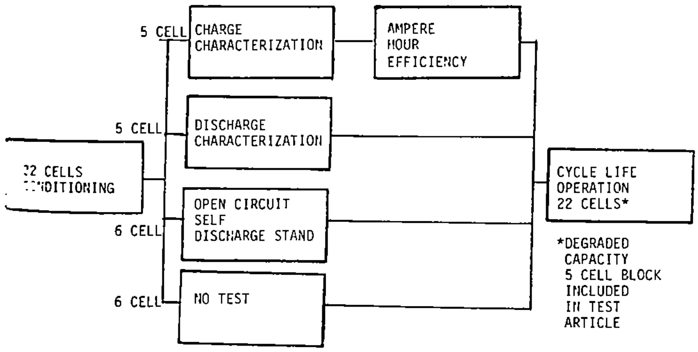
Figure 4-95

TEST PROGRAM

- o CONDITIONING
- o CHARGE CHARACTERIZATION
- o OPEN CIRCUIT STAND
- o CYCLE EFFICIENCY
- o DISCHARGE CHARACTERIZATION
- o CYCLE LIFE



PROGRAM FLOW DIAGRAM

Figure 4-96

NIFE L403 CELL DESCRIPTION

HEIGHT	405 mm	(15.9 in.)
WIDTH	194 mm	(7.6 in.)
LENGTH	55 mm	(2.2 in.)
WEIGHT	6.7 Kg	(14.8 Lbs)
ELECTROLYTE VOLUME	2.0 L	(0.53 g)
RESISTANCE	1.1 mΩ	

*FROM 100% S.O.C. TO 80% DISCHARGE @ 25°C

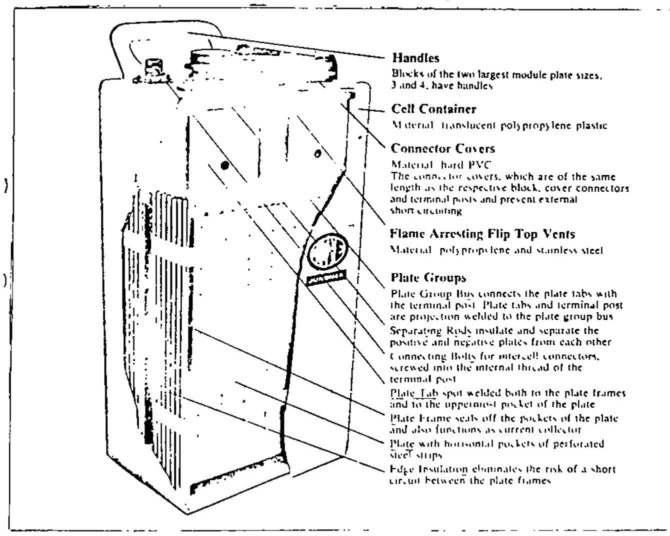


Figure 4-97

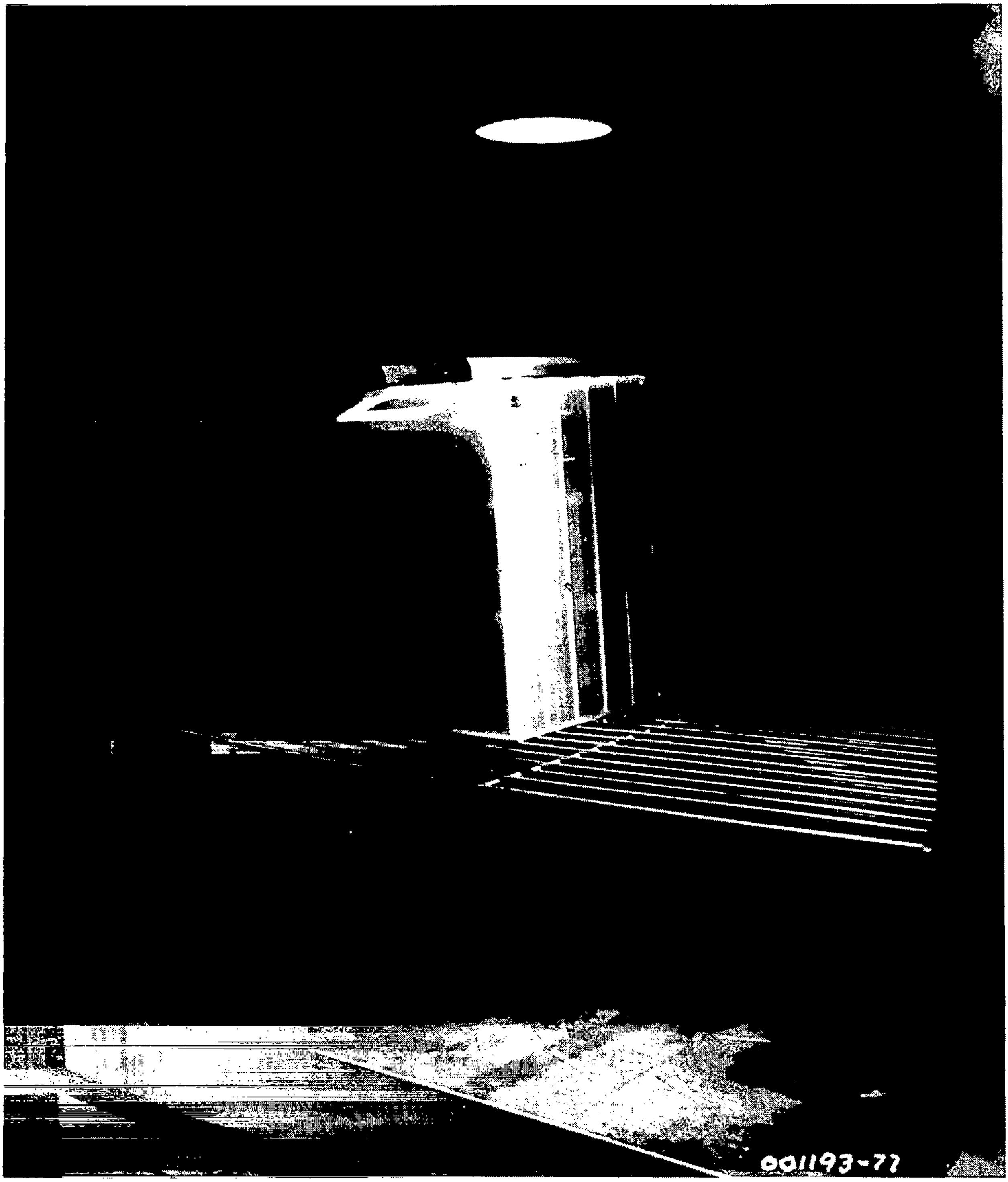


Figure 4-98

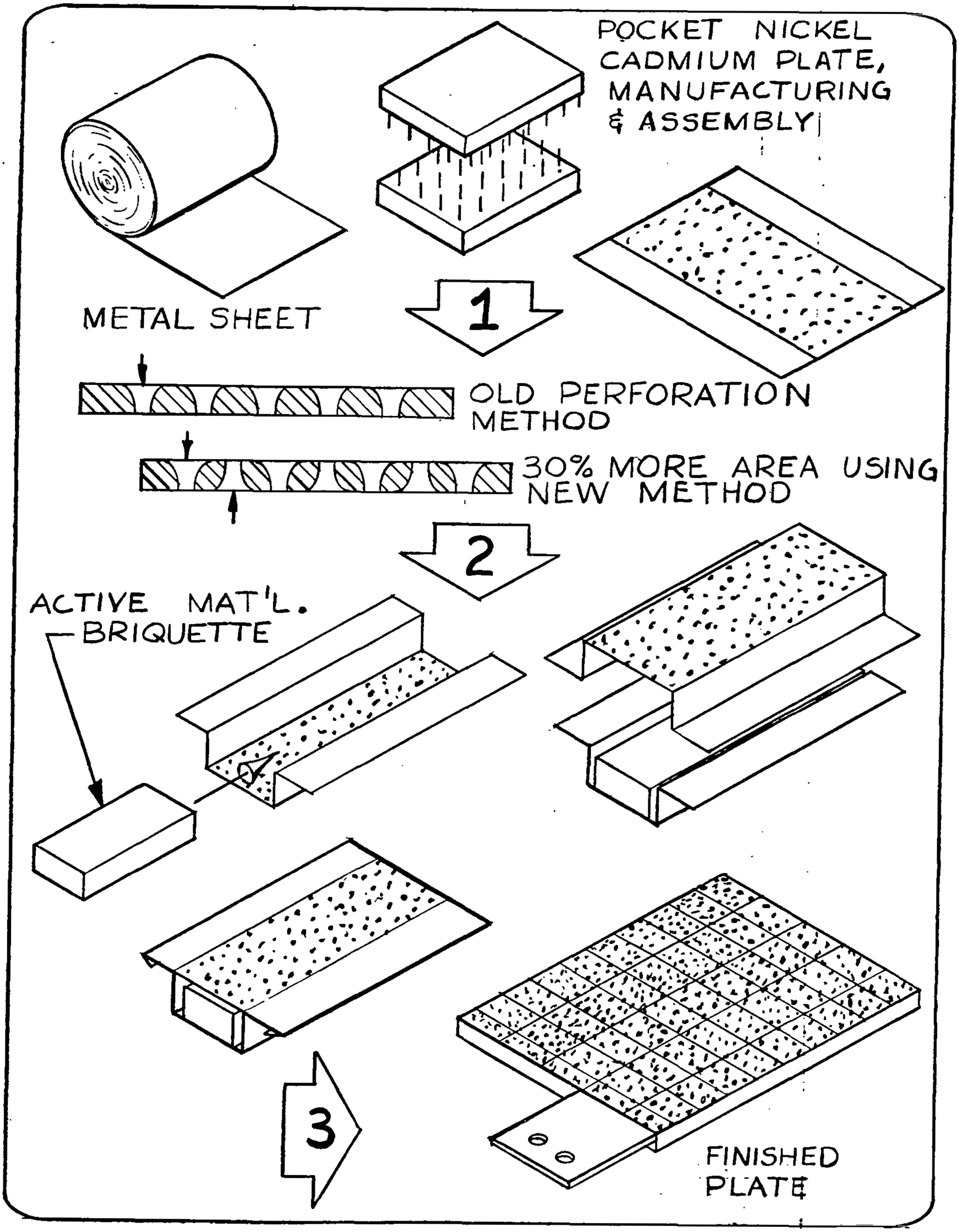

POCKET NICKEL CADMIUM PLATE, MANUFACTURING & ASSEMBLY
METAL SHEET
1
OLD PERFORATION METHOD
30% MORE AREA USING NEW METHOD
2
ACTIVE MAT'L. BRIQUETTE
3
FINISHED PLATE

Figure 4-99

CHARGE CHARACTERIZATION MATRIX

CHARGE RATE (AMPERES)	TEMPERATURE C°	SELECTED VOLTAGE CUTOFF	MANUFACTURE RECOMMENDED CUTOFF
5	-10	1.72	1.82
5	25	1.63	1.66
5	40	1.58	1.61
10	-10	1.75	1.88
10	25	1.67	1.72
10	40	1.62	1.64
15	-10	1.76	1.89
15	25	1.70	1.74
15	40	1.65	1.66
25	-10	1.77	1.94
25	25	1.74	1.78
25	40	1.70	1.70

ALL DISCHARGES CONDUCTED AT A CONSTANT 10 AMPERE RATE

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Figure 4-100

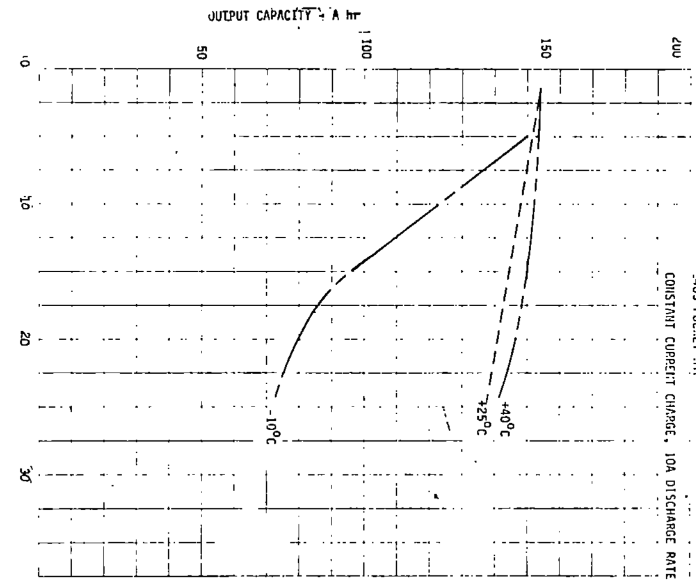
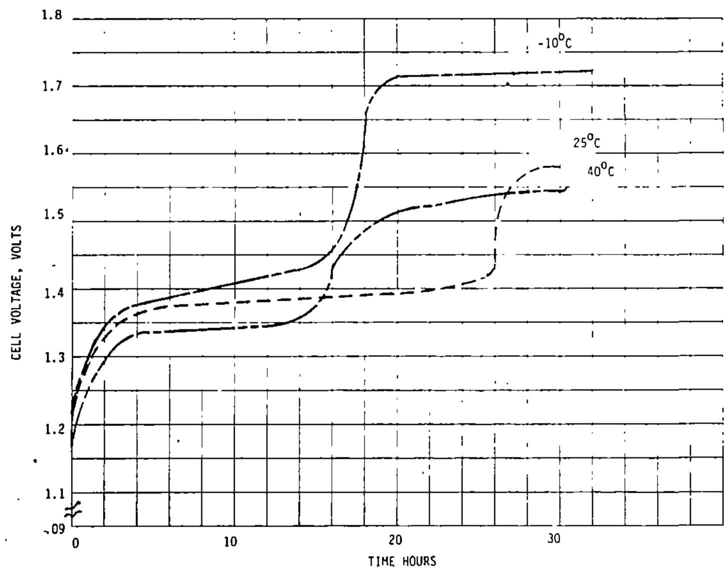
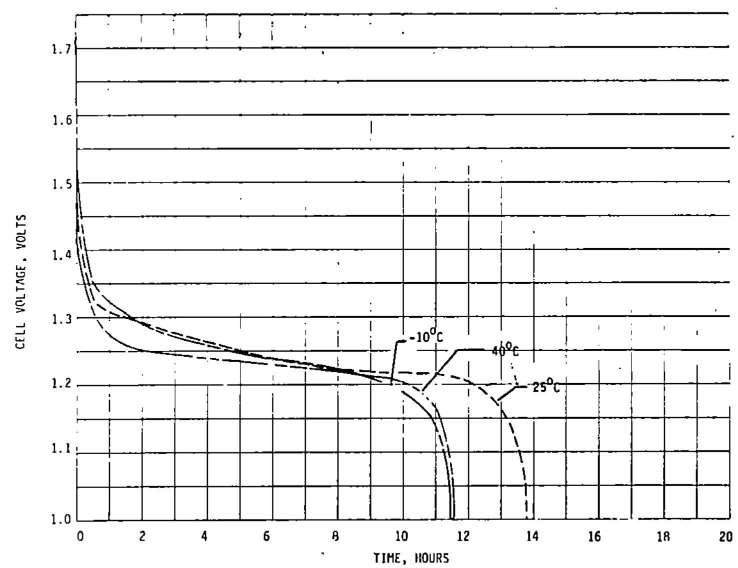


Figure 4-101



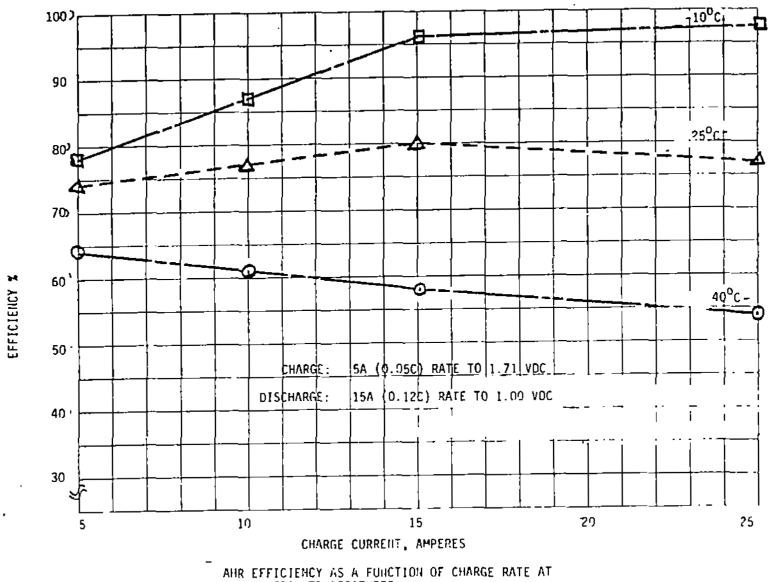
CONSTANT CURRENT CHARGE CURVES AT 5 AMPERE RATE AS A FUNCTION OF TEMPERATURE

Figure 4-102



CONSTANT CURRENT DISCHARGE CURVE AT 10 AMPERE RATE AS A FUNCTION OF TEMPERATURE TO 1.0 VDC

Figure 4-103



AHR EFFICIENCY AS A FUNCTION OF CHARGE RATE AT SEVERAL TEMPERATURES

Figure 4-104

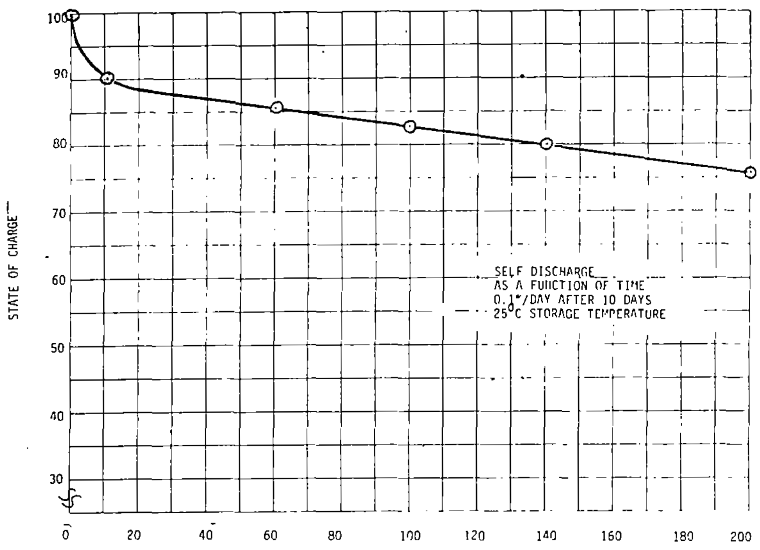


Figure 4-105

DISCHARGE CHARACTERIZATION AND CYCLE LIFE TESTS

- 5 CELL BLOCK DESIGNATED FOR THE DISCHARGE CHARACTERIZATION TEST SUFFERED AN UNEXPLAINED ELECTROLYTE LOSS DURING 180 DAY OPEN CIRCUIT STORAGE PERIOD.

- SUBSEQUENT CYCLING AFTER RESTORING ELECTROLYTE TO SPECIFIED LEVEL SHOWED A PERMANENT CAPACITY LOSS OF APPROXIMATELY 40%.

- RESULTS OF SUBSEQUENT CHARACTERIZATION AND CYCLE LIFE TESTING ARE NOT CHARACTERISTIC OF NORMAL CELLS.

Figure 4-106

CONCLUSIONS:

- CELLS DELIVERED EXCELLENT CAPACITY AT 25°C AND 40°C.
- HIGHER CUTOFF VOLTAGE REQUIRED AT -10°C AT CHARGE RATES IN EXCESS OF 5 AMPS.
- REASONABLE AMPERE-HOUR EFFICIENCIES ARE ACHIEVABLE UNDER PROPER CHARGE CONDITIONS.
- CELLS EXHIBIT GOOD CHARGE RETENTION CHARACTERISTICS (APPROXIMATELY 3% LOSS PER MONTH AT 25°C).
- ELECTROLYTE MANAGEMENT REQUIRED TO PREVENT CAPACITY LOSS.

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Figure 4-107