ORBITING SOLAR OBSERVATORY BATTERY AND POWER DESIGN

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INTRODUCTION

FORD: The OSO-I represents a recent vintage satellite, or more recent design satellite. It represents the philosophy, I guess, of the early seventies.

(Figure 29)

Basically what I have provided here is a summary of the battery design. It is a 12 ampere hour G.E. cell, with 21 series connected cells packaged in two packs, 11 and 10 cell packs. There are also two batteries on the spacecraft. It had a design life of one year, and it is in a near earth orbit. Incidentally, if you haven't recognized it, all the discussions you have heard so far deal with satellites in near earth orbit. I believe the last three papers this morning will deal with the synchronous satellite. We designed for a 10 to 16 percent depth of discharge, a temperature range of 10 to 15 degrees C with a thermostat that would place the battery on open circuit. If the battery temperature ever exceeded 35 C, the charge control has eight commandable voltage versus temperature. I am going to put these up here because as the next gentleman talks to you he is going to be talking about voltage levels, and that represents the eight levels that are in the charger. And I believe there are two chargers. Right? One for each battery is that right? Yes, two chargers.

(Figure 30)

It has an undervoltage setting at 1.18 volts per cell. The spacecraft was launched in June of 1975, and at this time Stan Bober is going to talk to you about the performance of OSO-I and give you some insight into the operational modes that they have gone through. And I will leave the curve on the left for you to refer to as he talks about a voltage level because I don't think he will be talking about actual voltages per cell.

OPERATIONS

(Figure 31)

BOBER: I would like to begin by describing the OSO spacecraft itself before I go into the battery performance. You will notice that I have an OSO-8, and Mr. Ford was telling you about OSO-I. They are both the same except that when the spacecraft was being built it is given a letter designation for a model, and after it is launched it is numbered. This is OSO-8, the Orbiting Solar Observatory, eighth in the series. The rest of it is pretty much self-explained except that I would like to bring your attention to the number of orbits that we have completed as of yesterday, 13,240. That is almost the same number of cycles that the batteries have gone through.

The two sections of the spacecraft, the solar panel is called the sail, and the drum at the bottom of the sketch is called a wheel. The wheel rotates at approximately 6 rpm while the sail is stationary. The sail is actually on a shaft or an axle through the middle of the wheel, and it is driven in the opposite direction to the point where it is standing still and points at the sun. The two rectangular boxes are the solar observing telescope. One belongs to the University of Colorado, the other one to the Paris or French experimenter.

There are six other instruments or experimental instruments located within the wheel. The booms with the weights just provide additional mass for gyroscopic stability as the wheel rotates.

The spacecraft orbits around the earth at a 550 kilometer height, and it goes through spacecraft day and night. When it comes into the sunlight it is spacecraft day, and when it is eclipsed by the earth it is spacecraft night.

The length of the orbital period is 95.7 minutes. The day although variable is pretty well over 60 minutes. I will show you a graph of the day occurrence later.

Mr. Ford mentioned the two batteries are made up of two packs, one 11 cell and the other 10 cell. The 11 cell pack is mounted closer to the outside wall, the peripheral wall of the wheel. And the temperatures run somewhat cooler than the 10 pack, which is closer to this, within one of the sections of the wheel. Battery 1 is in section 3. Battery 2 is in section 9.

(Figure 32)

Our orbital operation is very much standard. With some differences as far as to the loading, the total behavior is repetitive. In this graph and in the next three the data are actual data taken from one orbit, 12,931, fairly recent, and you will see a little stepping on the graph. That is because the data are sampled at one minute intervals, and the currents, the telemetry readouts, or increments, are fairly fine. The voltage is a little coarser, and the temperature when we get to it will be large steps. That is because of the telemetry readout.

Here we show, starting during the spacecraft day of the charge cycle, and there is a drop in the current at the beginning of the graph. That is because we come to the end of the playback, tape recorder B ends its playback. And this required some 400 mils of current. But then we continue fairly steadily with some variation because the experimental instruments always varied their mode of operation; maybe a wave length change or something like that requires a little. Then we come into the spacecraft night or the discharge period, and the current as the voltages decrease, the preregulator draws more current. So the current is increased until we come to the next sunrise and repeat the cycle again.

(Figure 33)

There are also periods of time when some of the experiments turn off because they do come into the high radiation area for the South Atlantic anomaly area. But overall the operation is fairly standard.

Here we show the charge and the discharge currents of both batteries. You notice they are fairly identical. When the batteries are being charged the current is fairly high, and then it starts tapering off after the voltage clamp or the limiting takes place until it gets down to just a trickle rate or trickle current of about .32 amperes. Then we cross over to the discharge period, where we require about 3 amperes of current from each battery.

(Figure 34)

On the voltage profiles again very much alike.

(Figure 35)

As I mentioned earlier, the slight coarseness in the graph is because of the telemetry increment. Again, the charging cycle and maintaining the voltage at a predetermined level set by the charge control, we are operating since launch in level 2, which runs somewhere, oh, 30 point, I forget the exact figures, depending on the temperature. The charge control compensates for the temperature. As the temperature increases we do not push the battery too hard, and therefore we get a lower charge level.

Then we come to the discharge cycle. The battery provides the operating power and repeat over and over again.

Temperature rise, where the great stepping comes in, I am showing the temperatures of the 10 and 11 cells. As I mentioned earlier the 11 cells are located closer to the outer wall of the wheel and they start cooler, but since they are 11 cells their operating range or temperature range is somewhat higher than those of the 10 cells. And I have intended to portray the actual or possibly the actual temperature curve as it most likely is.

(Figure 36)

I have stated earlier that the operating temperatures of the batteries will vary as the length of day or duration in sunlight of the spacecraft varies. This is the exact or graph with data taken from the predicts showing the length of day. Normally we are in the 60 to 62 minute range, but periodically we are extending upward to 71 minutes of sunlight for orbit. Those are just short duration, about five orbits, and then it starts decreasing again.

During these periods we modify the plan where our spin axes are maintained perpendicular to the sun normal. That is to minimize the temperature rise because if we go into positive pitch angle where the top of the sail leans toward the sun then we get a reflection from the sail onto the top of the drum, and the temperatures increase about degree of pitch forward leaning. So to keep the temperatures reasonable during these longer and hotter periods we keep spacecraft pitch angle at 0 degrees.

(Figure 37)

Now to show you what happens to the battery temperatures I have prepared a graph which covers the period from day 160 to 220, covering this high sunlight period.

This is battery 2 only. I didn't want to crowd it too badly, but both batteries behave pretty much the same. The temperatures are mainly effected by the duration in sunlight. But I show you here the pitch angle, ranging from 0 to 3 and 0 to minus 3. Each time we go into a positive angle the temperatures rise also, the peaks. When we drop into the negative regions it does not affect it as much. Things like heating the bottom of the spacecraft aren't as serious as the top of the spacecraft.

(Figure 38)

During the same period here is what the battery voltages look like. This is based on data taken from one orbit per day, and the computer extracts the minimum and maximum values. This is plotted for the same two month period as the warmest day where visible. You will notice that at this point the charge controller compensated for the temperature and did not allow the battery to charge up as high. Also because it is a longer day the terminal voltage at the end of the discharge cycle is higher. Both batteries behave pretty much the same way.

(Figure 39)

Now the next three graphs are also two-month periods based on one per day sampling, for a comparison of what they would look like in 75. You will note that the maximum voltage is around 29.94 volts on the average. When the days get longer it drops. The average minimum voltage is somewhere in the vicinity of 25.8. This is in 75, days 250 through 300.

(Figure 40)

In 76 the maximum voltage is pretty much the same. The minimum voltage dropped about .25 volts.

(Figure 41)

And again in 77, which is most recent, we have another drop.

I don't know if I attempt to put all three together and match them you will probably notice a difference in the levels at the bottom. The top appears to be charging pretty much to the same level, which is fine, speaks well for the charge control. The batteries are losing at the lower or the end-of-discharge cycle. And I am told that you can expect that also.

So, gentlemen, as you see, we in the OSO Operations Control Center are like the TV Maytag repairmen standing by and another tv ad says, "Thank you, Hughes Aircraft Corporation or Company for a well-designed power system."

OSO-I BATTERY DESIGN SUMMARY

- 12 AH GENERAL ELECTRIC NICKEL-CADMIUM CELLS
- 21 SERIES CONNECTED CELLS (11 CELL AND 10 CELL PACK)
- DESIGN LIFE — 1 YEAR IN NEAR EARTH ORBIT; 10 TO 16 PERCENT DOD
- TEMPERATURE — 10 TO 15 C, OPEN CIRCUIT @ 35 C
- CHARGE CONTROL — VOLTAGE VS. TEMPERATURE; 8 COMMANDABLE LEVELS
- TWO BATTERIES ON SPACECRAFT
- UNDERVOLTAGE @ 1.18 VOLTS/CELL
- SPACECRAFT LAUNCHED — JUNE '75

Figure 29

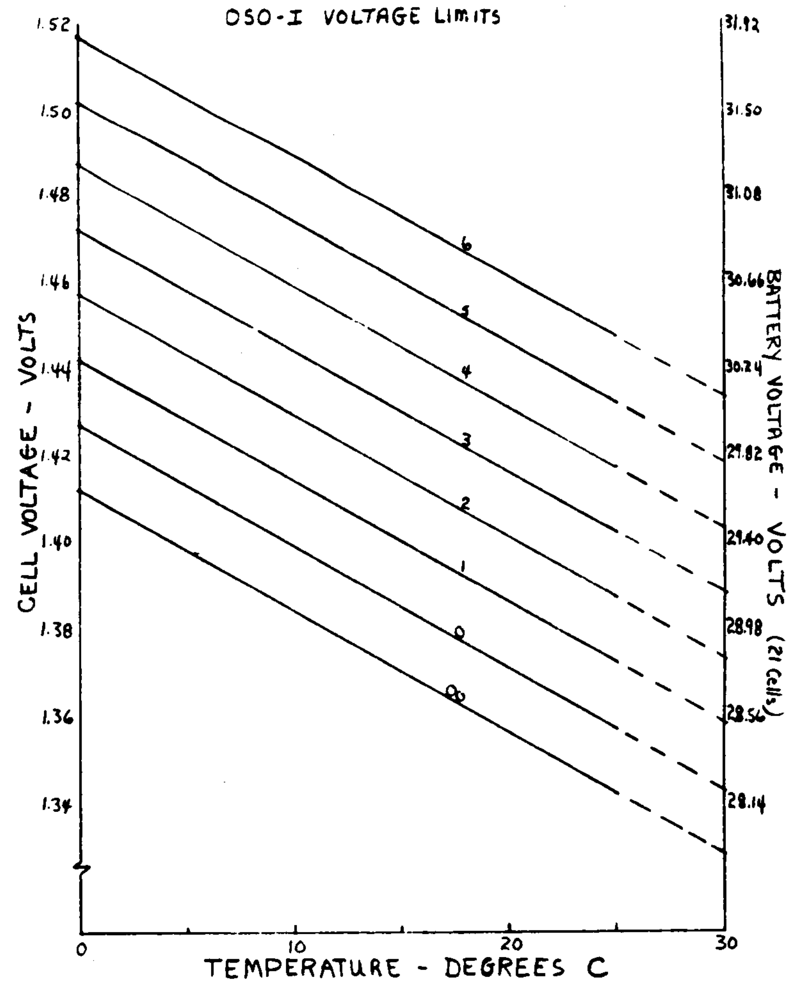
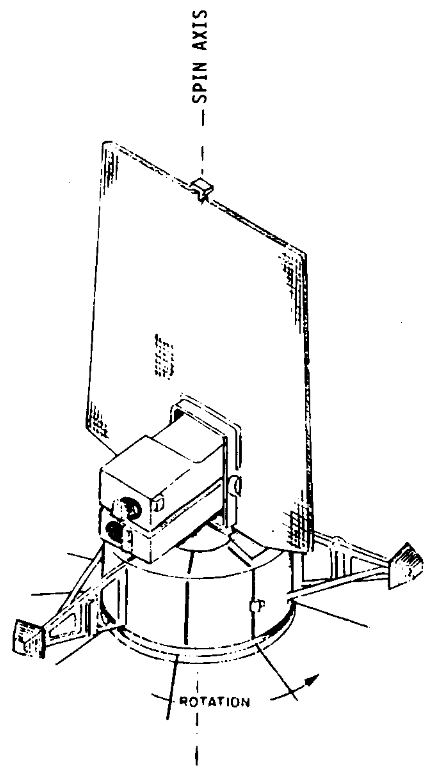


Figure 30



OSO-8

(ORBITING SOLAR OBSERVATORY, EIGHT IN THE OSO SERIES.
LAUNCHED 21 JUNE 1975 FROM ETR AT 1147Z.)

OSO-8 IS CURRENTLY IN ITS THIRD YEAR OF OPERATION.
ON 14 NOVEMBER 1977, OSO-8 COMPLETED 13240 ORBITS.

Figure 31

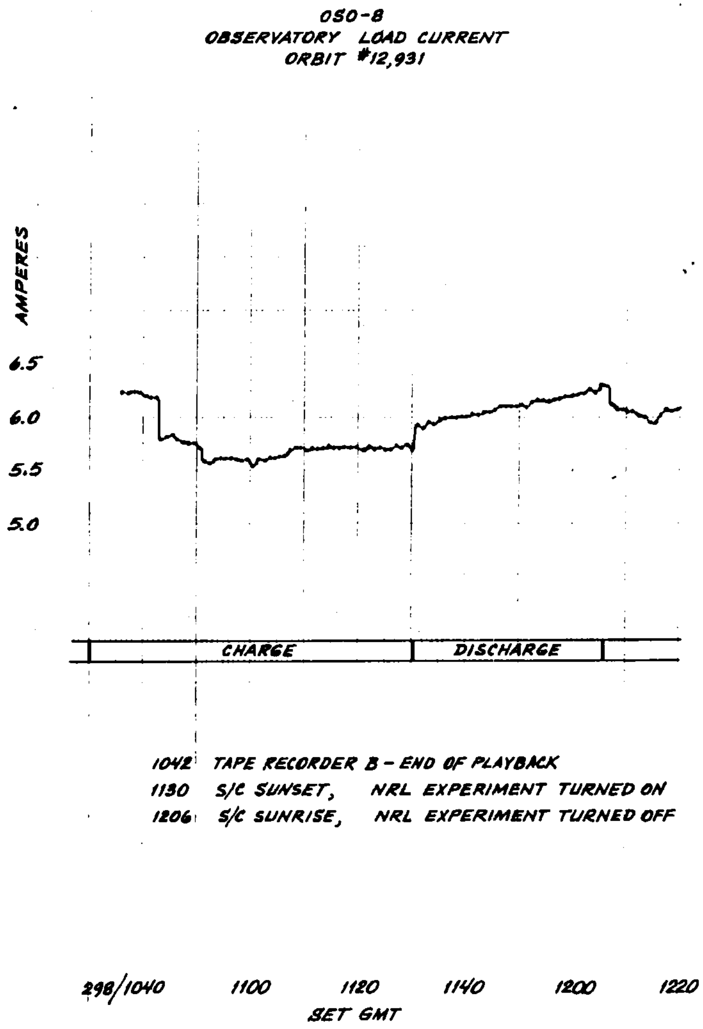


Figure 32

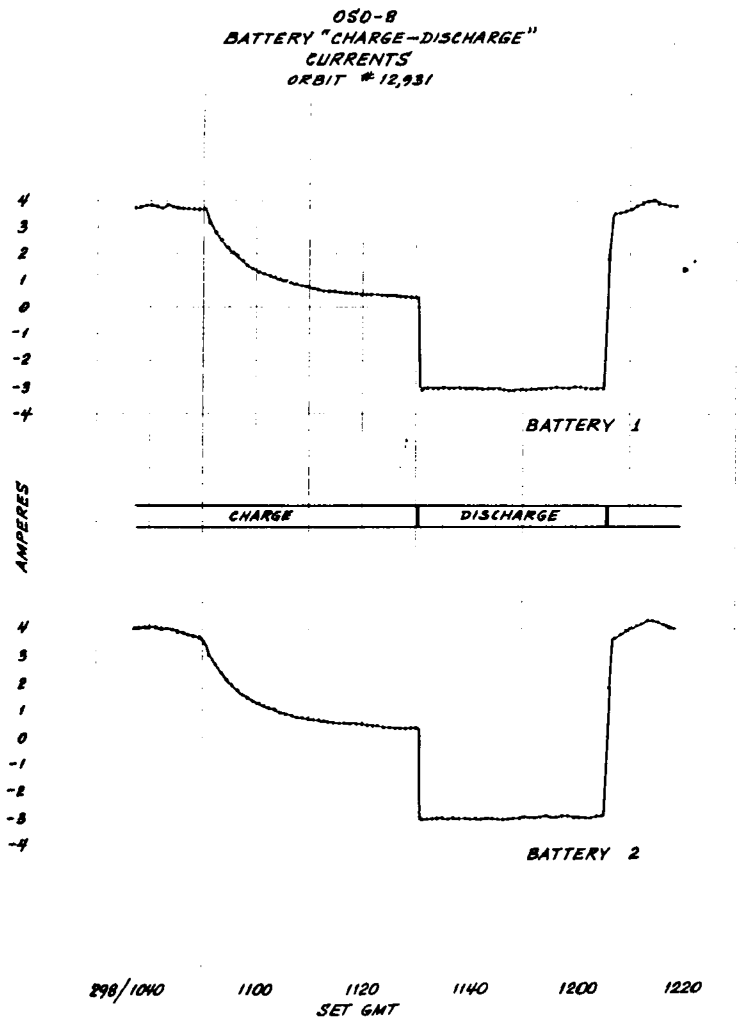


Figure 33

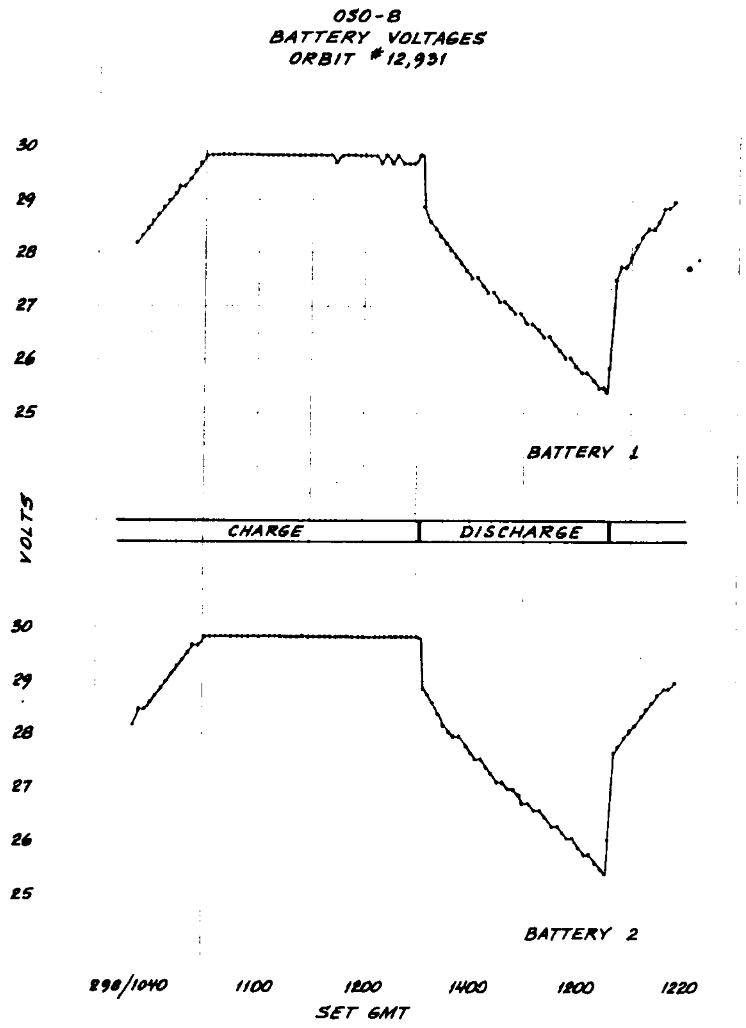


Figure 34

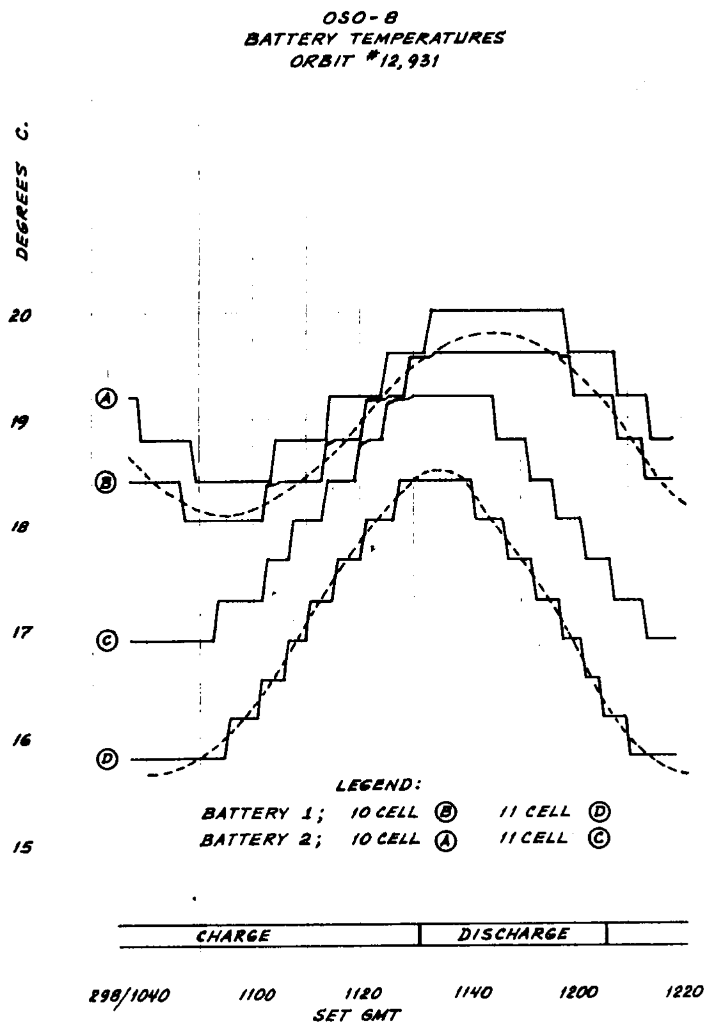


Figure 35

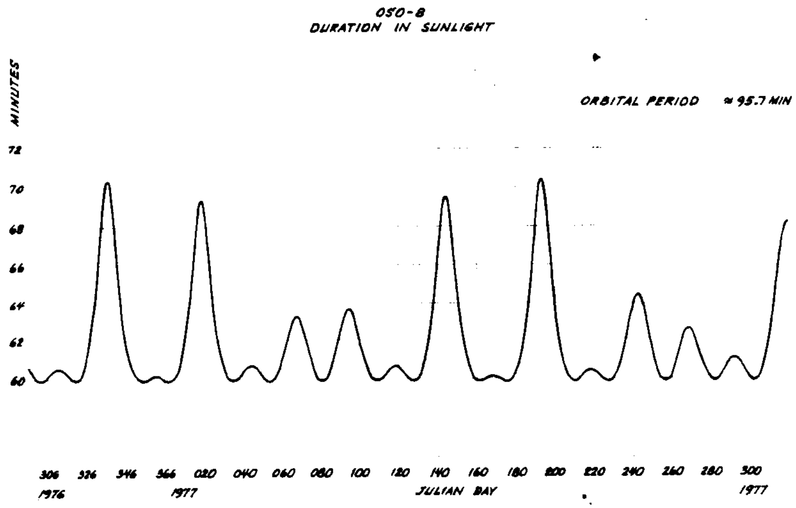


Figure 36

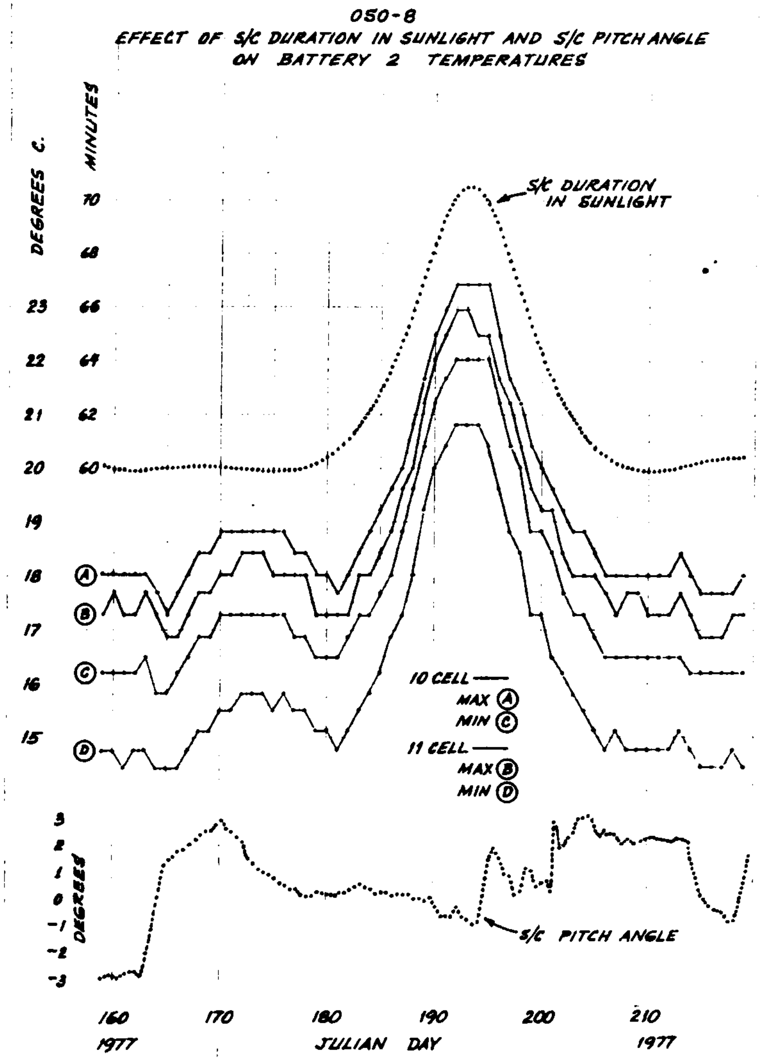


Figure 37

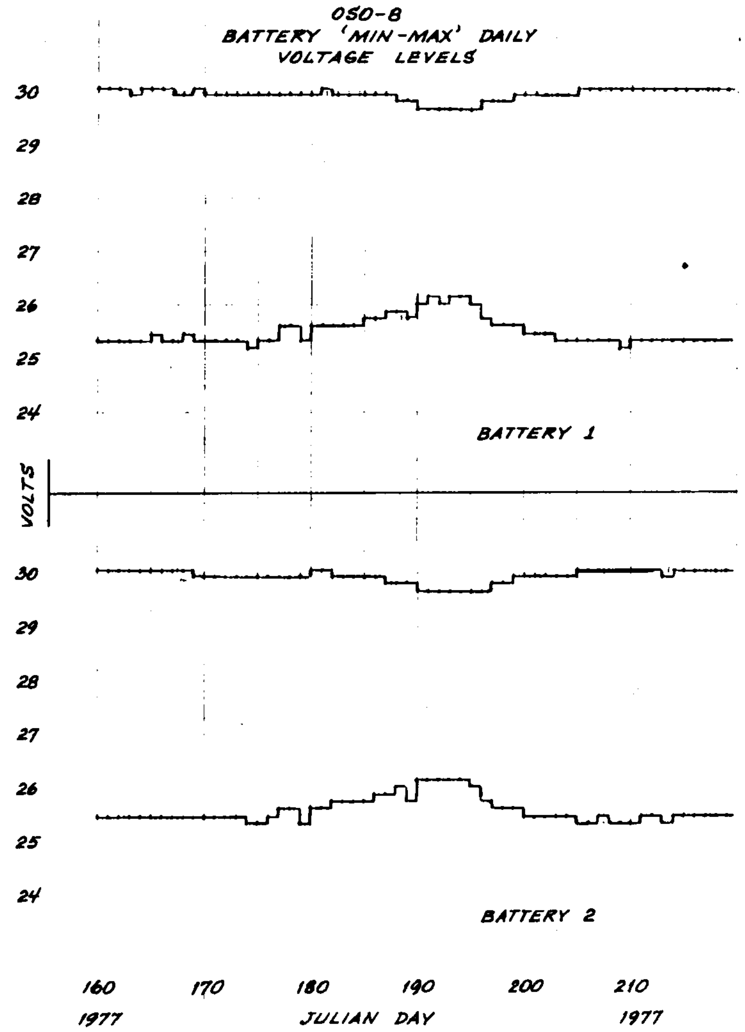


Figure 38

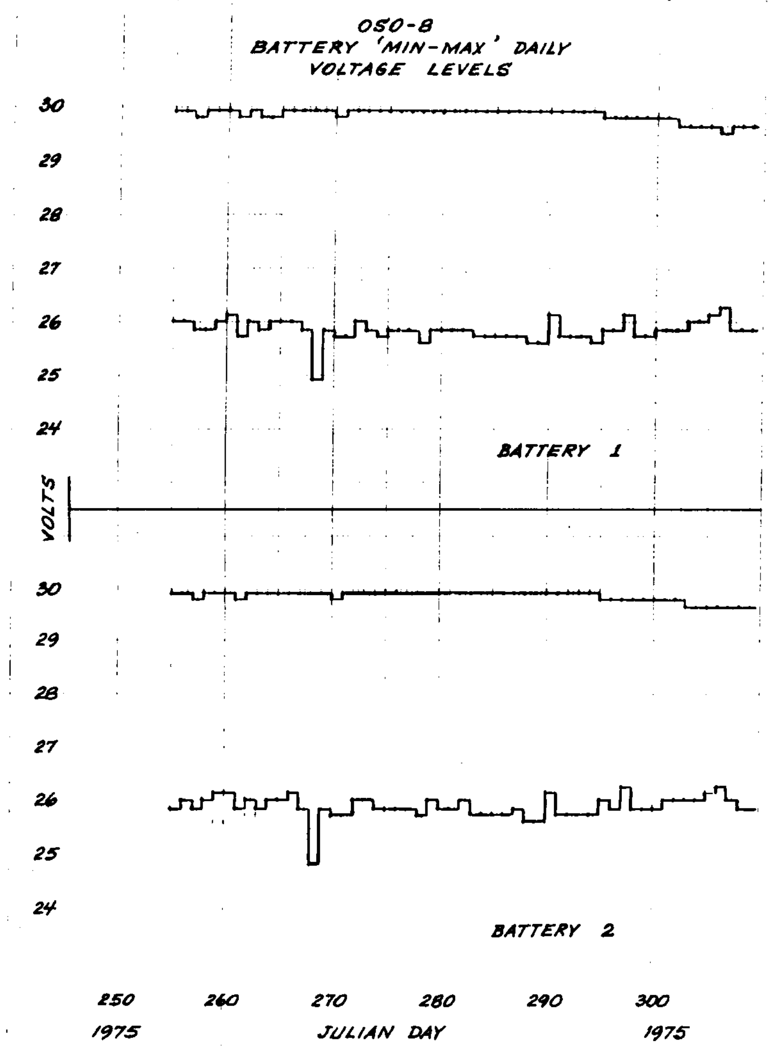


Figure 39

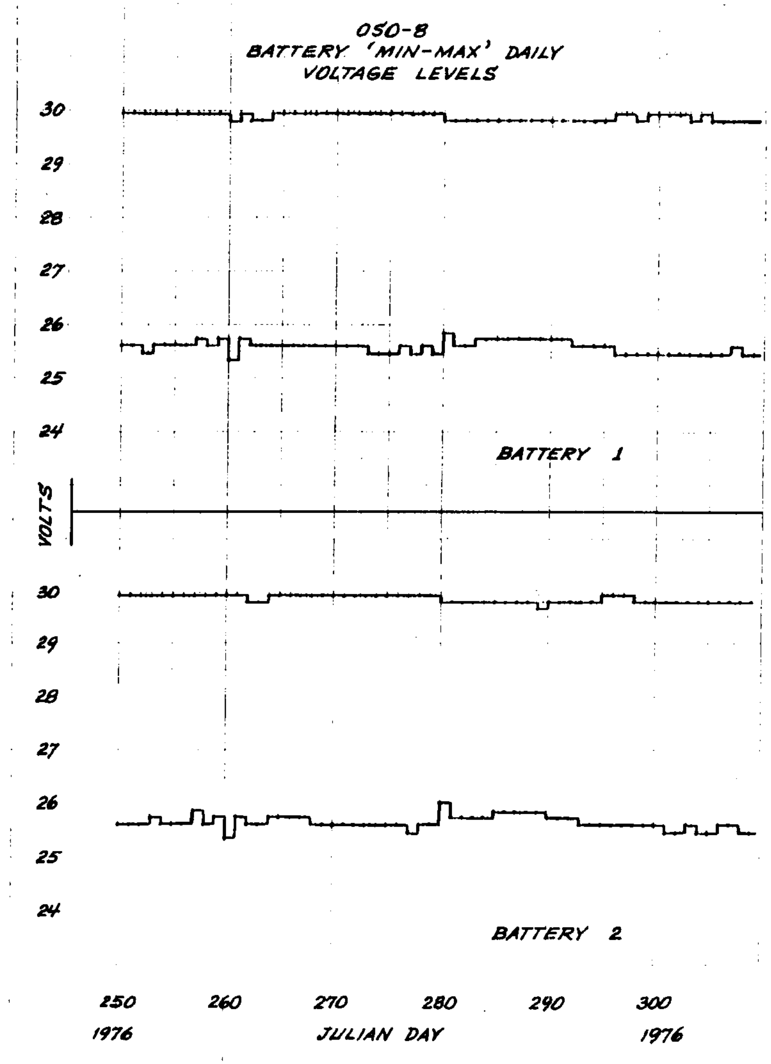


Figure 40

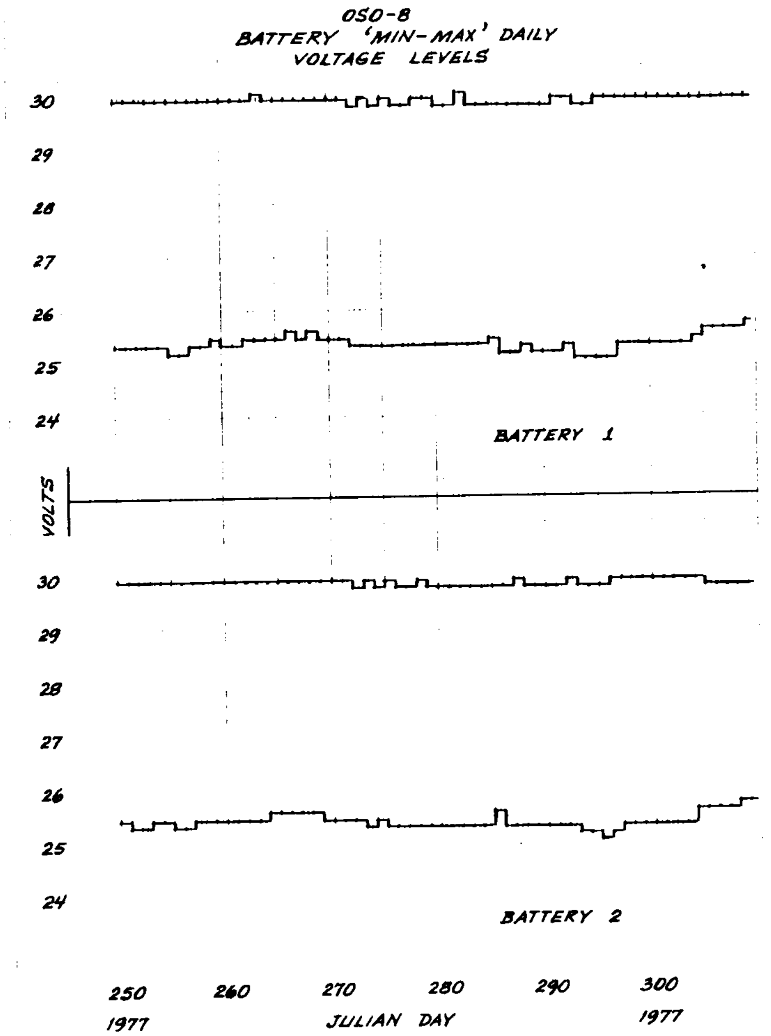

OSO-8
BATTERY 'MIN-MAX' DAILY
VOLTAGE LEVELS
30
29
28
27
26
25
24
BATTERY 1
VOLTS
30
29
28
27
26
25
24
BATTERY 2
250
1977
260
270
JULIAN DAY
280
290
300
1977

Figure 41