LIFE TEST RESULTS OF THE NASA STANDARD 20 AMPERE HOUR CELLS

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NASA had a program to develop what is called Standard 20-ampere hour cells. We went to four manufacturers, General Electric, SAFT, Eagle Picher, and Yardney, to determine if there were some cells that could be used for competitive purposes in the future.

(Figure 4-44)

The manufacturers all delivered some 50 cells, 30 of which we sent to Crane for testing. Of the 30 which all were put through the initial evaluation tests that I described last year, 21 were placed in cell packs. There were four cell packs for near-Earth orbit and one cell pack for synchronous for each of the manufacturers.

My first chart here is a summary. You will recall that in the initial evaluation test, the GE cells all passed with flying colors. There were no problems at all. The SAFT cells experienced overpressure on the low-temperature tests. The Eagle Picher cells experienced overvoltage greater than 1.52 on several of the tests. And the Yardney cells had some kind of polarization and also had a variation in the characteristics. Nevertheless, we did select the better of these 30 to put into the four cell packs. The summary of where we are right now is the following:

We see the four manufacturers listed at the top. One pack from each manufacturer at 40-percent DOD and 10°C; one pack from each at 25-percent DOD and 20°C; one pack at 40-percent DOD and 20°C; and the fourth pack at 40-percent DOD and 30°C. All of these are near-Earth Tests.

Pack numbers, for your reference in the future, are associated with these various packs and begin with 12F for General Electric on the first, going down the column, 12F, then 12G, then 12H, and 12I. And back up to the top, SAFT would be 12J, K, L, and M. Eagle Picher would be O, P, Q, and R. N is left out for some reason. And Yardney would be S, T, U, and V. They are all "12" numbers, beginning with 12 and can be spotted in the Crane references.

As you can see where we are on the 10°C, 40-percent depth test, all the cells are continuing to work, giving reasonable voltages and capacities during this time period.

Every 6 months we do a capacity test on the pack. After the first 6 months, we take out cell 4 and perform a discharge on it – capacity test, that is. Next, at the end of 1 year, we do 3 and 4. At the end of 1 1/2 years, we do 2, 3 and 4; and at the end of 2 years, we do 1, 2, 3, and 4.

At the end of 2 years, we always have one cell that has never been discharged before during the 2-year period, whereas every 6 months we discharge the first cell.

In all conditions now for all four manufacturers under the two test regimes at 10 degrees and 40, and 20 degrees and 25 percent, we have had no failures.

The GE cells were removed at 40-percent DOD, 20°C tests on cycles run 11,000- 7 or 800, as you see there is 97. We had a significant deviation in voltages across the cell, and some cells were in overvoltage while others were not being charged. So we discontinued the tests at that time.

On the Eagle Picher cells we had a similar problem to what we had experienced in the early test. That is, they were running into overvoltage condition. When we cut back on the voltage, charged voltage level, we weren't getting the capacity. So we had to terminate that point.

They particularly showed up poorly on the 40°C – 40 percent, 30°C test. We see that we cut out very early for that very reason. That is, we were not getting capacity out, and when we raised the voltage level, we were running into high pressures.

The GE cells were deviating considerably from each other, some running high voltage and others running low. We ended up terminating it. You will see some of the voltage curves in a moment. The rest of the Yardney cells were all going. The SAFT cells were all going as of this point with those cycles.

(Figure 4-45)

Here is the capacity voltage test for cell number 4 only. In other words, every 6 months we discharged this cell in this particular pack which is a 20°C, 25-percent DOD.

You see several important points on this curve, as you will recognize, to be a consistent feature. That is, after you start going through this type of cycle which is charged to a given voltage level at a fixed current, and then taper, followed by a discharge at a constant rate, we see this second plateau, after we get over the 25-percent mark.

Here we have 25-percent DOD, and after that, we go to this very low plateau. If you will note, we are still above, in this case above 1.0 volts. So, on a battery level, we would still be above somewhere around 23 or 24 volts. So at this particular DOD, we are not in too bad a case.

We are running at a voltage level of 5, which is a 1.4, 1.5 volts per cell average, and the cells are pretty uniform.

The interesting thing on the table here is that the capacities are staying pretty well up there. Over the 2-year time period, the charge-to-discharge ratios are very low. It is going to be consistent with what you are hearing this morning and this afternoon about minimizing the C/D, and the end-of-charge current is staying rather constant. It is dropping a little bit, but staying rather constant.

Now, you might say you know cell 4 has been reconditioned every 6 months. What happens if you take one that's not reconditioned? So, I plotted the identical curve showing the first-time discharge for all four cells.

(Figure 4-46)

As you see, it is the same kind of thing that we are getting here, the same kind of results. I can almost overlap them, and you will see that there is hardly any difference between the two, which means the reconditioning really has not affected them very much. You will see some differences which are due to differences in individual cells.

There is one lower one here on the ones that have been discharged every 6 months. So, let's say that that had little effect.

(Figure 4-47)

Going now to the more severe cases, here we have the 20°C, 40-percent DOD. Again, you see the significant dropoff after we hit the approximately 40-percent mark, or right around the 40-percent mark. As you see, we already have failed here. Getting close to failure at this point is defined as a half volt across a given cell.

Again, the C/Ds are still fairly low for 40-percent DOD. This is CAP for capacity and has dropped off rather significantly over the time period. We did, at the very end, raise the voltage on this last one from 1.355 to 1.455 to see if we can get more capacity out. As you see, it didn't help very much.

(Figure 4-48)

These are all General Electric cells that we are still continuing to refer to here.

This is the last one of the four packs, 30°C, 40-percent DOD. We see rather a rapid dropoff within the first 6-month period, again, significant over the next 6-month period.

Again, we are getting out approximately 40 percent for quite a number of cycles, or close to the 40 percent before we drop off rather severely capacitywise. We do see a slightly small second plateau.

(Figure 4-49)

We don't have a lot of capacity data on the other cells because they haven't been operating that long. I did select the SAFT ones because we have three capacity discharges on it that have been completed.

This is a 10-degree, 40-percent DOD. You can see these are all at the level of 6; 1, 4, 5, 8 volts per cell at 10°C. You see again the second plateau, so that those who might say the second plateau is only with GE cells, obviously we see it here, too, although they are slightly similar processes, fairly similar processes.

Again, we are still striving for that low C/D ratio, and the end-of-charge current is reasonable. I might add at 40-percent DOD. We charge at 16 amperes until the voltage cutoff, and then we discharge at 16 amperes until the 30 minutes is up.

At the 25-percent DOD, we charge at 100 amperes and then charge at 10 amperes until the voltage limit and then taper. On discharge we discharge at 10 amperes. So obviously we have different rates.

(Figure 4-50)

This is the 20°C, 25-percent DOD. As you see, we are seeing a rather significant second plateau after the 5 amperes.

(Figure 4-51)

Going up to 20 and 40 percent, there are similar kinds of things.

(Figure 4-52)

Finally, at the 30°C, 40-percent DOD, we have only completed the three capacity cycles there, and we are at about the 40-percent depth before we start failing at that point in time.

So the critical thing here is that although we are getting the capacity that we desire, we are a little concerned about the voltage, the second plateau, which means that under certain conditions, we might have to run a 22-cell battery at around 22 volts, which, I think, the electronics people would be very nervous about. It may be something we are going to have to look at in the future.

(Figure 4-53)

Now, with regard to the synchronous orbit cells, this is a summary table of the work that has been done to date on the synchronous cells.

Here we see the eclipse season, the seasons that we've had so far, and which, if we are looking down, the first one is running 16-percent DOD and 20°C here, we see here the first time we discharge cell 5, then 4, and 5, and then 3, 4 and 5, just as I indicated before, in sequence.

You notice, kind of interesting, that the capacities are staying up there rather well during that period of time, and they look pretty good even after six eclipse seasons of real-time operation.

Now, on the SAFT cells again, after three seasons, capacity is still holding up rather well. I have some data on GE, but I don't have the SAFT full data.

One interesting thing that really just came to light as I put this table together was that even though every one of these manufacturers produced cells that were supposed to be 24 plus or minus 2 ampere-hours, which was our requirement, in the initial testing that was done all of them came in almost exactly at 24. I would say at 24 plus or minus 1 ampere-hour. Very, very close.

But you will notice that even though the GE ones have been decreasing all the way down during this time period and the SAFT ones have been staying pretty close, look what is happening to the EP ones. They just increased. If that is correct, I don't understand it very well. But that is something strange.

On the Yardney ones, they have gone down in one case, in this lower cell. We indicated the Yardney cells had some kind of variation to it that weren't really very close.

(Figure 4-54)

Now, one on the voltage curve, I only have for the GE cell right now. You will notice that there is no second plateau on this curve on this particular orbit.

And the fifth orbit, I don't know if you can see the dots down here, I just hand-plotted them just before we went to press here. You can see they are coming down after the fifth orbit. They are still a little bit less than what they were before. At the 0.5 volt, they are still doing pretty well. But there is no second plateau in this type of orbit.

DISCUSSION

GASTON: I have a question. When you say SAFT, do you mean SAFT America or SAFT France?

HALPERT: SAFT America cells built in this country.

GASTON: The second question on the geosynchronous cycling, is that a real-time or accelerated test?

HALPERT: Real time. Everything is real time.

GASTON: Did you recondition during suntime?

HALPERT: No reconditioning, except if you consider every 6 months, we took the same cell down, then the next cell, and the next cell, and so on. No specific attempt to discharge a short in any particular time other than to measure the capacity.

GASTON: When you say "taking them down," do you take in major eclipse time on a specific cell?

HALPERT: Yes, a specific cell. Two for the next 6 months, 3 for the next, and so on.

HENNIGAN: I was wondering how you keep the temperature constant on these cells?

HALPERT: The cells are in a temperature cabinet in which the air is blown. And there are fins between the cells but not mounted to any baseplate.

HENNIGAN: The other question is, did you compare these GE cells with the 6 ampere-hour cells that are running for quite a while now?

HALPERT: You mean the accelerated test cells?

HENNIGAN: Well, what we call the normal cells, the control cells.

HALPERT: I have not had a chance to relate these to those.

NASA STANDARD CELL

NEAR EARTH ORBIT TEST
AT
NWSC CRANE

TEST REGIME: 40% DOD, 10° C

CELL	GE	SAFT	EP	YD
	CYCLES			
1 to 4	12710	6953	6173	5180

TEST REGIME: 25% DOD, 20° C

CELL	GE	SAFT	EP	YD
1 to 4	12851	7131	6159	5375

TEST REGIME: 40% DOD, 20° C

CELL	GE	SAFT	EP	YD
1	11703-F		4570-F	
2	11897-D	7006	4080-F	5457
3	11794-F	(all cells)	4523-F	(all cells)
4	11794-F		4687-F	

TEST REGIME: 40% DOD, 30° C

CELL	GE	SAFT	EP	YD
1	9266-F		677-D	
2	8124-F	7042	679-D	5361
3	9012-F	(all cells)	679-D	(all cells)
4	8933-F		626-F	

F - Failed
D - Discontinued

NOTE: Test status as of 9 November 1979

Figure 4-44

NASA STANDARD 20AH CELL
NWSC/CRANE PACK 12G – GE CELLS
20°C 25% DOD

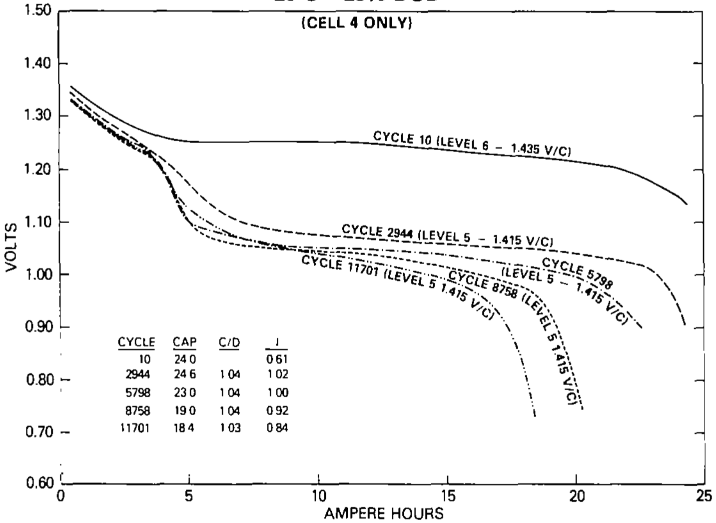

Figure 4-45

NASA STANDARD 20AH CELL
NWSC/CRANE PACK 12G – GE CELLS
20°C 25% DOD

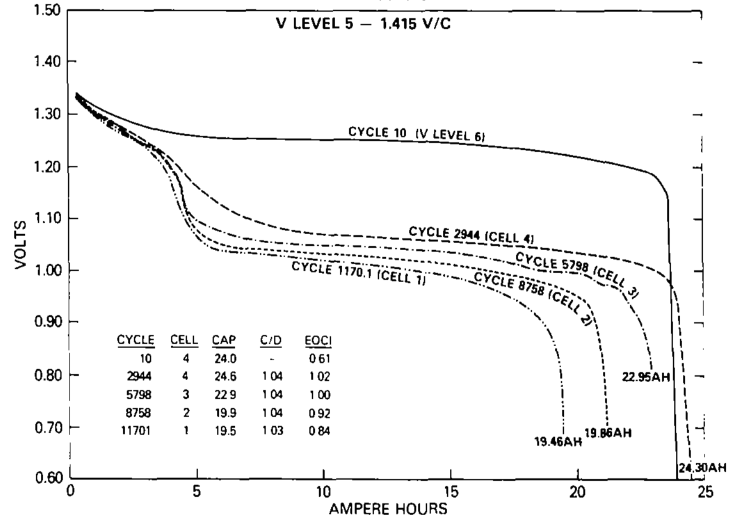

Figure 4-46

NASA STANDARD 20AH CELL
NWSC/CRANE PACK 12H – GE CELLS
20°C 40% DOD

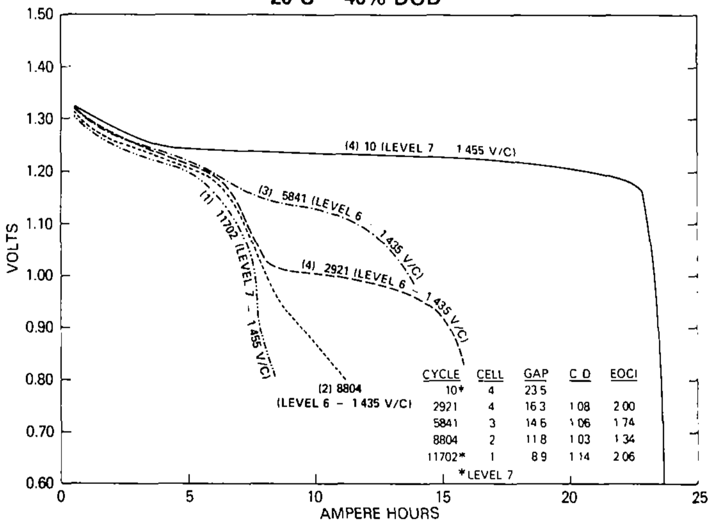

Figure 4-47

NASA STANDARD 20AH CELL
NWSC/CRANE PACK 12I – GE CELLS
30°C 40% DOD

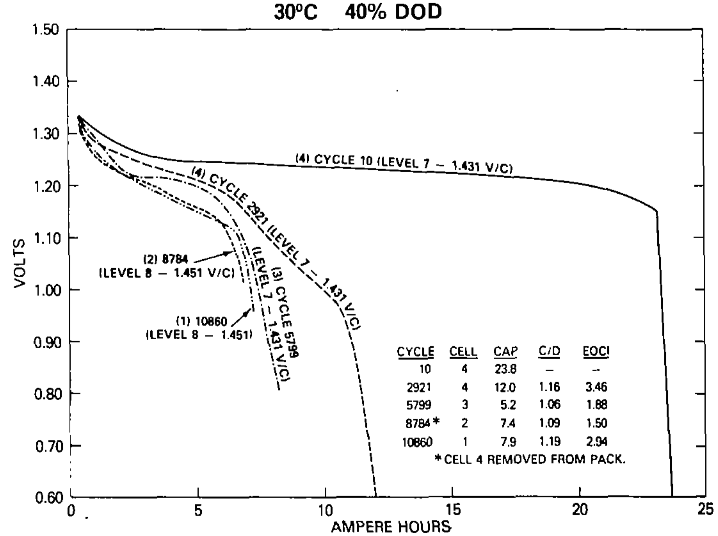

Figure 4-48

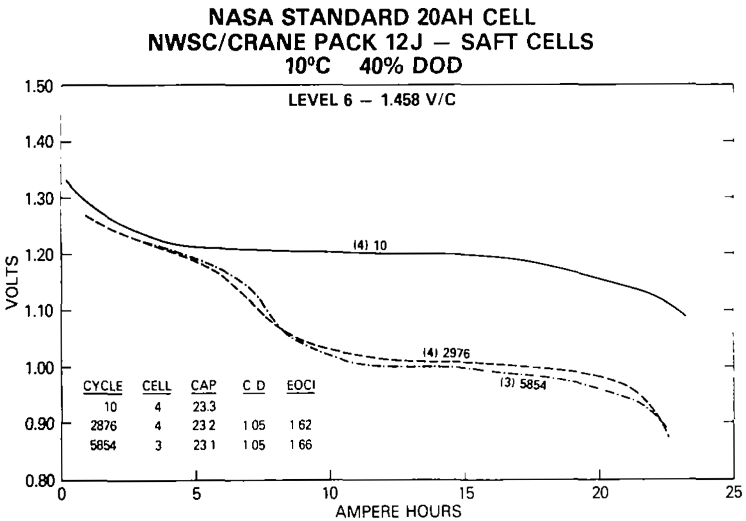

Figure 4-49

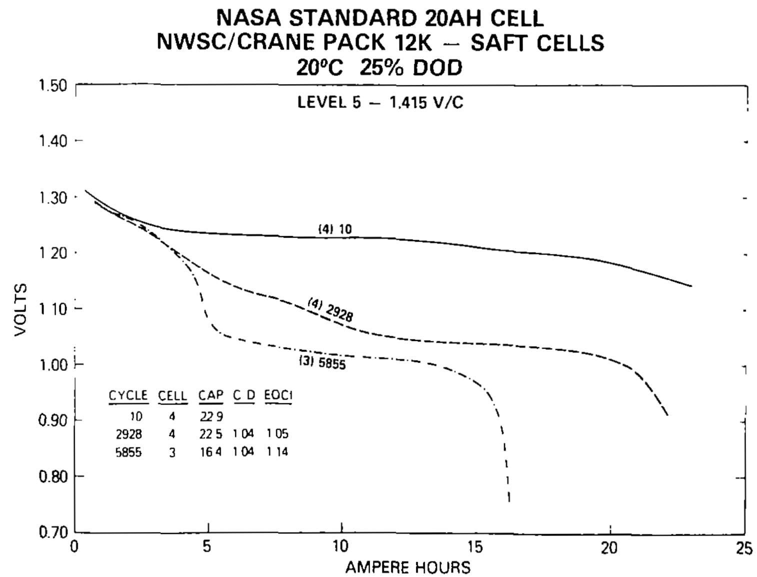

Figure 4-50

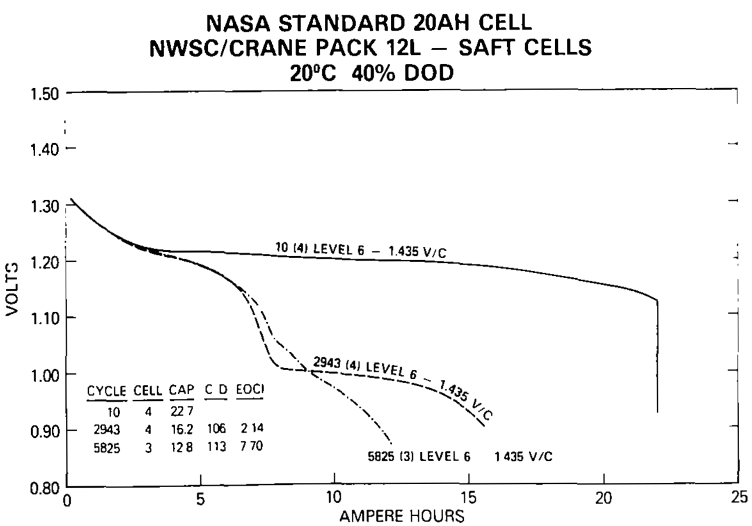

Figure 4-51

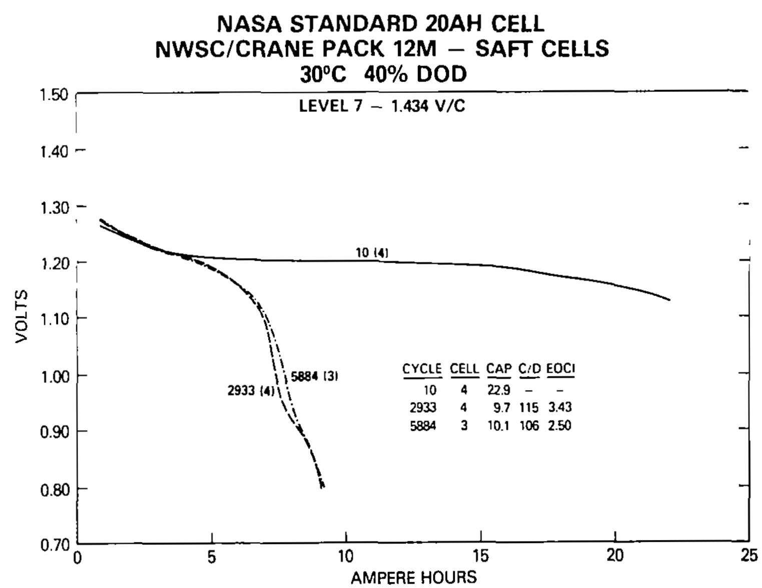

Figure 4-52

NASA STANDARD CELL

SYNCHRONOUS ORBIT TESTS
AT
NWSC CRANE

TEST REGIME: 60% DOD, 20° C

CAPACITY TESTS

AMPERE-HOURS OUT

ECLIPSE	CELL	GE					SAFT			EP			YD		
1	5					24.6			23.6			26.1			24.1
2	4,5				24.1	22.5		23.7	23.3		28.0	27.6		21.9	24.1
3	3,4,5			22.6	21.9	21.4	23.7	23.5	23.2	28.6	28.0	28.0	23.8	21.5	24.4
4	2,3,4,5		22.0	20.9	20.4	20.9									
5	1,2,3,4,5	21.7	20.7	20.7	20.1	20.7									
6	5					21.0									

Figure 4-53

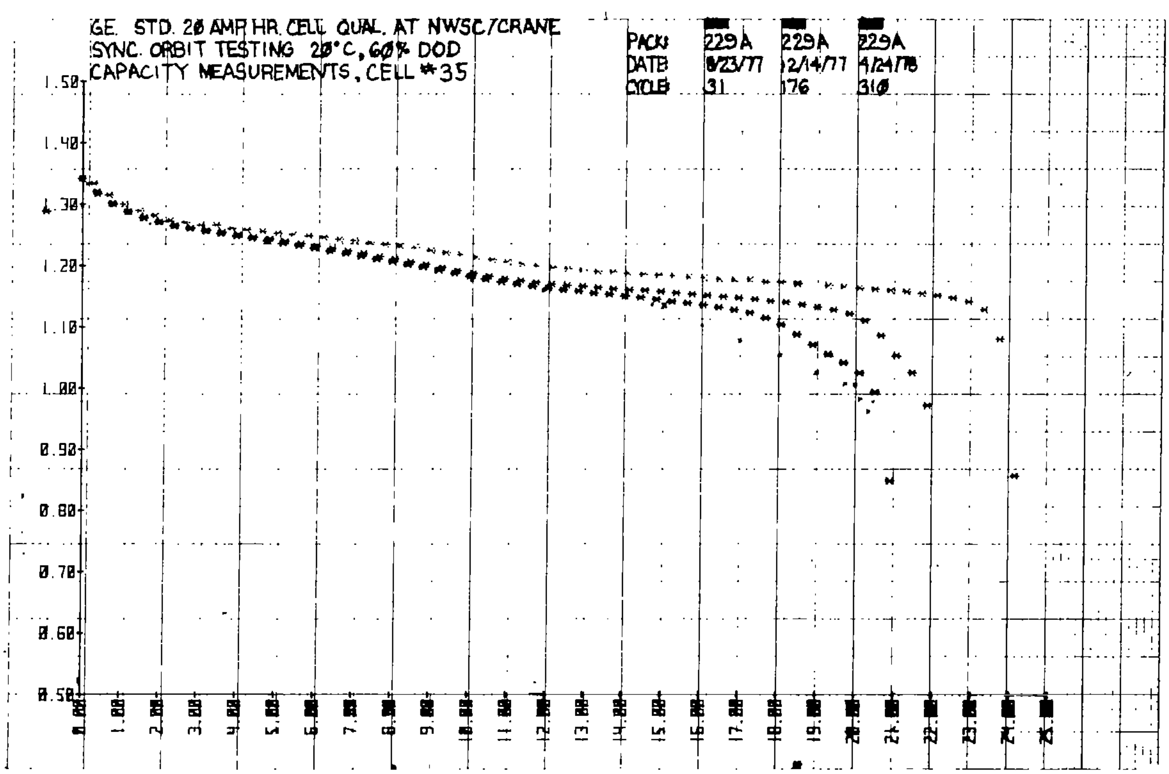

Figure 4-54