TDRSS BATTERY LIFE CYCLE TESTS INTERIM REPORT

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(Figure 4-22)

I am going to be reporting on some life cycle testing we have been doing on the battery that has been designed for the tracking and data relay satellite system. But I would like to first share with you some of the design features of the battery itself.

On the right you will see a colored picture, and actually there are two batteries assembled, as you see on the right, to make up the spacecraft set. In each of the three sections you see, there is a 12-cell battery which is a half battery. When these two batteries are electrically connected in the spacecraft, we connect 12 cells from one battery to 12 cells in the other one to make up actually three 24-cell 40-ampere hour batteries.

(Figure 4-23)

Going around the battery, again we have the three sets of 12 cells each that are interconnected in series. The battery is constructed by making up what we call modified cell assemblies, which is where we take each two cells and we pot it. We first wrap individual cells with glass cloth, and then we pot them to heat sink shims which are L-shaped shims which are then connected to the battery assembly plate that is on the bottom of the battery.

On the cell side of the battery assembly plate, we have heaters. We have a primary heater and a redundant heater. On the space side of the plate, we have second surface mirrors mounted for radiating heat to space. We have thermistors on each end of the battery. There are three on each end, and they are used for battery temperature control, telemetry, indications telemetering the battery temperature, and we also have thermal switches for operating the prime battery heater.

We have a total of seven connectors on the battery. You will see a cutaway of a cover which is, of course, nonflight. We also have in this battery a scanner, which is used for monitoring individual cell voltages in flight.

(Figure 4-24)

This is the component breakdown of the battery. We have 36 cells in each assembly weighing 114 1/2 pounds. You can read down from the top. The end plates are 3.6 pounds and so on. This was the final calculated weight, 138.45 pounds. The qual model battery, which you see on the right, actually comes out to be 138.7 pounds.

(Figure 4-25)

This is a description of the cell chosen for the battery. It's a General Electric cell rated at 40 ampere-hours. The minimum required capacity is 46.6 ampere-hours. Actually, this design was chosen as a scaled-up version of the cell that TRW is flying on the fleet Satcom program.

The reason we chose to scale it up was our experience and also life-cycle testing on that battery, where we had achieved 40 or 42 seasons of life-cycle testing without a failure.

The cell size at 6.6 reaches over the can, 6.6 over the terminals with width 3.4, thickness, 1.3. The weight of the cells is 3 1/4 pounds. The container is 19 mils thick, 304L stainless, and both terminals are insulated from the case.

We have 120 cc's or 31-percent KOH, and some information from the plates is included on the bottom: 16 positives, 17 negative size, or 5.4 by 3.2 by 0.26, 26 mils to 28 mils thick for a positive and 31 to 32 mils for the negative. We do have silver treatment in the negative, and we do not have teflon treatment in the negative.

(Figure 4-26)

This is a brief description on how the batteries are operated in the system. On discharge, the three-battery complement is required to supply 1440 watts for 1.2 hours, which is the mid-season eclipse cycle. That represents a 50-percent DOD for a three-battery operation, and 75-percent DOD for two batteries.

Ordnance loads are estimated to be up to 50 amperes for about 0.13 seconds. We will be reconditioning the batteries before each eclipse season, will be reconditioning them down to approximately 3 volts per battery. The reconditioning will be through one resistor for the entire battery at approximately C/100 rate.

(Figure 4-27)

Now for recharge, the batteries will be allowed to remain on the bus for a few minutes into the sunlight period, so that the batteries will be used to stabilize the cold array voltage down below 40 volts. At that point, they will be removed from the bus.

The TDRSS system will have a dedicated ground system, and it will be manually controlled from the ground at all times. There is no automatic charge control or discharge control anywhere in the system. It is designed to be totally manually operated at all times. This requires somebody to be watching it 24 hours a day, and we hope he will.

After the array warms, the battery will be taken off the bus, and it will be switched on to the full-charged array section. We have dedicated charge array strings, we have dedicated trickle charge strings on each array.

We can adjust the trickle charge by using the reconditioning resistors if we choose, as one method of also controlling battery temperature. We have an onboard automatic protective control system in the event of loss of ground system. If the battery reaches 27°C, there is an automatic switch to trickle charge.

(Figure 4-28)

Our test plan consists of two packs: one 12-cell pack, which we are calling Pack 1; a second 12-cell pack, which we are calling Pack 2; one 50-percent DOD and one we are running at 75-percent DOD.

The 50-percent DOD represents the TDRSS mission simulation, and Pack 1 represents two things. First, we are trying to establish that this cell design truly will be similar as a scaled up Satcom cell; and in the second case, we will be looking at the fact of a one-battery failure mode where we would have to use the two batteries left at 75-percent DOD.

All discharges would be at constant power; recharges at constant current. Then we have dedicated strings on the array. So we can have constant current recharge to a temperature compensated voltage cutoff.

Trickle charging after recharge will be 0.4 ampere for Pack 1; 0.27 ampere for Pack 2. We are controlling temperatures on discharge 15 to 20°C and recharge between 5 to 10°C. Trickle charge from 7 to 10 in one case and 0 to 5 in the other.

I mentioned before the fact that the batteries would be left on the line to stabilize the cold array voltage. So we are simulating that operation by imposing inrush current for the first 10 minutes of each charge period. On Pack 1, of course, it doesn't apply, so we are doing it on Pack 2, cycles 1 and 45. It will be a 6-ampere charge current for 10 minutes. On cycles 21 to 25, it will be 21 amperes, and on all others will be 12 amperes. This will be a constant current.

Our reconditioning will be down, as actually on this test pack, down to about 1 volt, and we will be doing it between each eclipse season. Actually, the simulation will not be simulating the solstice season. It will just be simulating the eclipse season periods.

(Figure 4-29)

These are the two test packs mounted on two heat exchanger plates, thermal control systems. You see here on cell number 6 and on cell number 12 in each pack we have pressure transducers so that we can monitor pressures. We have thermocouples mounted so we can monitor the cell temperature. On the baseplate we have thermocouples mounted so we can control the temperature of the packs.

(Figures 4-30 and 4-31)

I am going to cut time and try to show Test Pack 1 data and Test Pack 2 data at the same time. Remember the one on the right is 50-percent DOD and the one on the left is 75-percent DOD. What we are looking at here is in mid season, end-of-discharge and end-of-charge voltages versus season number.

We have completed seven seasons on number one and eight seasons on number two. Right now the plan is to run this for ten seasons, and we hope that before the ten seasons are up, we will be able to get permission to continue it for twenty seasons, which would be simulating the 10-year life, which is the TDRSS requirement.

You can see that the end-of-discharge voltages are really flat. You are looking at possibly something less than 0.2 volt difference here, 27.8, 27.9. And over here we are looking at 28.8, 29.0.

End-of-charge voltages, we have a change here. We started here with a temperature compensated voltage limit when we were cutting off – I believe we started at 18.5 volts for the 12-cell pack, and we lowered it to 18. This adjustment here was lowered to 17.75 volts. I will explain why in probably the second vugraph after this, where you can see those pressures starting to increase on some of those cells.

I have adjusted the voltage here to be representative of our 24-cell battery rather than 12-cells.

(Figures 4-32 and 4-33)

We had a little problem with controlling the temperature when we started out. Actually, some of this is from some of the data – I think it was the noise. I am not sure that was a true data point, but it was there, so I had to put it down.

You can see our temperatures started and now leveled off to about 10.6 to 10.8°C. Here we got up to 11°C. Over here on Pack 2, we bounced around a little bit here. We had a problem with temperature control, but we are still about the same level, about 10 to 11°C. The ends of discharges are up to 17, 18, and 19°C, and over here they are running 20 to 22°C.

(Figures 4-34 and 4-35)

There are the cell pressure plots. Again it's all mid-season data, end-of-charge and end-of-discharge for mid season. We had a problem again at the beginning, getting the thing under control. But you can see it come down nicely. A P-1 and P-2. P-1 would be cell number, 6, P-2 cell number 12.

The circles are end-of-discharge pressure, and the squares are end-of-charge pressure. So these here would be the end-of-charge pressures, and these here would the the end-of-discharge pressures. You can see they are running nicely here.

Over here what is happening, the reason we had to do this voltage adjustment was that we were starting to get up a little bit high in pressure. It's really not high. We are looking at psia, so we are still looking at only a 2120, which is a little bit more than atmosphere. As soon as we made the adjustment, the pressure came right down and is looking very good.

(Figures 4-36 and 4-37)

The next ones we will be looking at are machine plots and are a little difficult to see, but they are the best we could do. The one on the right is a little bit better. The first scale over here is pack voltage, and the next one is pack temperature. This is cell pressure. These two are cell pressures and this is pack current.

This is for cycle 23, season six on both cases. This is pack voltage, and this line here is pack temperature. Up here we have the cell pressures, and that is the same in each case.

The reason again this is not a normal looking line here is that the current actually comes over here and then drops straight down as you would expect it would. Again, these are machine plots, and this is just the way the data came out when it was a product from the machine off the mag tapes.

(Figures 4-38 and 4-39)

We have chosen season six in both cases, again, 50-percent DOD there and 75-percent DOD over here. What we are looking at is the parameters for an entire season from 0 to 44 cycles: end-of-discharge voltage, end-of-charge voltage, recharge ratio, end-of-charge temperature, and end-of-discharge temperature.

Again, this is noise in the data. These are not true data points. Actually, our recharge ratio is running about 105, 106, in some cases, 104. Over here we are looking about 104, 105. Over on the end it looks about 106, 107.

(Figures 4-40 and 4-41)

We thought you would be interested in seeing what's happening when we reconditioned these 12-cell packs. They are reconditioned from a full state of charge, and they are reconditioned through the fixed resistors.

This is season number on the left. This is the capacity that we measured to 1 volt. This is the capacity we measured, residual capacity from 1 volt down to the cutoff voltage. This is the capacity that we put back in our recharge, and this is the end-of-recharge temperature.

Now, over under cell pressure, again P-1 is cell 6 and P-2 is cell 12. We have tabulated the cell pressure at the 1-volt point at the end of the residual capacity and then the cell pressure at the end of recharge.

You will notice on P-1 here, these are significantly higher than all the rest of them you see on either chart. The reason for this is that at the end of the first eclipse season on the discharge, we recharged the pack normally. At that time, we decided to do a worst-case kind of test on this current inrush, so we applied 20 amperes constant current for 10 minutes. As a result, the voltages got rather high, 1.6 volts, and we pumped the cell up.

I cannot explain why we got only high on one and not the other. But that is the reason these are so much higher than all the rest of them.

But you can also see a trend near the end. The pressures are starting to come down.

We have also made some measurements, and we did find that there was a significant amount of hydrogen in the cell. We think what is happening here is that our hydrogen is leaking slowly into the combinant. So things are looking very good.

(Figures 4-42 and 4-43)

The last vugraph is a summary of the reconditioning discharge cutoff voltages. On the bottom you will see pack voltages, 1.0, 1.7, and 1.1; and over here the same thing, 1.05, 1.01, 2, and so on.

If you look across, this is season 1, 2, 3, 4, 5 up to 7, and you can see they are staying – there is a little bit of a trend up here, but again we are looking at psia. So we are looking at practically zero volts, which is not much of a change.

We do have a couple in each pack. Here's two and here's a third one down here. But it is not getting down to 1/10 volt level. But they remain pretty constant. We have one over here. This is high. This one started out at 0.07 and it started to look as if it were working its way down. Now it is up to 0.95 volts again.

So far the cells are acting as we expected they would, and we expect they will last ten seasons, probably twenty seasons.

DISCUSSION

BAER: I have two questions: The first question is, when you figure your percent return, that is right to the voltage cutoff. That doesn't include any trickle charge, does it?

KIPP: No, it does not.

BAER: The second question is, where were your temperatures measured?

KIPP: The temperatures are measured on the sides of the cells, on the narrow face halfway up.

THIERFELDER: You mentioned these cells had silver in the negative plates. Did the fleet Satcom have several negative plates?

KIPP: Yes, they do. By the way, one thought came to me in one question you asked on the previous paper, about whether the pressure or the temperature would get there first.

You notice we also have a temperature and emergency temperature cutoff in case the ground cover goes to sleep. We did do a check. We did make a test where we measured – we took a cell pack, we put on a heat exchanger plate, and we completely isolated it as best we could. We did run a test to determine which would get there first, temperature or pressure. Temperature won out. The pressure lagged the temperature significantly.

THIERFELDER: That's a function of the thermal system, so what you find would not necessarily be true on different thermal systems.

KIPP: That's true.

GASTON: You did mention that you are simulating the eclipse season, but not the suntime season. Yet, you do want to do reconditioning, so there has to be some suntime. How long is the suntime period, or the simulated suntime period?

KIPP: We did not simulate any solstice season at all. The end of the last cycle recharge period, we merely went into reconditioning discharge.

GASTON: But you do have each eclipse season?

KIPP: Absolutely.

HALPERT: That was an active cooling system you have?

KIPP: Yes.

HALPERT: What was the temperature of the cooling system, the cooling plate?

KIPP: I am sorry, I don't have the data for what the temperature of the cooling plate was.

HARKNESS: Ed, I have got one question on that one. When you reconditioned, you got over 50 ampere-hours out. When you put a resistor across the battery, did it take you about a week for the battery to run down?

KIPP: Yes. Actually, on the Pack 2, the 50-percent DOD, we had a 44-ohm resistor, which simulated one-half of what it would be for the full battery in the spacecraft. It takes about 8 to 9 days to get down. On the other one, it took about 4 or 5.

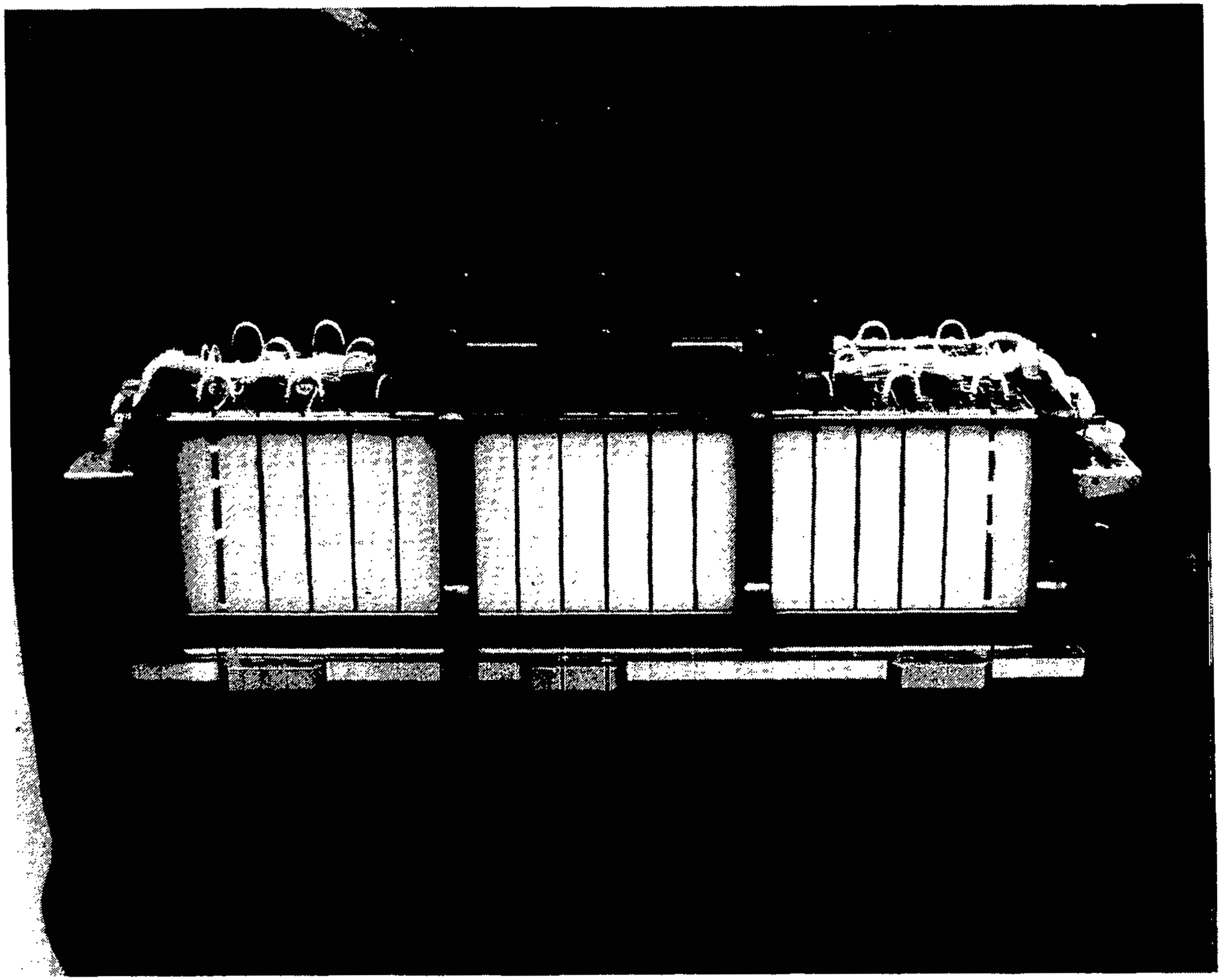

Figure 4-22

BATTERY DESCRIPTION

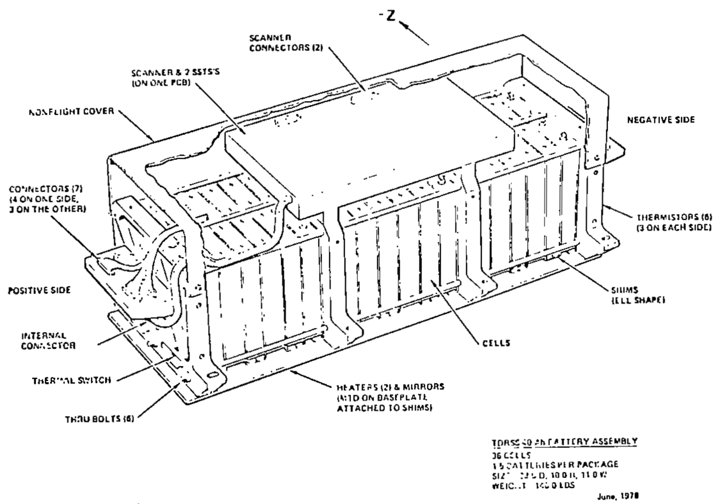

Figure 4-23

COMPONENT WEIGHT BREAKDOWN

CELLS (36)	114.48
END PLATES (2)	3.57
CENTER SUPPORTS (2)	2.04
THRU BOLTS (6)	2.16
THERMAL PLATE ASSY.	3.72
SHIMS	3.57
SPACER	.24
SCANNER	3.71
WIRE	1.20
POTTING & BONDING	.85
CONNECTORS	.55
MIRRORS	.38
MISC. (HARDWARE)	1.99
	138.46
TOLERANCE	2.00
	140.46

Figure 4-24

CELL DESCRIPTION

RATING: 40 AMPERE HOURS @ C/2 TO 1.0 VOLT @ 20°C

MINIMUM REQUIRED CAPACITY: 46.6 AMPERE HOURS

MANUFACTURER: GENERAL ELECTRIC

SIZE: HEIGHT 6.240" (6.62 OVER TERMINALS)
WIDTH - 3.404"
THICKNESS - 1.314"

WEIGHT: 3.25 LBS. (1482 GRAMS) MAXIMUM

CONTAINER: .019" THICK 304 L STAINLESS STEEL

TERMINALS: POSITIVE AND NEGATIVE INSULATED FROM CASE

ELECTROLYTE: 31.0 ± 0.5% KOH

PLATES:

		POSITIVE	NEGATIVE
QUANTITY		16	17
SIZE	LENGTH	5.4"	--------
	WIDTH	3.2"	--------
	THICKNESS	.026"-.028"	.031"-.032"
SILVER TREATMENT		-----	YES
TEFLON TREATMENT		-----	NO

Figure 4-25

BATTERY OPERATION - DISCHARGE

- BATTERY COMPLEMENT DISCHARGE CAPABILITY - 1440 WATTS FOR 1.2 HOURS.
- 3 BATTERY OPERATION - ~50 DOD.
- 2 BATTERY OPERATION - ~ LESS THAN 75% DOD.
- ORDNANCE LOADS ESTIMATED AT UP TO 50 AMPERES FOR 0.130 SECOND.
- BATTERIES ARE RECONDITIONED PRIOR TO EACH ECLIPSE SEASON.
- EACH RECONDITIONING DISCHARGE AT A ~C/100 THROUGH THREE PARALLEL RECONDITIONING CONTROL RESISTORS.

Figure 4-26

BATTERY OPERATION - RECHARGE

- BATTERY ON BUS ON RE-ENTRY TO SUNLIGHT. BUS VOLTAGE STABILIZED BELOW 40V.
- AFTER ARRAY WARMS, BATTERY COMMANDED OFF BUS AND ON TO FULL CHARGE SECTION OF ARRAY.
- BATTERY CHARGED AT CONSTANT CURRENT RATE TO A TEMPERATURE COMPENSATED VOLTAGE LIMIT.
- BATTERY COMMANDED OFF FULL CHARGE SECTION TO TRICKLE CHARGE SECTION OF THE ARRAY.
- TRICKLE CHARGE ADJUSTABLE BY SHUNTING RESISTORS.
- ON BOARD AUTOMATIC PROTECTIVE CONTROL SYSTEM IN EVENT OF LOSS OF GROUND SYSTEM.
  - AT 27°C AUTOMATIC SWITCH TO TRICKLE CHARGE.

Figure 4-27

(not available)

Figure 4-29

TEST PLAN

TEST MODE	[illegible]	PACK 2 [illegible]
DISCHARGE - CONSTANT POWER	[illegible] WATTS	240 WATTS
RECHARGE - CONSTANT CURRENT TO TCVL	[illegible] AMPERES	[illegible] AMPERES
TRICKLE CHARGE	[illegible] AMPERES	0.27 AMPERES
TEMPERATURE - DISCHARGE	[illegible]	[illegible]
RECHARGE	[illegible]	[illegible]
TRICKLE CHARGE	[illegible]	[illegible]
INRUSH CURRENT - FIRST 10 MINUTES *OF EACH CHARGE PERIOD. APPLICABLE TO PACK 2 ONLY TDRSS SIMULATION — CYCLES 1 & 45	N/A	[illegible]
CYCLES 21-25	N/A	[illegible]
ALL OTHERS	N/A	[illegible] AMPERES
RECONDITIONING - TO ≈1.0 VOLT PACK VOLTAGE BETWEEN ECLIPSE SEASONS	22 OHM LOAD	[illegible] OHM LOAD

*TCVL LIMITS DISABLED

Figure 4-28

MIDSEASON END OF DISCHARGE AND END OF CHARGE VOLTAGE VERSUS SEASON NUMBER

TDRSS LIFE CYCLE TEST
PACK NUMBER 1
75% DEPTH OF DISCHARGE

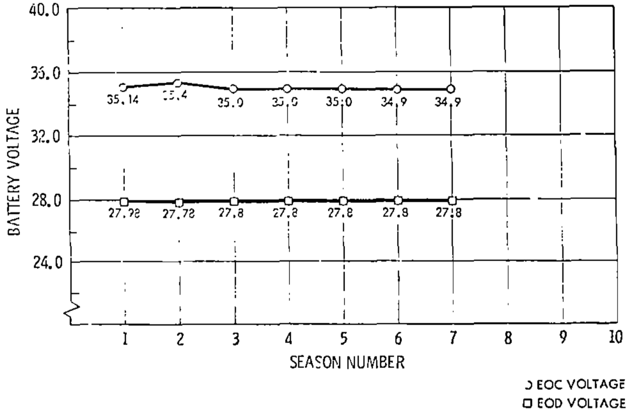

Figure 4-30

MIDSEASON END OF DISCHARGE AND END OF CHARGE VOLTAGE VERSUS SEASON NUMBER

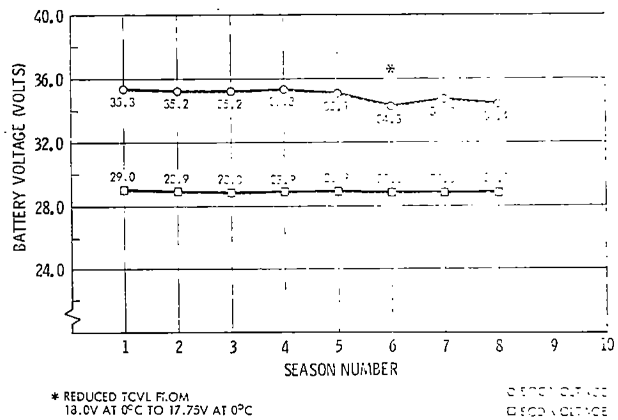

Figure 4-31

MIDSEASON END OF DISCHARGE AND END OF CHARGE PACK TEMPERATURE VERSUS SEASON NUMBER

TDRSS LIFE CYCLE TEST
PACK NUMBER 2
50% DEPTH OF DISCHARGE

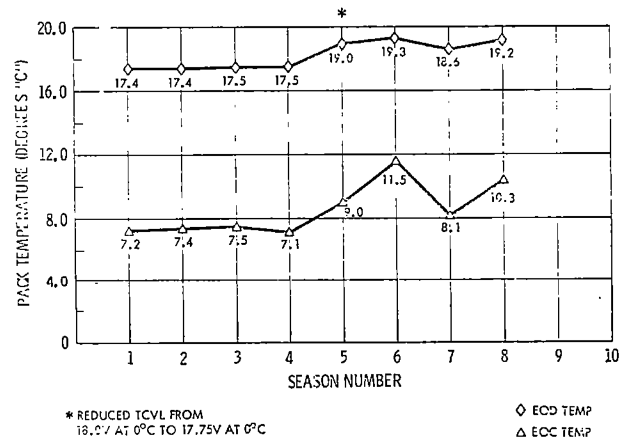

Figure 4-32

MIDSEASON END OF DISCHARGE AND END OF CHARGE PACK TEMPERATURE VERSUS SEASON NUMBER

TDRSS LIFE CYCLE TEST
PACK NUMBER 1
75% DEPTH OF DISCHARGE

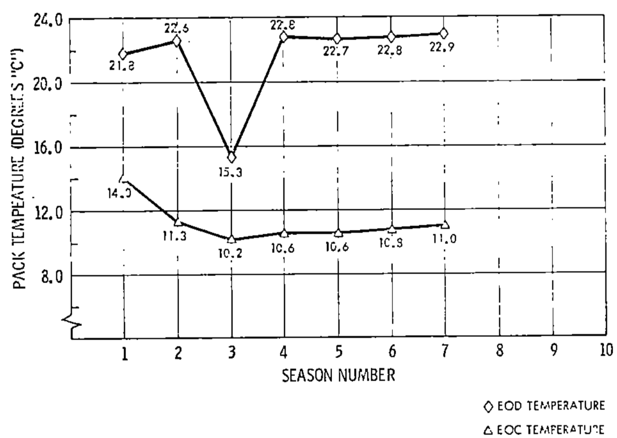

Figure 4-33

MIDSEASON END OF DISCHARGE AND END OF CHARGE PRESSURE VERSUS SEASON NUMBER

TDRSS LIFE CYCLE TEST
PACK NUMBER 2
50% DEPTH OF DISCHARGE

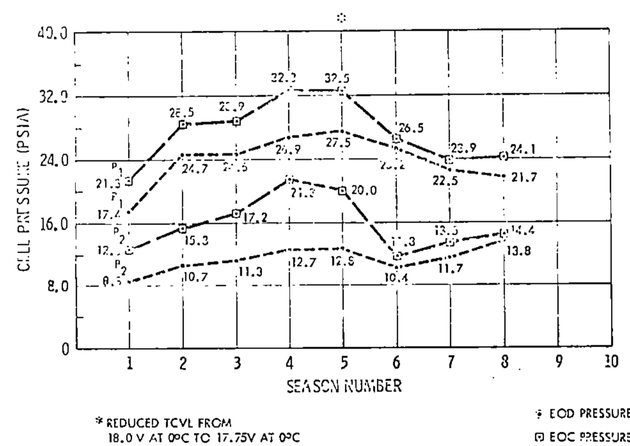

Figure 4-34

MIDSEASON END OF DISCHARGE AND END OF CHARGE PRESSURE VERSUS SEASON NUMBER

TDRSS LIFE CYCLE TEST
PACK NUMBER 1
75% DEPTH OF DISCHARGE

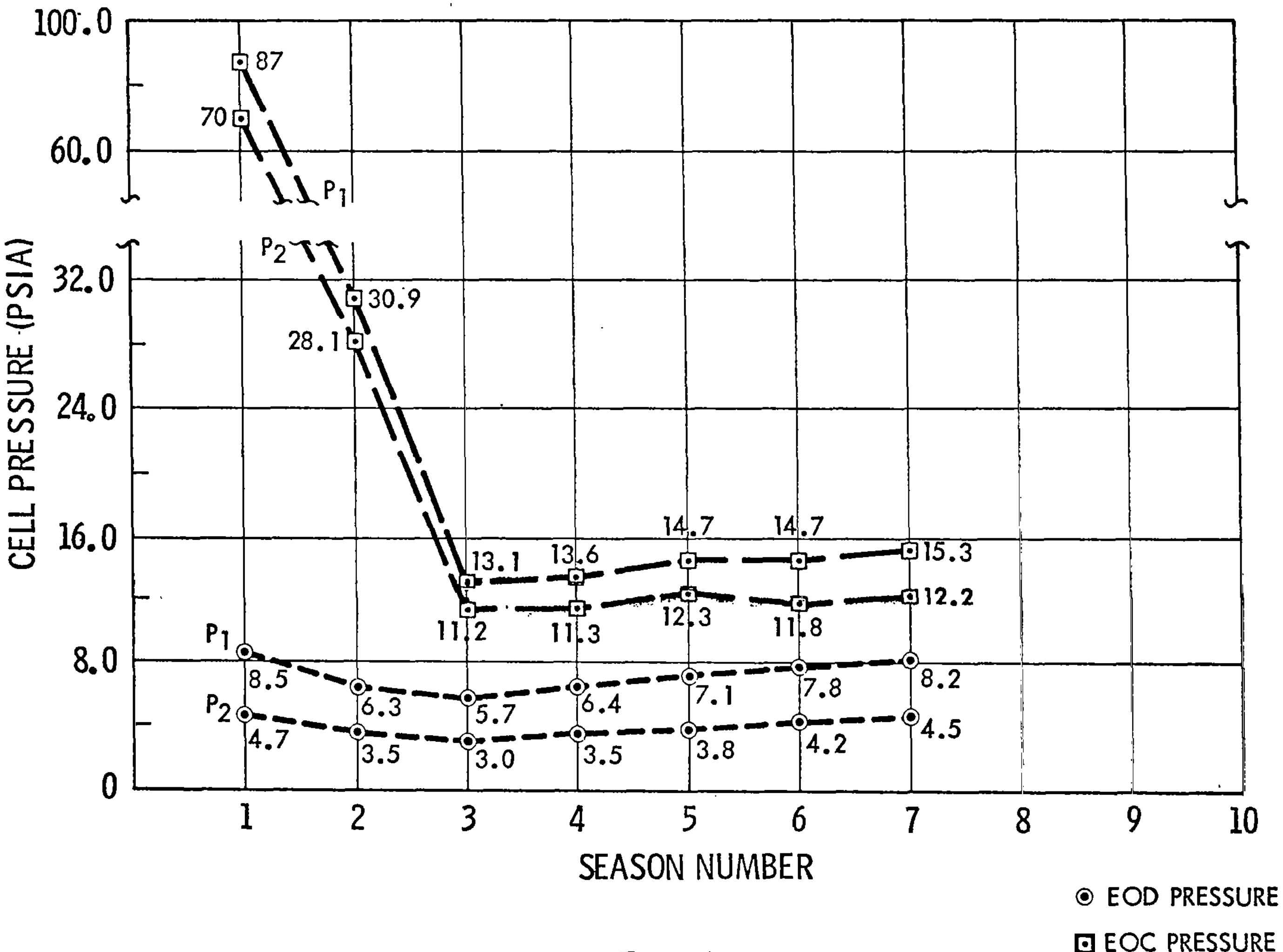

Figure 4-35

TEST PACK 2
CYCLE 23 SEASON 6

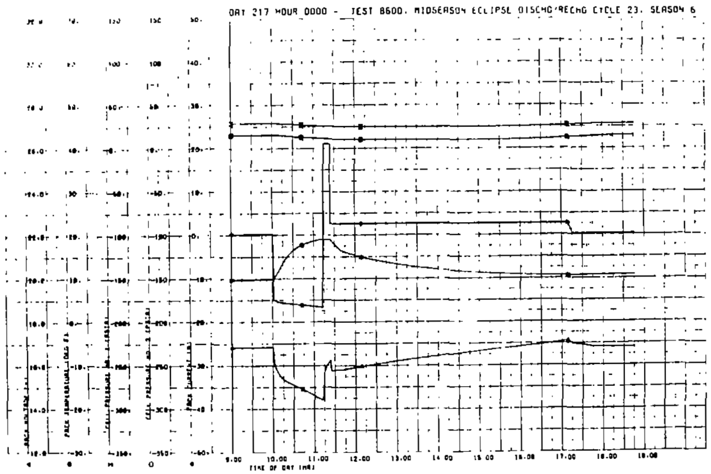

Figure 4-36

TEST PACK 1
CYCLE 23 SEASON 6

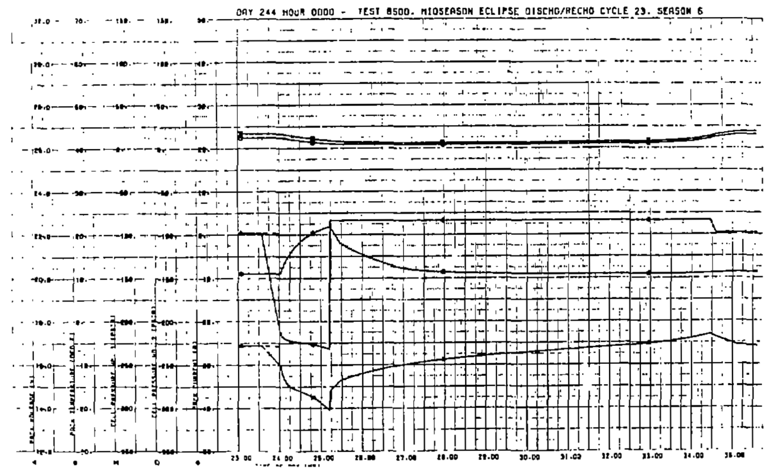

Figure 4-37

TEST PACK 1
SEASON 5

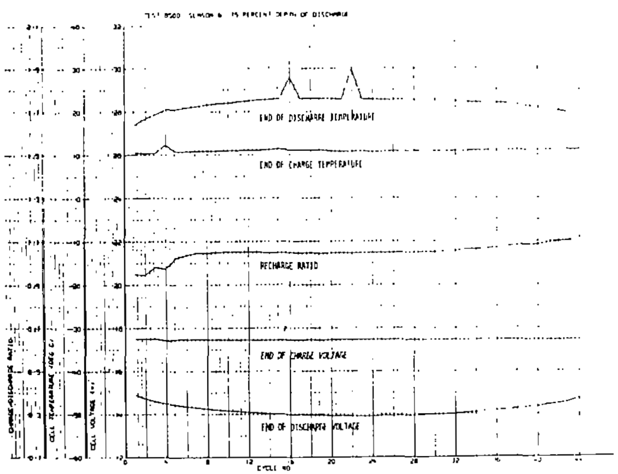

Figure 4-38

TEST PACK 2
SEASON 6

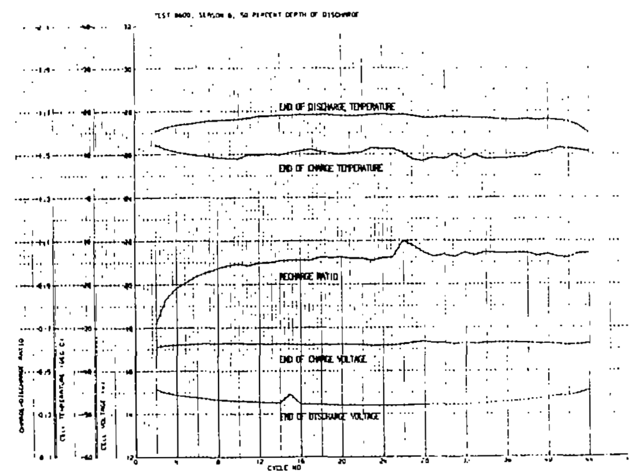

Figure 4-39

RECONDITIONING DISCHARGE AND RECHARGE

TDRSS LIFE CYCLE TEST
PACK NUMBER 1
75% DEPTH OF DISCHARGE

					CELL PRESSURE (PSIA)					
					P1			P2		
SEASON NO.	TO 1.0V	CAP RESI-DUAL	RECHG	END RECHG TEMP.	AT 1.0V	END RESI-DUAL	RECHG	AT 1.0V	END RESI-DUAL	RECHG
1	49.9	4.8	59.8	10.0	0.6	0.0	9.6	0.2	0.0	8.4
2	56.6	2.3	58.0	10.0	3.1	0.4	2.8	2.3	0.8	4.1
3	54.6	4.9	57.7	10.0	2.4	1.0	3.2	0.8	0.6	1.4
4	55.5	4.8	57.9	---	2.8	1.62	3.7	0.9	0.3	1.7
5	55.7	1.3	58.3	10.3	3.3	3.3	4.3	1.2	1.5	2.0
6	52.0	3.9	58.3	8.5	3.7	2.6	5.6	1.4	0.3	3.1
7	55.4	3.9	58.5	10.1	5.3	3.0	5.8	3.2	0.6	3.3

Figure 4-40

RECONDITIONING DISCHARGE AND RECHARGE

TDRSS LIFE CYCLE TEST
PACK NUMBER 2
50% DEPTH OF DISCHARGE

					CELL PRESSURE (PSIA)					
					P1			P2		
SEASON NO.	TO 1.0V	CAP. RESI-DUAL	RECHG	END RECHG TEMP.	AT 1.0V	END RESI-DUAL	RECHG	AT 1.0V	END RESI-DUAL	RECHG
1	52.8	3.62	57.3	6.3	17.3	40.5	35.8	6.8	7.0	9.9
2	53.3	3.89	59.1	6.6	16.7	32.0	41.7	6.4	5.3	13.6
3	52.0	4.38	58.2	6.4	16.7	50.4	50.3	6.4	4.9	7.1
4	53.2	3.75	56.0	9.6	16.7	39.0	39.5	8.0	5.7	6.1
5	55.5	4.76	57.8	7.8	17.1	43.2	41.8	8.2	5.6	7.3
6	55.3	2.89	56.3	7.4	14.3	26.6	23.1	6.9	5.9	7.1
7	54.8	3.77	60.5	17.6	15.6	31.1	31.6	8.6	7.6	17.0

Figure 4-41

RECONDITIONING DISCHARGE CUTOFF VOLTAGES

TDRSS LIFE CYCLE TEST
PACK NUMBER 2
50% DEPTH OF DISCHARGE

CELL NO.	1	2	3	4	5	6	7
1	-0.060	-0.071	-0.035	-0.068	-0.024	-0.090	-0.145
2	-0.060	-0.070	-0.041	-0.031	-0.021	-0.037	-0.134
3	-0.061	-0.070	-0.048	-0.054	-0.019	-0.030	-0.087
4	-0.058	-0.061	-0.067	-0.075	-0.103	-0.137	-0.152
5	-0.059	-0.070	-0.069	-0.074	-0.028	-0.099	-0.441
6	-0.058	+0.031	-0.066	-0.073	-0.081	-0.130	-0.153
7	-0.060	-0.071	-0.060	-0.073	-0.037	-0.078	0.138
8	-0.060	-0.072	-0.072	-0.079	-0.089	-0.131	0.464
9	+1.070	+0.975	+0.705	+0.933	+0.726	+0.994	0.955
10	+0.517	+0.645	+0.592	+0.639	+0.626	+0.449	0.582
11	-0.059	-0.072	-0.072	-0.077	-0.059	-0.127	-0.144
12	-0.058	+0.611	+0.344	+0.610	+0.105	+0.520	0.539
PACK VOLTAGE	1.00	1.73	1.13	1.55	1.00	-	1.47

Figure 4-42

RECONDITIONING DISCHARGE CUTOFF VOLTAGES

TDRSS LIFE CYCLE TEST
PACK NUMBER 1
75% DEPTH OF DISCHARGE

CELL NO.	1	2	3	4	5	6	7
1	-0.063	-0.069	-0.073	-0.116	-0.130	-0.150	-0.154
2	-0.067	-0.073	-0.079	-0.127	-0.146	-0.152	-0.156
3	-0.066	-0.072	-0.075	-0.100	-0.136	-0.148	-0.153
4	-0.065	-0.070	-0.074	-0.103	-0.137	-0.148	-0.153
5	+0.516	+0.558	+0.609	+0.595	+0.569	+0.585	+0.594
6	+0.509	+0.541	+0.354	-0.324	+0.476	+0.568	+0.582
7	-0.065	-0.070	-0.074	-0.052	-0.100	-0.149	-0.153
8	-0.060	-0.066	-0.020	-0.279	-0.382	-0.535	+0.595
9	-0.063	-0.068	-0.072	-0.105	-0.138	-0.149	-0.155
10	-0.067	-0.074	-0.077	-0.100	-0.139	-0.150	-0.155
11	-0.066	-0.073	-0.076	-0.123	-0.087	-0.150	-0.155
12	+0.598	+0.642	+0.650	+0.620	+0.592	+0.593	+0.608
PACK VOLTAGE	1.05	1.11	1.02	1.01	1.01	1.10	1.15

Figure 4-43