

ITOS POWER SYSTEM DESIGN

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I thought we would start off with a brief description of what the ITOS power systems look like. It is a rather conventional RCA/AED design from the mid-sixties.

(Figure 1)

There is a set of three solar arrays which are directly connected to an unregulated power bus that runs along here. The upper end of the voltage is controlled at approximately 38 volts by nine shunt dissipator legs. Each of the two 6 ampere hour batteries is controlled with an individual current limited versus time battery charger. The batteries are then discharged through diodes in parallel back to the load bus. The loads are distributed between an unregulated bus and also a regulated bus through series dissipated 24.5 volt regulators. One regulator at a time is coming on. It is a rather conventional unregulated bus distribution system.

(Figure 2)

The next viewgraph shows a few characteristics of the battery pack. The spacecraft, as I mentioned, was developed by RCA/AED. The cells are from G.E. Gainesville. There are two 23 series connected cells in each pack with a capacity of 6 ampere hour. Each battery weighs 9.08 kilograms. The charge control is a taper charger with multiple temperature control. The nominal operating range is 10 to 35 degrees C. There is a C/4 or 1.5 amp per battery charge rate until you get to the taper charge, where the taper charge is then determined by the battery voltage and temperature.

There is a ground commandable trickle charge. There is not an automatic reduction charge to trickle charge. We will see what the effects of that are a little bit later when we get into the flight experience. The depth of discharge is nominally 15 percent with a maximum of 24 percent.

(Figure 3)

Finally to look at the V/T curve, because this again will have an influence on what we talk about later, the two curves right here are the upper and lower tolerance. As you see, for a 23 cell battery, nominally you work

between about 35 volts at 0 degrees C down to somewhere in the order of about 32 volts or a little bit less at 40 degrees C. This curve was used for many, many years on the ITOS program successfully. But as the later missions came along and the charge characteristics themselves began to change, we did start to have some difficulties.

OPERATIONS

(Figure 4)

Normally when you come out of an eclipse and you are coming into sunlight, this is the characteristic the battery sees. You go through a period of constant charge at a C/4 until you hit the V versus T, and where you hit it depends on what the sun time is. A 45 degree sun angle is a lot better for the spacecraft so you have a lot more available charge. You hit it a lot faster and you taper down, taper along. For 60 degrees sun it just takes you longer, but you still taper down. You essentially get to the same place.

And this is what you would like to see. You would like to see something in here on the order of about C/25. It would be a nice taper at the end, but certainly no greater than C/10 to C/15.

(Figure 5)

The top curve is the sun, the percent of deep orbit in sun. The top two curves are the battery temperature, battery 2, battery 1. And then down here we have voltage, battery 2, battery 1.

You can see that after about nine or ten months in orbit the battery charge current of battery number 2 started coming back up. The V/T curve was too high, and one of the batteries just started taking more charge than it should have. And its temperature started going up correspondingly. Where you notice this dip here, they had to turn that battery into a trickle charge and essentially just used the other battery in trying to load the spacecraft so you maintain a reasonable charge without a significant overcharge into battery number 1, with battery number 2 into a trickle charge, which is C/40, 150 mils nominal.

At this point right here they decided to try to turn the battery number 2 back on again. You see that immediately within a very few days it went right back up to a temperature of close to 40 degrees C. They had to take it back off again. And this is how they are having to run the spacecrafts. They have to continually watch the temperature of the two spacecrafts. As the temperature

of a particular battery starts to rise, they have to take it off and put it into a trickle charge mode and let the other one essentially carry the entire load until it also runs into a problem.

(Figure 6)

This is number 3, a later satellite. Here we see a little bit different characteristic for the sun time because it is a slightly different clock orbit. Notice that the battery voltage of both batteries, again for you know a relatively long period of time, six to eight months after a launch, is going along very nicely with a few excursions in temperature. But for the most part the end-of-charge is very nominal. In fact, here on battery number 2 you see something like a C cover 24 is a nominal end-of-charge taper, whereas at this point right here, battery number 1, is up to C/15 and the battery temperature starts to rise. At that point battery number 1 was then put into trickle charge, and the temperature stabilized and it went to a rather low value.

(Figure 7)

And here is the same satellite with just a little bit later—the extent of the previous curve. But we started running into a problem with both batteries simultaneously. They were starting to get hot, so we put both of them in a trickle charge. They remained there for a period of time.

Historically what they are trying to do on all the ITOS spacecraft right now routinely is they maximize the load by turning on instruments that maybe one would not like to be on so that they can minimize the charge into the batteries by just taking it out of the array and putting it into the load as opposed to having it available for batteries.

They monitor the array current and the battery temperature. When the battery temperature starts to get above a preset limit of about 25 degrees C, they just put that battery into trickle charge and then let the other one take the load until it also runs into a small problem.

The spacecraft have flown for years now and they have never had a battery problem. It is an operational matter, not really a battery performance. Batteries seem to be presenting when they are discharged hard very close to what the rate of capacity was.

DISCUSSION

GROSS: Boeing. You referred to voltage as being the criteria that was changing. I wonder if you really meant current.

OBENSCHAIN: I meant current.

ROGERS: Hughes Aircraft. Is that a negative system, or will the diodes impact?

OBENSCHAIN: No, it is a negative system. In fact, probably everything you will see here in the next four presentations are all negative systems.

FORD: NASA Goddard. I would like to make a point which you can follow for the rest of the morning. The system that Rick just presented has a heritage of about 1964-65. When we go through several satellite programs, some of these systems are more recent heritage and some of them go back in the early sixties and some of them go through their own evolution, change, in voltage versus temperature characteristics. And I think the point I want to ask you to follow this morning is very carefully follow V versus T characteristics because two days later or one day later we are going to get into talking about volts, cells, and components of degradation. And what you are going to see this morning in all of this is that basically the overcharge characteristics of cells has come down since about 1970. And we are using much lower V versus T today to achieve the same C to D ratio as we were in the sixties or late sixties.

LACKNER: DRE, Canada. What do you mean by a negative system?

OBENSCHAIN: The positive is grounded. Everything is in relationship to ground. So it is minus 38 volts within shunt, and then the regulator is put at a minus 24-1/2 volts.

Just as a point of interest that has nothing to do with this, but everything really on these systems goes back to the very early sixties when they had a problem getting the NPM transistors. And so they used to use the PST's. And then when the NPM's became available and the high power applications instead of just changing over to a positive system they already had enough instruments and equipment developed, so they just kept on using the negative.

WESTROM: Goddard. Can you tell me how long those batteries are supposed to last?

OBENSCHAIN: Everything was a one year mission. They have all lasted between two and three years nominally, some as much as four.

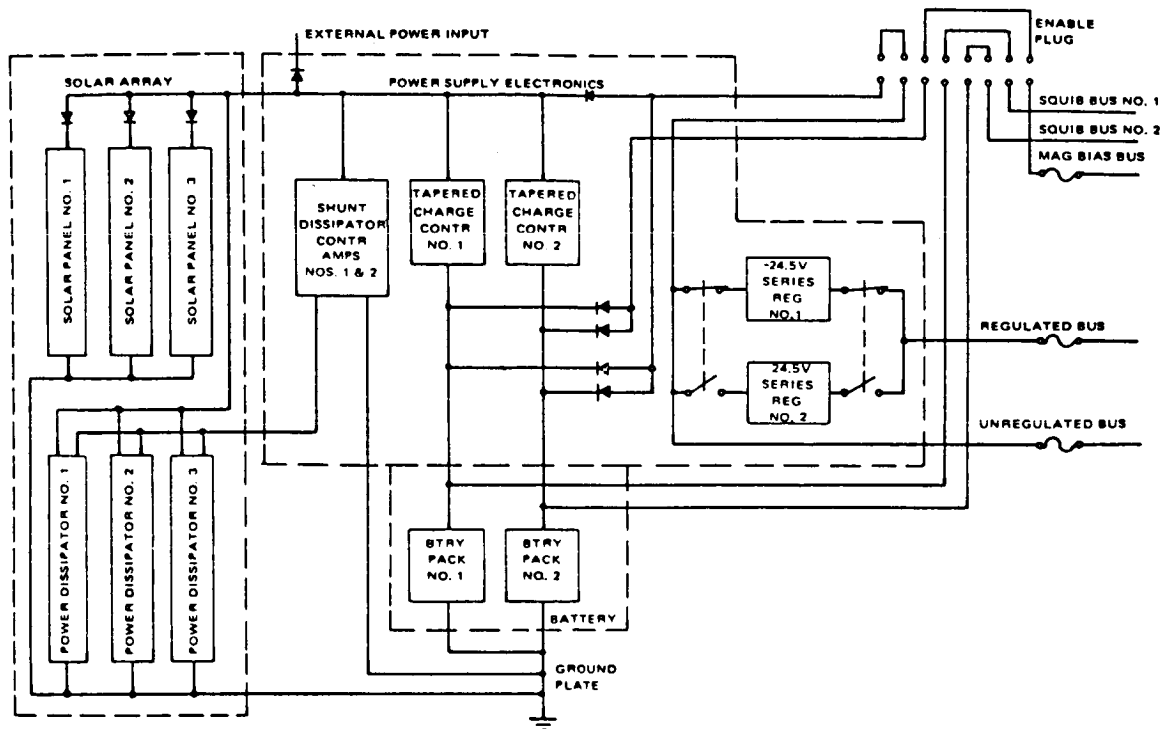


Figure 1. ITOS Power Supply Subsystem Block Diagram

CONTRACTORS	SPACECRAFT: RCA/AED
	CELL: GE
BATTERIES PER SPACECRAFT	2
CELLS PER BATTERY	23
STORAGE CAPACITY	6 AMPERE-HOURS
WEIGHT (PER BATTERY)	9.08 Kg
CHARGE CONTROL METHOD	TAPER CHARGING WITH VOLTAGE AND TEMPERATURE CONTROL
OPERATING TEMPERATURE	10° TO 35° C
CHARGE RATE	C/4 (1.5A) PER BATTERY (MAXIMUM) TAPER CHARGE RATE DETERMINED BY BATTERY VOLTAGE TEMPERATURE C/40 TRICKLE CHARGE VIA GROUND COMMAND
DEPTH OF DISCHARGE	24 PERCENT MAXIMUM 15 PERCENT NOMINAL

Figure 2. ITOS Battery Design

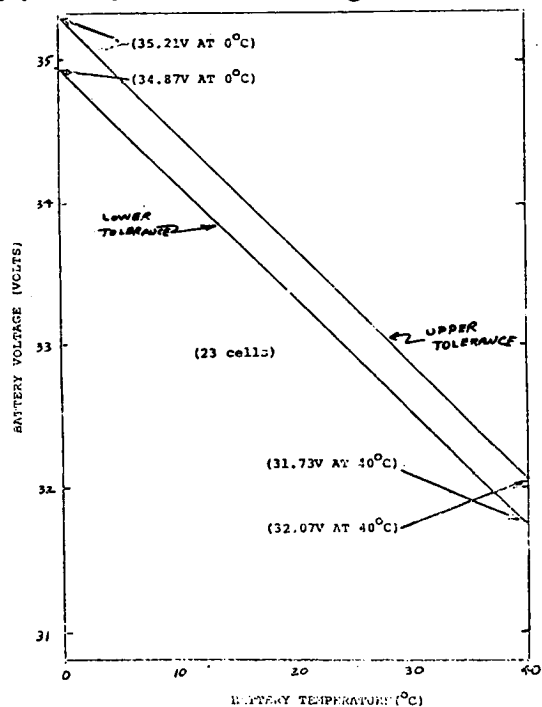


Figure 3. ITOS Voltage Limit Versus Temperature

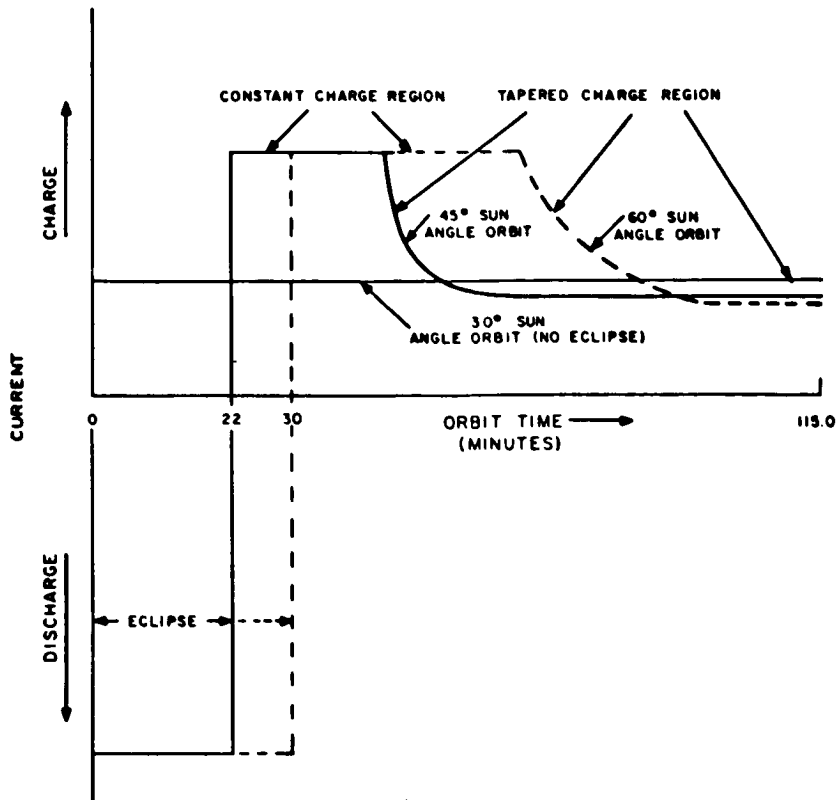


Figure 4. Battery Charge-Discharge Current Profile Over an Orbit Period

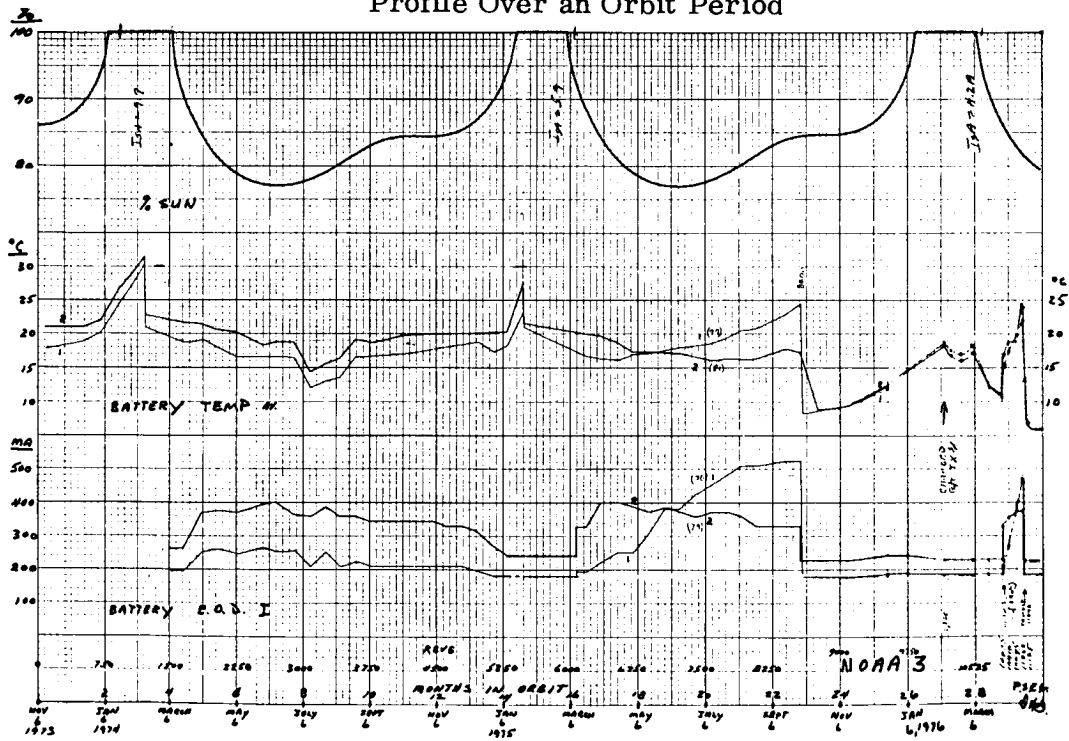


Figure 5

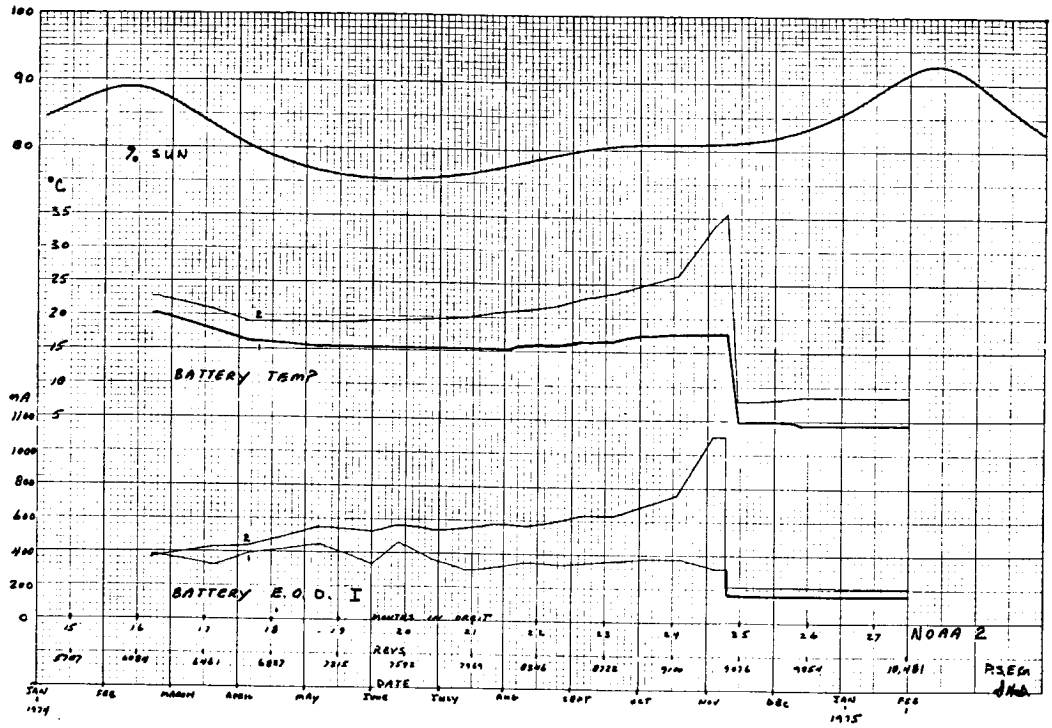


Figure 6

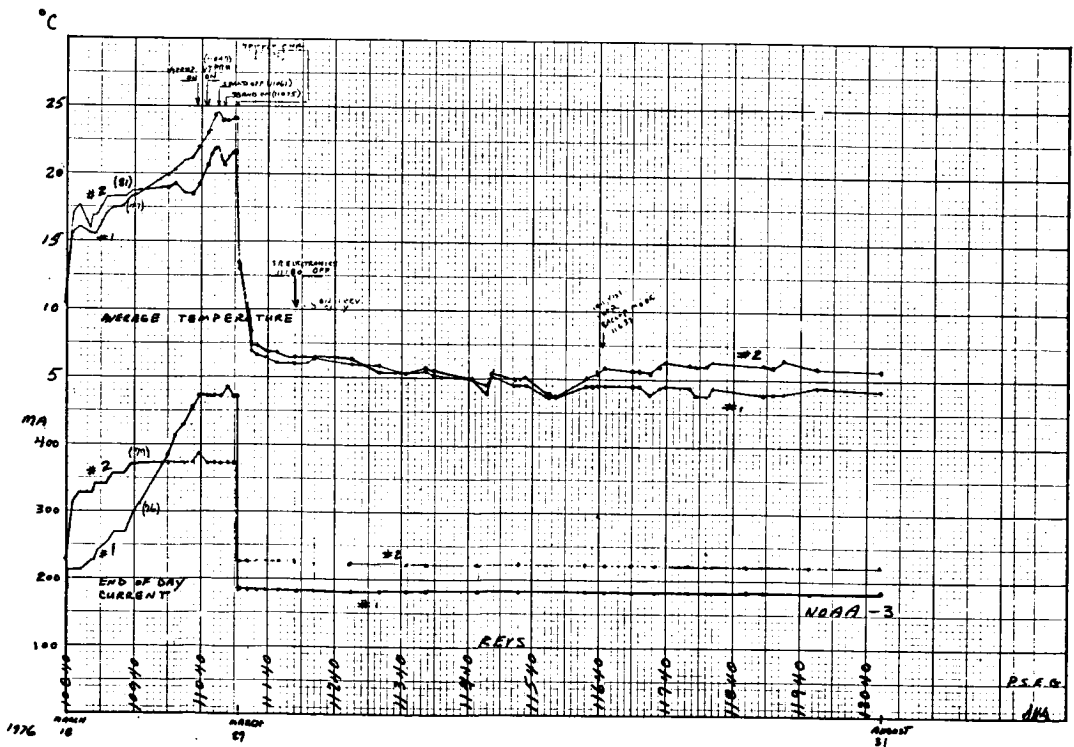


Figure 7