APPLICATIONS TECHNOLOGY SATELLITES BATTERY AND POWER SYSTEM DESIGN

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INTRODUCTION

(Figure 60)

FORD: A summary of the ATS battery design which is onboard the Applications Technology satellite (ATS) is provided here. The 15 ampere hour nickel cadmium cells were manufactured by Gulton, 19 series connected cells per battery, and there are two batteries in each spacecraft. The operating design life was two years in a synchronous orbit, and a maximum depth of discharge of 50 percent. The design temperature for the batteries in the spacecraft was 0 to 25 degrees C, and the charge control consisted of 1 volt versus temperature on a constant percentage voltage. Also, C/10 current limit, and a commandable trickle charge rate, using C/20 or C/60. The undervoltage was sent across a 9 cell and a 10 cell group, and it was set at one volt average per group on either group.

The spacecraft was launched in May of 1974 and not included in the design but old orbit requirements included the support of a site experiment which required for periods of about six months, I believe, two discharges each day. And these two discharges did not coincide with the eclipse mode, except to require that because the spacecraft load demanded more than the array could put out that the batteries had to go through approximately two cycles per day. And this was as of 5/76 there were over 337 cycles in this mode.

(Figure 61)

A picture of the battery, a photograph of the ATS battery, shows the construction. As I said earlier, there were two of these used in the spacecraft.

I will leave the V versus T at this point.

(Figure 62)

BEMIS: Early in the design phase of ATS-6 it was decided that instead of merely using the battery to support eclipse that they would be used to support experiment loads in excess of the solar array power.

(Figure 63)

And that is a history of what the solar arrays have done over the first two and a half years in orbit. That is about as predicted.

(Figure 64)

As time goes on the requirements on the batteries increase, or else we are going to have to start cutting off some experiments. Eventually we are going to have to start cutting off experiments anyway if we plan to keep the thing going.

This diagram shows the battery charge characteristics, battery voltage versus charge/discharge ratio. The taper charge comes in at about 95 percent state of charge at a C/60 rate. One of the problems that we have had with ATS-6 has been that at the C/60 rate we never reach full charge. So, we have had to command the standby charger into operation to attain a C/20 rate of charge to bring the batteries up to full charge.

Another of the problems that we have had on ATS-6 is that the location of the shunts to take the extra solar array power when the batteries are fully charged is such that they heat the battery up. Consequently, we have had to turn on an experimental load in order not to use the shunts during the hot temperature season.

(Figure 65)

We have got a couple of other curves here. These show battery capacity trends. There are three curves here that are NAD Crane curves on flight hardware, and I have two curves here. One is an in orbit eclipse curve, and this is a curve of the slight discharges. That is at 2.1 amp discharge, which is extended beyond the normal satellite, television program somewhere over India.

(Figure 66)

This is a little bit busy, and perhaps too many Xeroxes. But these are just the latest data -- in fact, they were just plotted yesterday I believe -- of the number seven eclipse. And one of the things that is of interest to us is that this number seven eclipse right along here seems to have a much steeper slope near the maximum discharge than these other ones did which were out fairly straight. And this is of concern to us. I don't know what has caused it, or what we can do about it.

So, the three problems that we are concerned about on an ATS are the battery degradation -- is there something that we can do to improve it, the fact that we have to command the C/20 rate in order to get back up to full charge, and the fact that we have to turn on an experiment load rather than using the shunt dissipators where they were designed to be used, in order to keep from heating up the batteries.

DISCUSSION

NAPOLI: RCA. We have a similar charge rate on our satellite, C/60. We never use that to return to charge. That should be a maintenance once the batteries have reached the charge. We just use it to maintain. We use it not to have any internal discharge. It is not really a means to return the charge to the battery. That may not be a problem --

BEMIS: Well, we use a C/10 rate as our normal charge rate. When we get to 95 percent state of charge we go into the C/60 rate automatically. That was part of the spacecraft design. Since that does not bring the battery up to full charge we are not commanding a C/20 rate by commanding the auxilliary charging.

FORD: Goddard. If you would clarify that, the way I understand it is C/10 is for the voltage limit. Then the current will cut back and maintain a voltage limit and it will taper down to C/60? Is that the mode? You indicated you got a bi-level C/10, C/60. It is really a C/10 taper to what you said is C/60.

BEMIS: I don't know. Could someone else comment on that? Bob Leone, can you comment?

LEONE: Yes, that is correct. It is not a step function. It is a gradual decrease from the C/10 to a C/60. And operationally what we do is when we taper down to the standby charge, C/20, and then we command it, we maintain that C/20.

LACKNER: Canadian Defense Research. I would like to have a bit of clarification on your voltage limit on charge. Does this mean that if you are charging at C/10 once you hit 1, 4, and 5 at 0 or 1, 4, 2 you are never going to go above that voltage? You are going to just put on a taper current, is that right?

BEMIS: Yes.

LACKNER: Now, I have the impression that provided the voltage does not escalate so high that you should have a little bit of a voltage peak because the more overvoltage presents when you have the more effective charge you are getting into this, as long as you are not getting into gas evolution. So if you had it in 1, 4, 5 at 25°C, I think perhaps you could get a little bit more increment.

FORD: Goddard. It is a big system. They have what they have.

LACKNER: But why do they have what they have?

FORD: It was designed with the voltage, the undercurrent charge, the voltage, and then a voltage tapering. With the two level charge rates available to them by command, and I believe those two levels do not have a voltage limit -- current -- when they go to that mode of operation. So they do have the other mode, which is not restricted by the voltage.

BEMIS: That C/20 rate is a fixed rate.

SPEAKER: Well, when you go to C/20 can you go above your 1.45?

LEONE: No, we try not to overcharge.

FORD: Goddard. Can you comment on what the temperature of the two batteries has been running?

BEMIS: We are trying to maintain the battery temperature below 30 degrees. Actually we maintain it below 28 degrees. When the temperature gets up to 28 degrees we go ahead and turn on a transmitter just to take the power off the shunts and we use a transmitter for a shunt.

ATS BATTERY DESIGN SUMMARY

- 15 AMPERE-HOUR NICKEL-CADMIUM CELLS (GULTON)
- 19 SERIES CONNECTED CELLS - TWO BATTERIES PER SPACECRAFT
- OPERATING DESIGN LIFE - 2 YEARS (SYNCHRONOUS)
  - 50 PERCENT DOD MAXIMUM
- TEMPERATURE - 0-25°C DESIGN RANGE
- CHARGE CONTROL - VOLTAGE VS. TEMPERATURE (1 LEVEL)
  - C/10 CURRENT LIMIT
  - COMMANDABLE C/20 OR C/60 CHARGE RATE
- UNDERVOLTAGE - SENSE ACROSS 9 AND 10 CELL GROUPS
  - 1.0 VOLTS/CELL AVERAGE EITHER GROUP
- SPACECRAFT LAUNCHED - MAY 1974
- SPECIAL ON ORBIT REQUIREMENTS - SITE EXPERIMENT
  - TWO DISCHARGES EACH DAY
  - 30%, 43%
  - 337 CYCLES AS OF 5/76

Figure 60

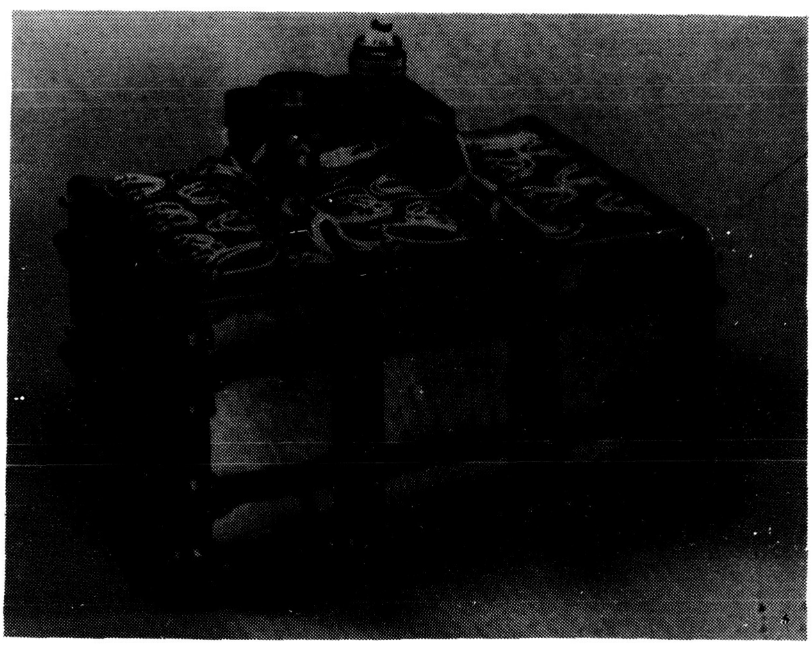

Figure 61

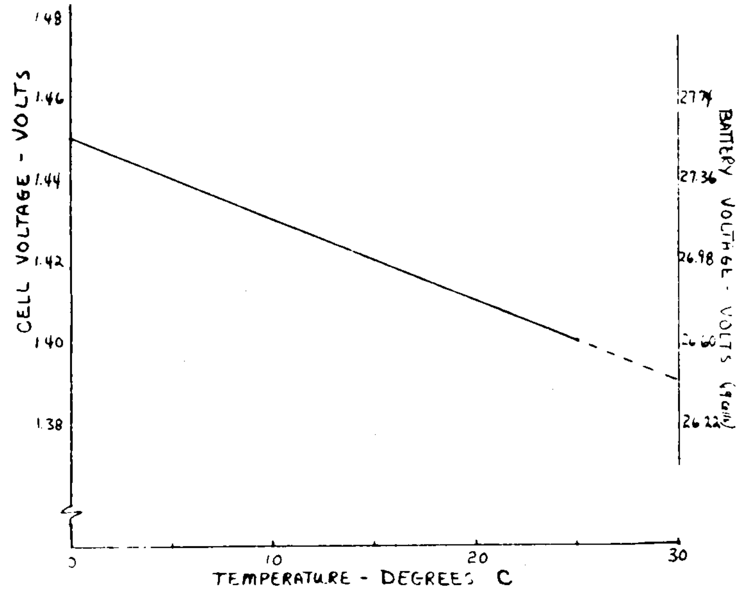

Figure 62

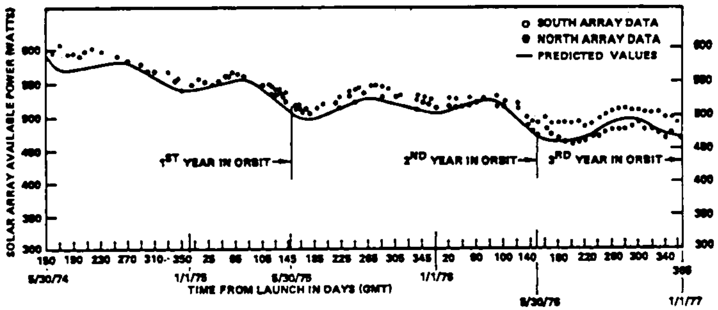

Figure 63

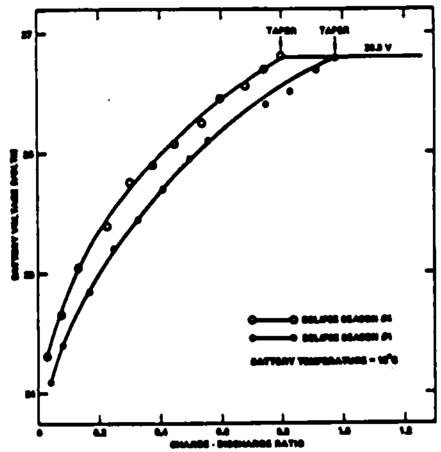

Figure 64

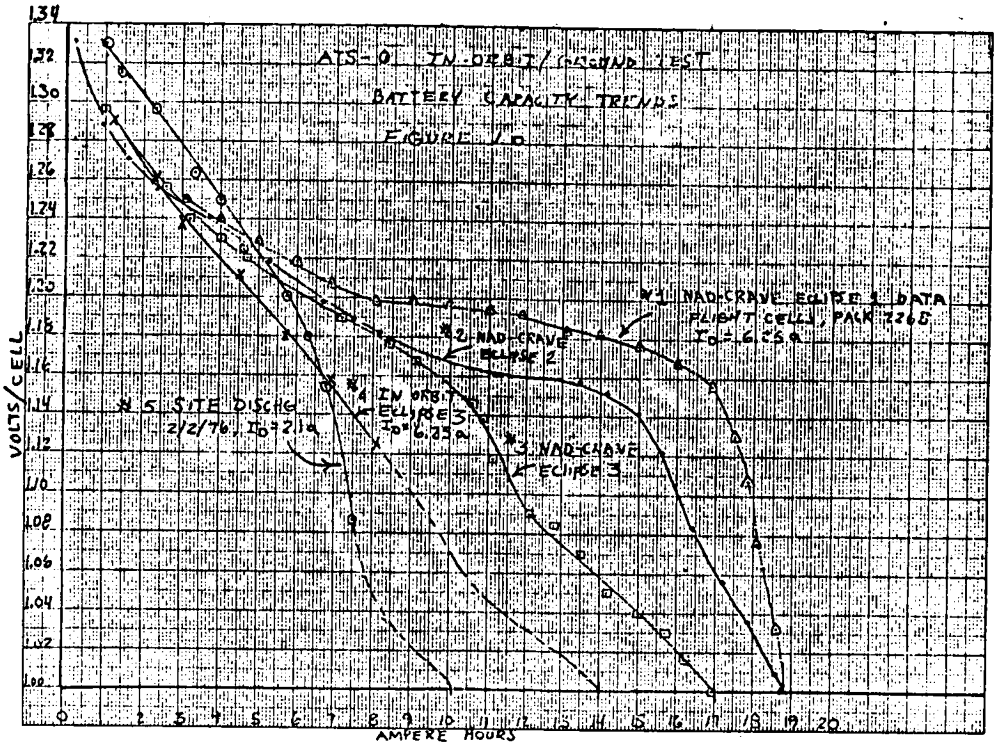

Figure 65

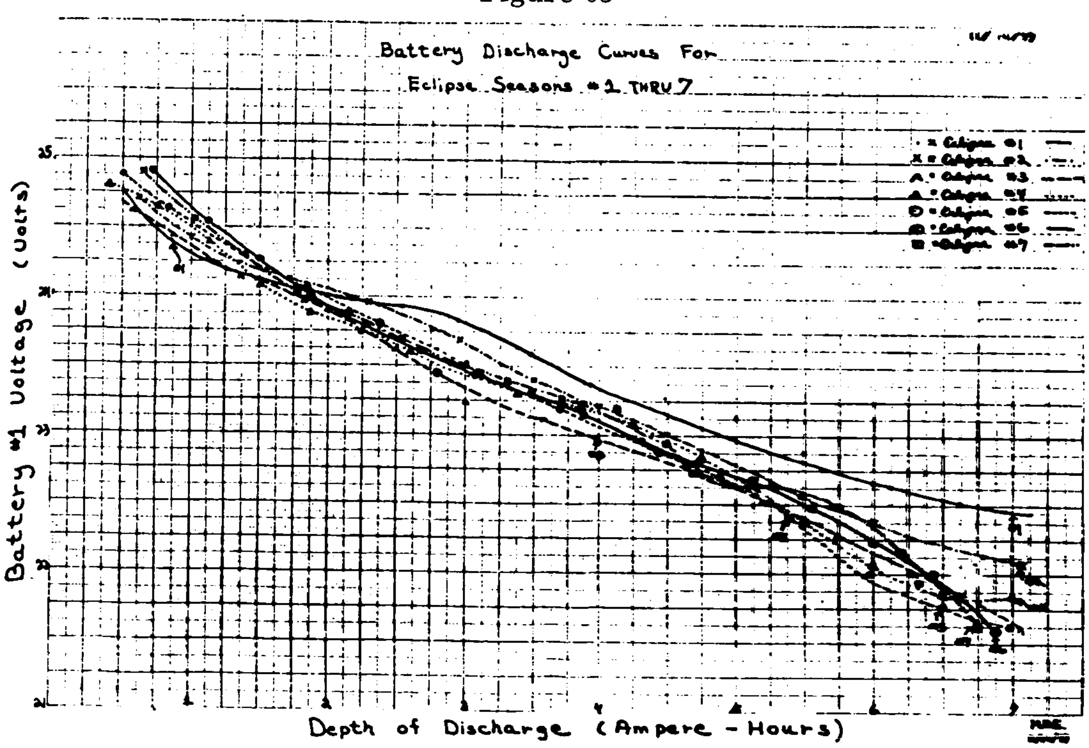

Figure 66