DEEP RECONDITIONING OF BATTERIES DURING DSCS III FLIGHT OPERATIONS*

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ABSTRACT

Deep reconditioning of batteries was defined at the 1982 Workshop as "discharge below the 1.0 volt/cell level to a value of about 1.0 volt/battery". This type of reconditioning was investigated for use on the Defense Satellite Communications System (DSCS) Spacecraft, and has been used during the first year of orbital operation. Prior to launch of the spacecraft, the deep reconditioning was used during the battery life test, which has now completed fourteen eclipse periods. Reconditioning was performed prior to each eclipse period of the life test, and is scheduled to be used prior to each eclipse period in orbit. The battery data for discharge and recharge is presented for one of the life test reconditioning cycles, and for each of the three batteries during the reconditioning cycles between eclipse period #1 and eclipse period #2 in earth orbit.

INTRODUCTION

During the 1982 Goddard Space Flight Center Battery Workshop, battery reconditioning was the subject of Session IV. The panel presented four aspects of reconditioning:

- Deep Reconditioning - discharging lower than 1.0 volts per cell with a resistor across a battery.
- Deep Reconditioning - discharging lower than 1.0 volts per cell with resistor across each cell.
- Cost versus benefits.
- Effect of reconditioning on the nickel electrode .

In 1981, we presented a progress report of the DSCS III battery life test, which included the reconditioning procedure. The DSCS III power subsystem includes a reconditioning circuit for each of the three batteries. By command, each of the batteries can be disconnected from its charge regulator and connected across a single reconditioning resistor. The resistor is sized to limit the discharge current to the one hundred hour rate for a fully charged battery. When the battery voltage drops to 18 volts (1.125 volts per cell), a second resistor is automatically added to the discharge circuit, to limit the discharge current to about the two hundred and fifty hour rate. The discharge is terminated by command when the battery voltage is lower than four volts.

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This procedure is in the category of "deep reconditioning" as discussed in the 1982 workshop.

LIFE TEST RECONDITIONING DATA

Before examining the flight data, we will review a typical reconditioning cycle from the life test. Figure 1 is data for the discharge and recharge performed between eclipse periods five and six. Battery voltage and current are plotted versus time. The time for discharge is 225 hours (between 9 and 10 days), and the time for recharge is about two days. We budget two weeks for a reconditioning cycle. At the start of battery discharge, the current is .35 amperes, the c/100 rate for the 35 ampere hour battery, and the battery voltage is 21 volts, 1.313 volts per cell for the 16 cell battery. After about 112 hours, the battery voltage has dropped to 18 volts and the discharge current is automatically reduced to .13 amperes, the c/270 rate. The discharge was allowed to continue until the battery voltage dropped to approximately 1.0 volts. At that time, the current had reduced to about 10 milliamps. We have annotated the time when the first cell went into reversal, at about 125 hours, at which time the discharge current was .12 amperes or about the c/300 rate.

In the life test, the battery is recharged by constant current at 2.8 amperes, with the voltage limit at 1.40 volts per cell for the 20°C temperature. After approximately five hours, the battery voltage reaches the limit, the current tapers and reaches steady state at approximately 36 hours.

FLIGHT RECONDITIONING DATA

The DSCS III electrical power subsystem includes three 16 cell, thirty five ampere hour nickel cadmium batteries. Each battery has a dedicated charge regulator and reconditioning circuit. Figure 2 is data for the reconditioning cycle for battery #1 between eclipse period #1 and #2. The time, voltage and current scales are identical to the scales used for the Figure 1 life test plot. The discharge current is not plotted because the discharge current telemetry is not calibrated below 0.5 amperes. However, the temperature is plotted. The automatic switch from high current to low current came at 109 hours, so we can conclude that the battery capacity was about 37 ampere hours, the same as the life test battery. The battery temperature can be seen to remain stable at about 3°C. The discharge was terminated when the battery voltage reached 4.0 volts.

In orbit, the battery is switched from reconditioning discharge to charge by command. When the charge regulator is turned on, it automatically is in the lower current limit mode, and after the battery voltage reaches 16 volts, a command is given to switch to the high current limit mode. The rise to 16 volts occurred within one minute, and so Figure 2 shows an instant rise to 4.65 amperes charge and 21.9 volts. The initial drop-off of charge current is due to rise in battery voltage. After about 13 hours, the battery reached the temperature compensated voltage limit and went into taper charge. Finally, the battery charge current returned to the stable 0.2 ampere charge.

The reconditioning data for battery #1 is very similar to the life test data, and when we look at Figures 3 and 4, the data for batteries 2 and 3 respectively, these data are also very similar. Battery #1 data for DSCS A-1 differs slightly from batteries #2 and #3 in general, because there is an eighteen month difference in the age of the cells.

SUMMARY

Based on the life test data and the flight data, we have confidence that deep discharge reconditioning is beneficial. A comparison of flight A-1 eclipse period #1 data, which was not proceeded with a reconditioning cycle, with eclipse period #2 data, which was proceeded with a reconditioning cycle, is shown in Table 1.

Table 1.

	BTRY #	ECLIPSE PERIOD #1	ECLIPSE PERIOD #2
Max Depth of Discharge	1	54%	58%
	2	51%	53%
	3	53%	57%
Min. Battery Voltage	1	18.6	18.7
	2	18.7	18.8
	3	18.7	18.7

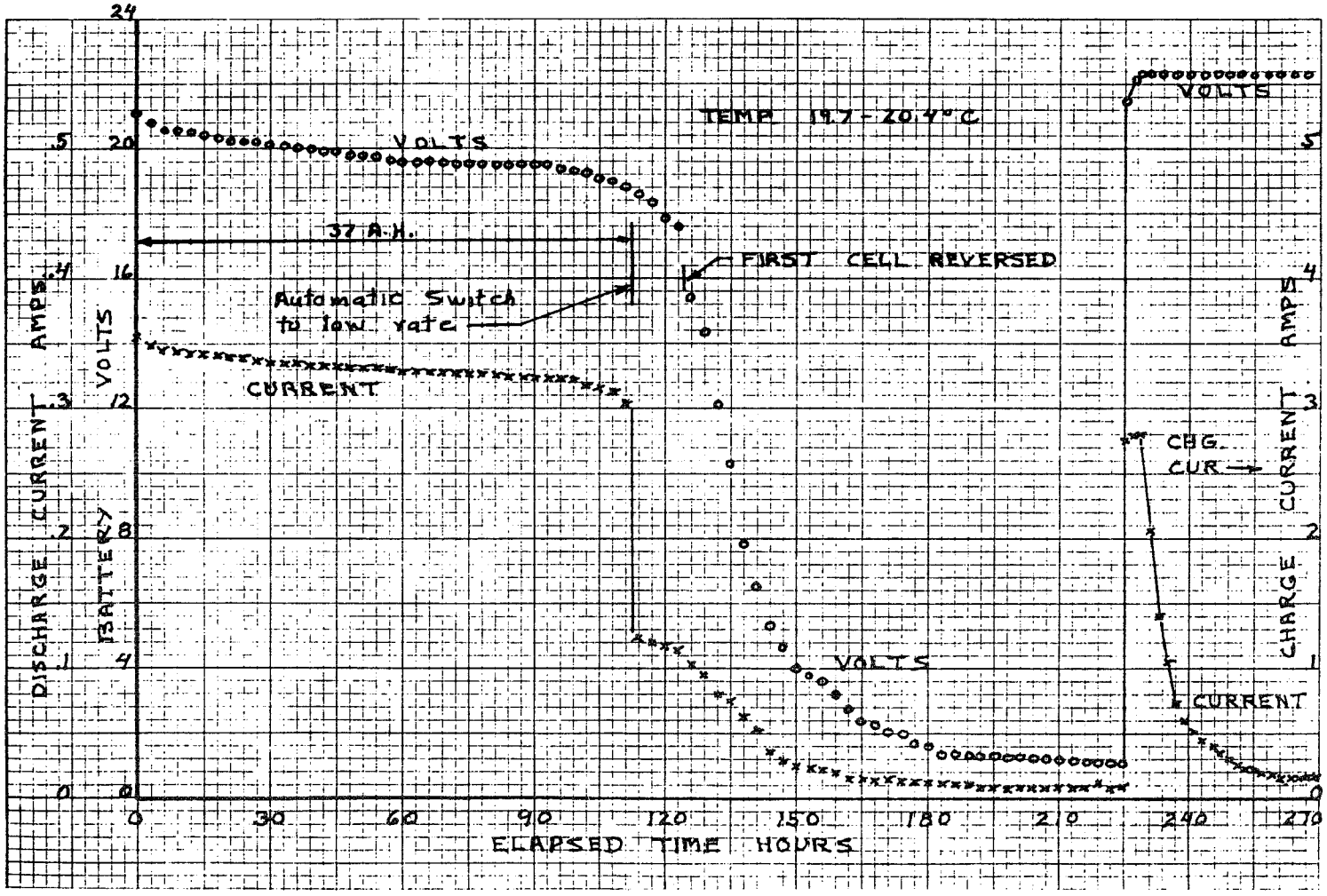

Figure 1. DSCS III Life Test Battery Reconditioning After Eclipse Period No. 5

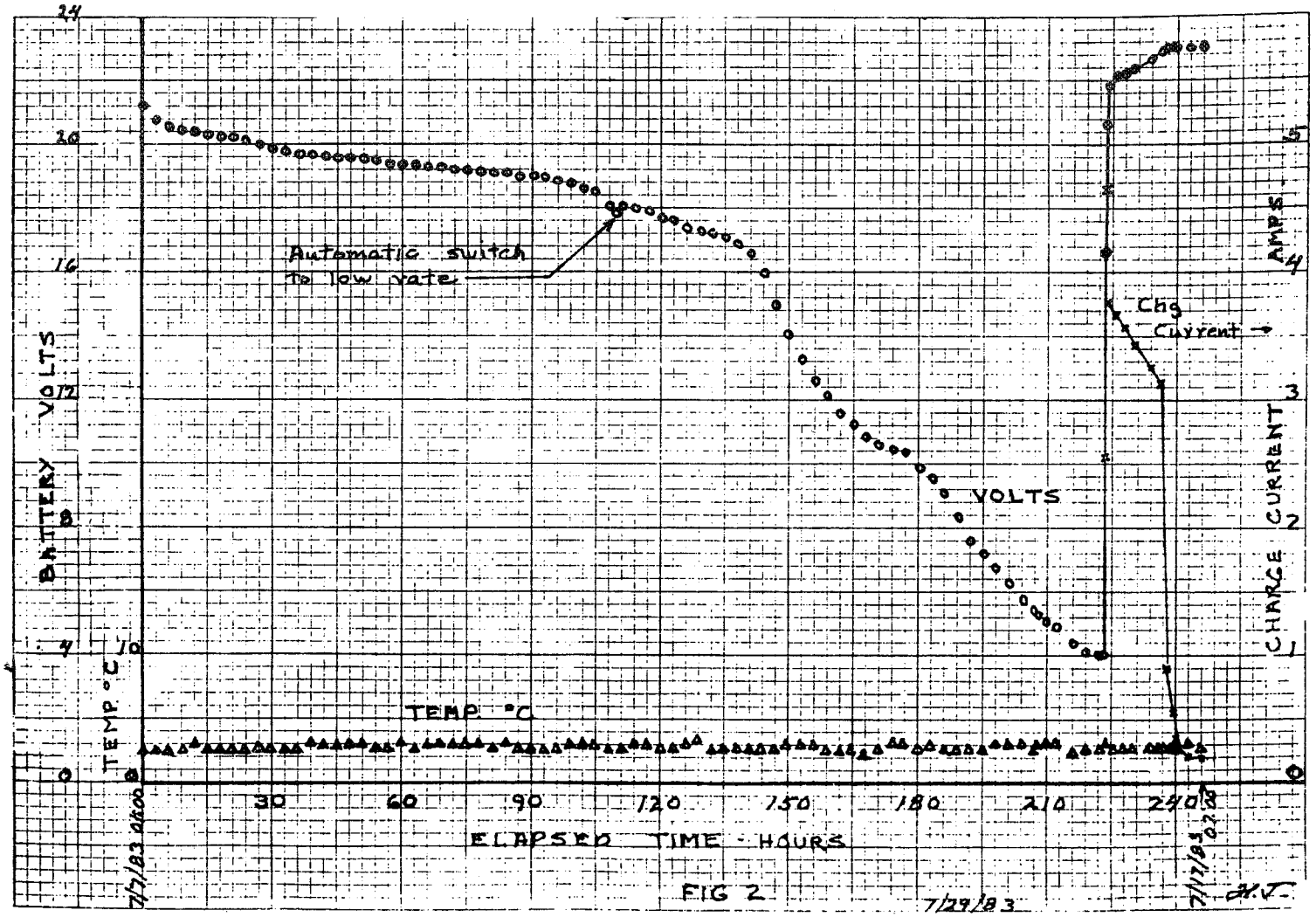

Figure 2. OSCS III A-1 Battery No. 1 (19) Reconditioning 7/7/83 0100 to 7/17/83 0700

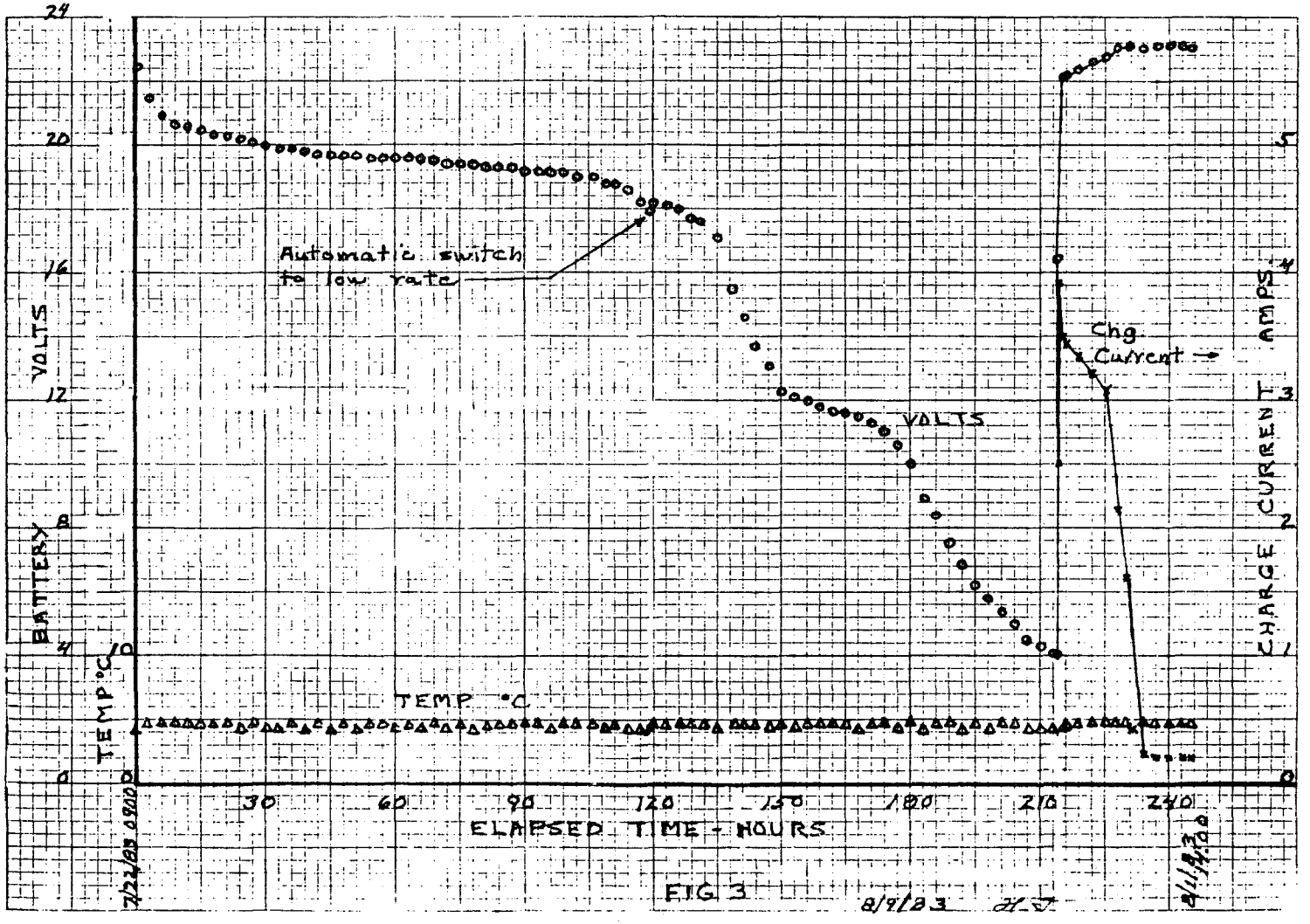

Figure 3. DSCS III A-1 Battery No. 2 (24) Reconditioning 7/22/83 0900 to 8/1/83 1400

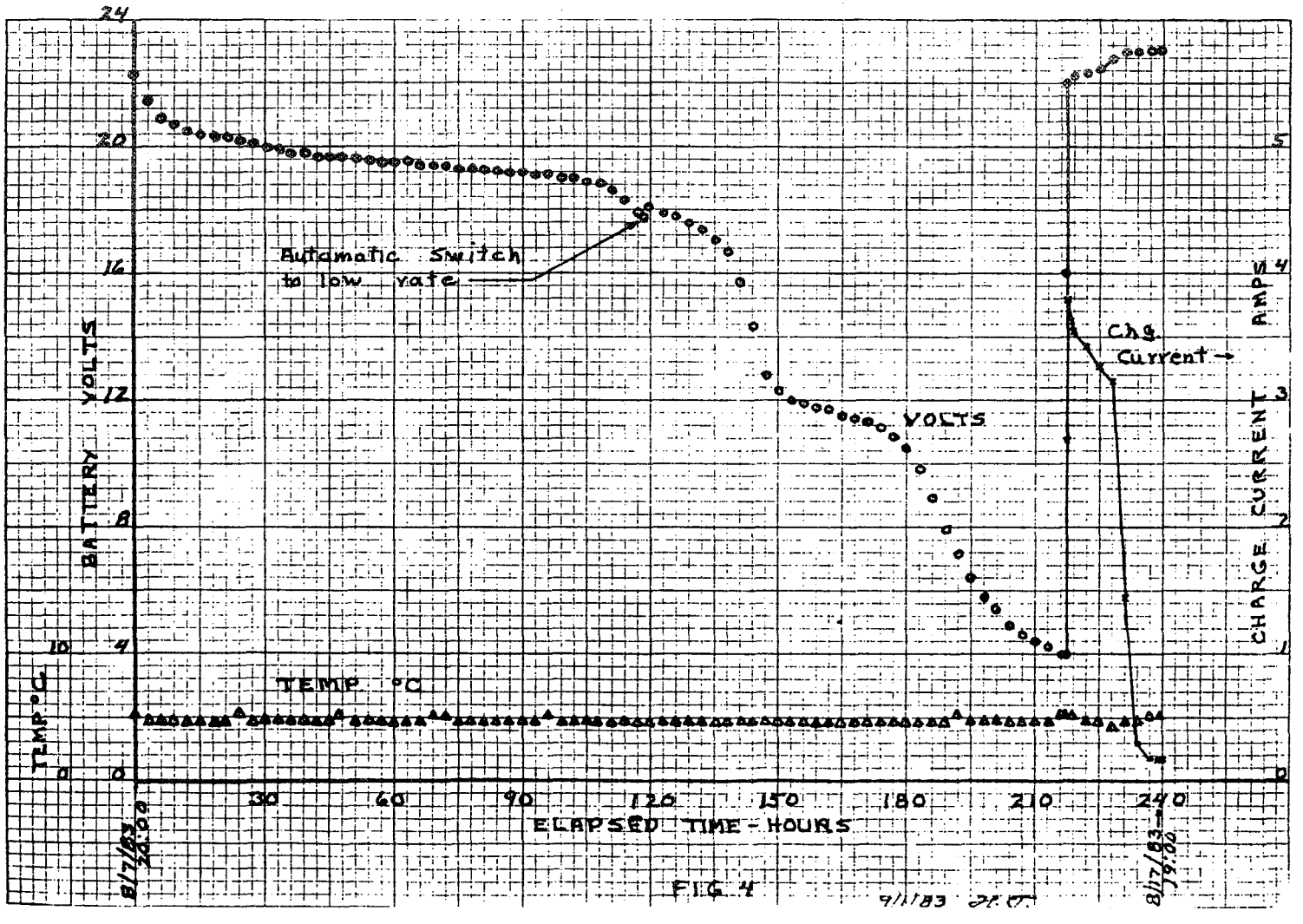

Figure 4. DSCS A-1 Battery 3 (25) Reconditioning 8/7/83 2000 to 8/17/83 1900