EMU BATTERY/MODULE SERVICE

TOOL CHARACTERIZATION STUDY

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ABSTRACT

The power tool which will be used to replace the attitude control system in the SMM spacecraft is being modified to operate from a self contained battery. The extravehicular mobility unit (EMU) battery was tested for the power tool application.

The results obtained during this study show the EMU battery is capable of operating the power tool within the pulse current range of 2.0 to 15.0 amperes and battery temperature range of -10 to 40 degrees Celsius.

INTRODUCTION

The Solar Maximum Mission (SMM) spacecraft was launched February 14, 1980. The attitude control system (ACS) has developed problems which have effected the normal spacecraft operation. During the shuttle mission (STS 13) scheduled April, 1984 the ACS will be replaced while the spacecraft is attached to the "flight support system" located in the cargo bay of the shuttle.

A power tool (Figure 1) has been designed and developed to operate from the alternating current (AC) power bus in the shuttle and therefore the area in which the tool can operate is limited. A direct current (DC) motor is being designed to operate from a battery contained in the tool, thereby allowing the power tool to operate independent of the shuttle's power bus.

Figure 2 shows the Extravehicular Mobility Unit (EMU) battery which is used by the astronauts during EVA maneuvers. The size, weight (4.35 Kg) and nominal capacity (25 Ah) of this silver-zinc battery is compatible with the power tool application. The battery is presently required to support one 15 amp pulse for 5 seconds and seven hours of continuous operation at 3.5 amperes (Reference 1) at the minimum battery temperature of 4.4 degrees Celsius (Reference 2), whereas the gearmotor of the power tool will introduce numerous high pulse current loads to the battery during initiation of removing the bolts from the ACS, which requires a high torque capability from the power tool.

There were no data available to define the EMU batteries' minimum operating temperature required to support the high current for the power tool application in the thermal environment of outerspace, and therefore it was necessary to perform this characterization study of the EMU battery as shown in Figure 3.

TEST PHILOSOPHY

In order to determine the temperature range in which the battery could operate for the power tool application, it was necessary to establish discharge voltage profiles at various pulse current loads and temperature levels to a 100 percent depth of discharge (DOD). The 3.5 ampere constant current drain for the EMU regime was used to simulate the power tool "full speed" current drain and the battery's maximum pulse current capability of 15 amperes for a 5 second duration was used to simulate the gear motors "stall time" current load. Figure 4 is a plot of the typical discharge profile used throughout this study. The battery was discharged at 3.5 amperes and pulsed at 15 amperes every other minute. At minute 59 of each hour the battery was sequentially pulsed at seven different current levels (2.0 to 14.0 amperes). Battery current, voltage and temperature data was monitored every minute, three times during each pulse current level, and one second after the completion of each pulse regime. In order to prevent cell reversal, each discharge was terminated (voltage cutout) when the voltage decreased to 12.0 volts.

Although the power tool application will not require "battery recharging" during the shuttle mission, this battery was recharged many times during the study. Battery charging was performed according to the EMU specifications (Reference 1), 1.5 amperes and 21.8 volt cutout at 20°C or at 1.0 amperes. Two different charge currents were used to allow sufficient time for the battery temperature to stabilize at the next successive discharge regime (approximately one hour per Δt of 10°C). The data were monitored every ten minutes.

EMU DISCHARGE CHARACTERIZATION TESTS

The first discharge (cycle 1) was performed at 20°C ambient temperature in order to establish the baseline voltage characteristics and battery capacity after the 7 month stand period, since the 3 previous cycles and recharge were accomplished at room temperature ambient. The capacity output was substantially greater than the pre-shipping recharge capacity because the battery had not been discharged to 100% DOD during the initial 3 cycles. Figure 5 is a plot of the entire discharge and Figure 6 shows the first sequential pulse regime during this discharge.

There was a significant decrease in battery voltage during the 0°C discharge and a severe decrease of -10°C (Figure 7). There was also a decrease in discharge capacity at the lower temperatures due to the inefficiency of the electro-chemical reactions within the battery cells. The battery voltage was slightly above 15 volts at the end of the first sequential pulse (Figure 8).

There was very little change in the battery voltage between the steady state load and pulse current load during the 40°C discharge shown in (Figure 9) which occurred during the seventh discharge of this test regime. The higher battery voltage which was evidenced at the beginning of this discharge is attributed to Ag_2O_2 which gradually increased during the extensive cycling regime rather, than the higher test temperature.

CONCLUSIONS

The battery is capable of operating the power tool within the pulse current range of 2.0 amperes to 15.0 amperes and battery temperature range of -10°C to 40°C.

The "plateau" voltage which occurs when the silver electrodes are at the monovalent voltage level substantially decreases at the lower temperatures and higher pulse currents during the sequential pulse regime presented in Figure 10. The battery impedance ranged from 73 milliohms when battery temperature was 42°C and increased to 162 milliohms when battery temperature was -6.7°C. Figure 11 is a graph of the calculated battery impedance derived from the change in battery voltage (ΔV) which occurred at the various current levels during the sequential pulse regimes after the battery voltage stabilized at the monovalent potential.

Although the battery was capable of supporting numerous simulated "stall time/full speed" power tool operations at all temperature levels, the number of power tool operations will be reduced at sub zero temperatures if the power tool requires a higher operating voltage than the 12.0 volt cutout used to terminate all discharges throughout this study.

REFERENCES

1. "Space Shuttle Activation And Recharging Procedures For The Shuttle EMU & MMU Battery," Document JSC 11617 (Rev. A) February 11, 1982.

2. "Battery Manufacturing Control Document 04236," Martin Marietta Corporation.

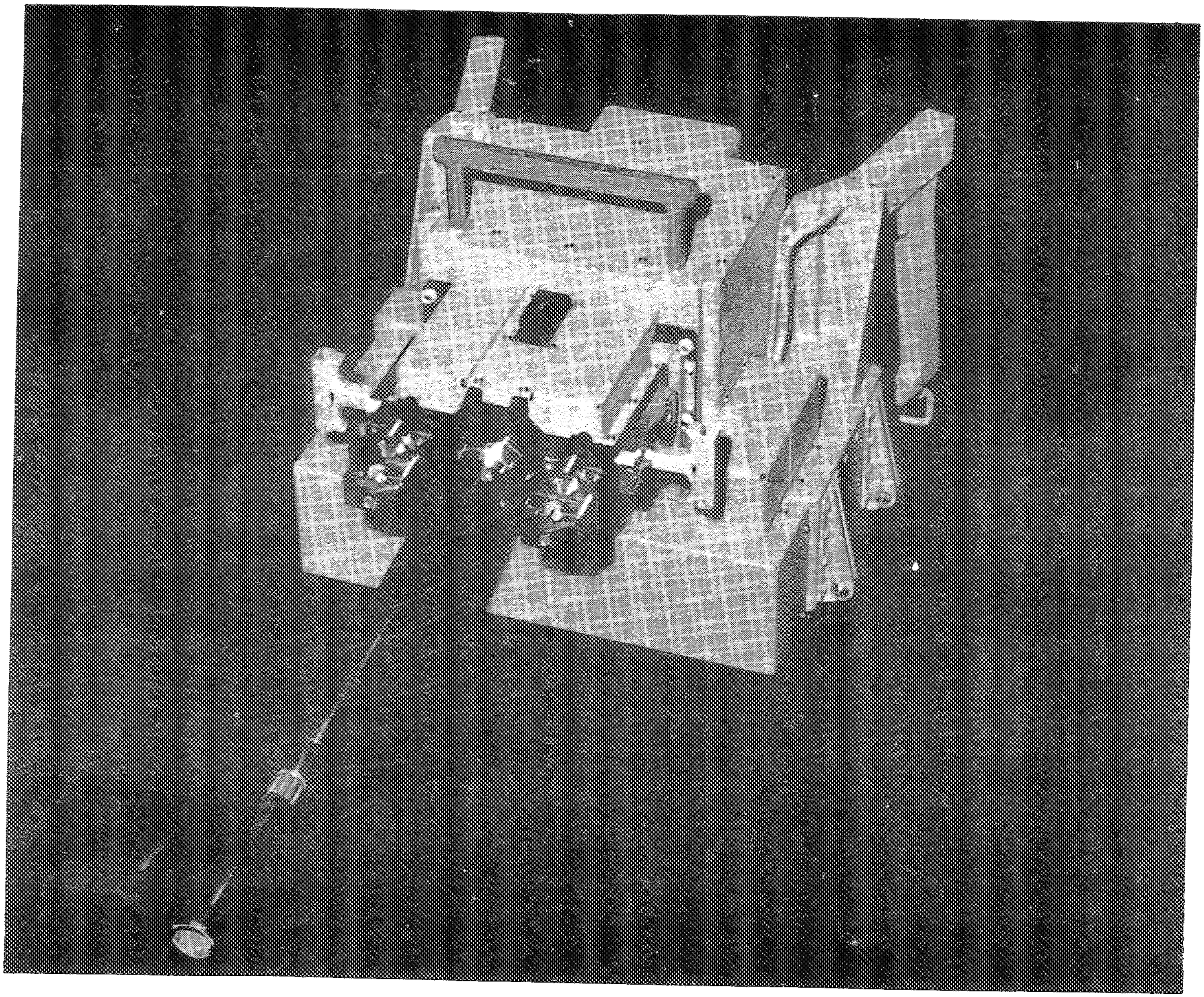


Figure 1. Module service tool.

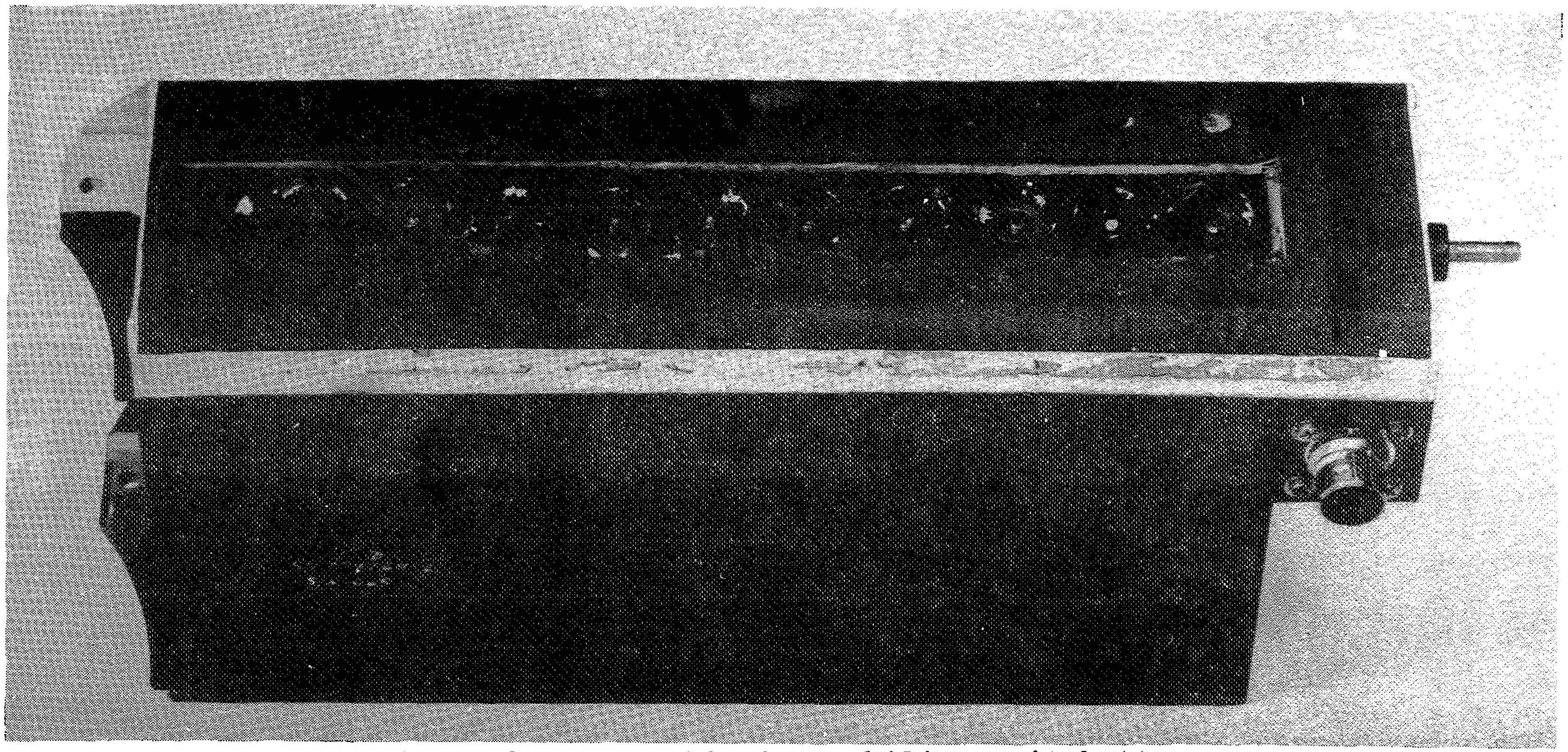


Figure 2. Extravehicular mobility unit battery.

EMU BATTERY/SMM POWER TOOL CHARACTERIZATION STUDY

PURPOSE

- DETERMINE TEMPERATURE RANGE FOR BATTERY OPERATION WITHOUT HEATERS
- ESTABLISH VOLTAGE PROFILES AT VARIOUS PULSE CURRENT LOADS AND TEMPERATURE LEVELS
- CHARACTERIZATION OF BATTERY IMPEDANCE FOR EACH TEMPERATURE LEVEL
- DETERMINE BATTERY DISCHARGE CAPACITY AND EFFICIENCY AS A FUNCTION OF TEMPERATURE

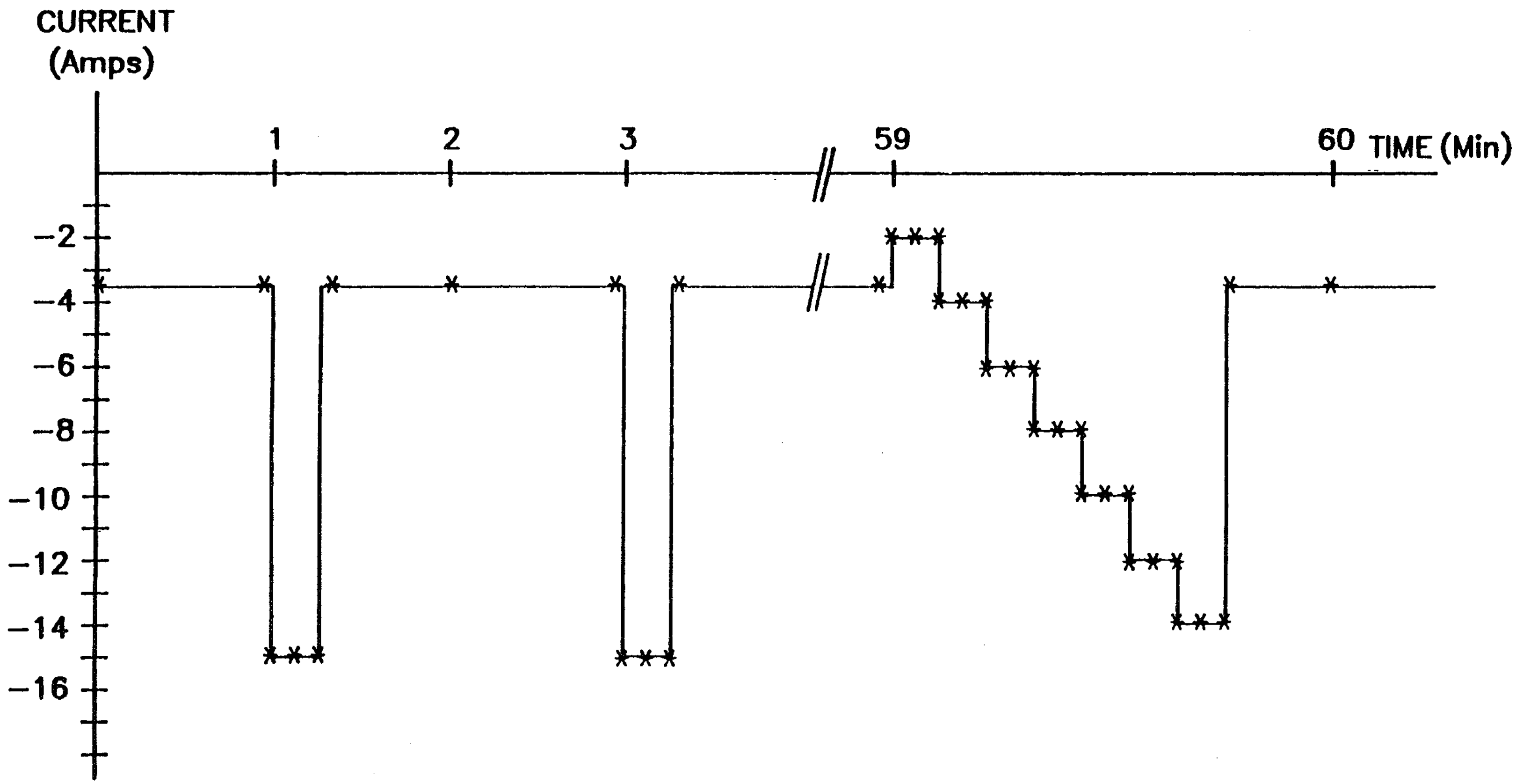
TEST PARAMETERS

- BATTERY CHARGING AT 20°C AND 1.0 OR 1.5 AMPS
- 3.5 AMP CONSTANT CURRENT LOAD (POWER TOOL FULL SPEED LOAD)
- 15.0 AMP, 5 SECOND PULSE LOAD (POWER TOOL STALL LOAD)
- SEQUENTIAL PULSE REGIME (2.0 TO 14.0 AMPS, 5 SECOND DURATIONS)
- 100% DOD AT -10°C TO 40°C (10 DEGREE INCREMENTS)

Figure 3. Characterization study profile.

EMU BATTERY / SMM POWER TOOL CHARACTERIZATION TEST

DISCHARGE PROFILE



NOTE: * indicates readings taken at this point

Figure 4. Typical discharge profile.

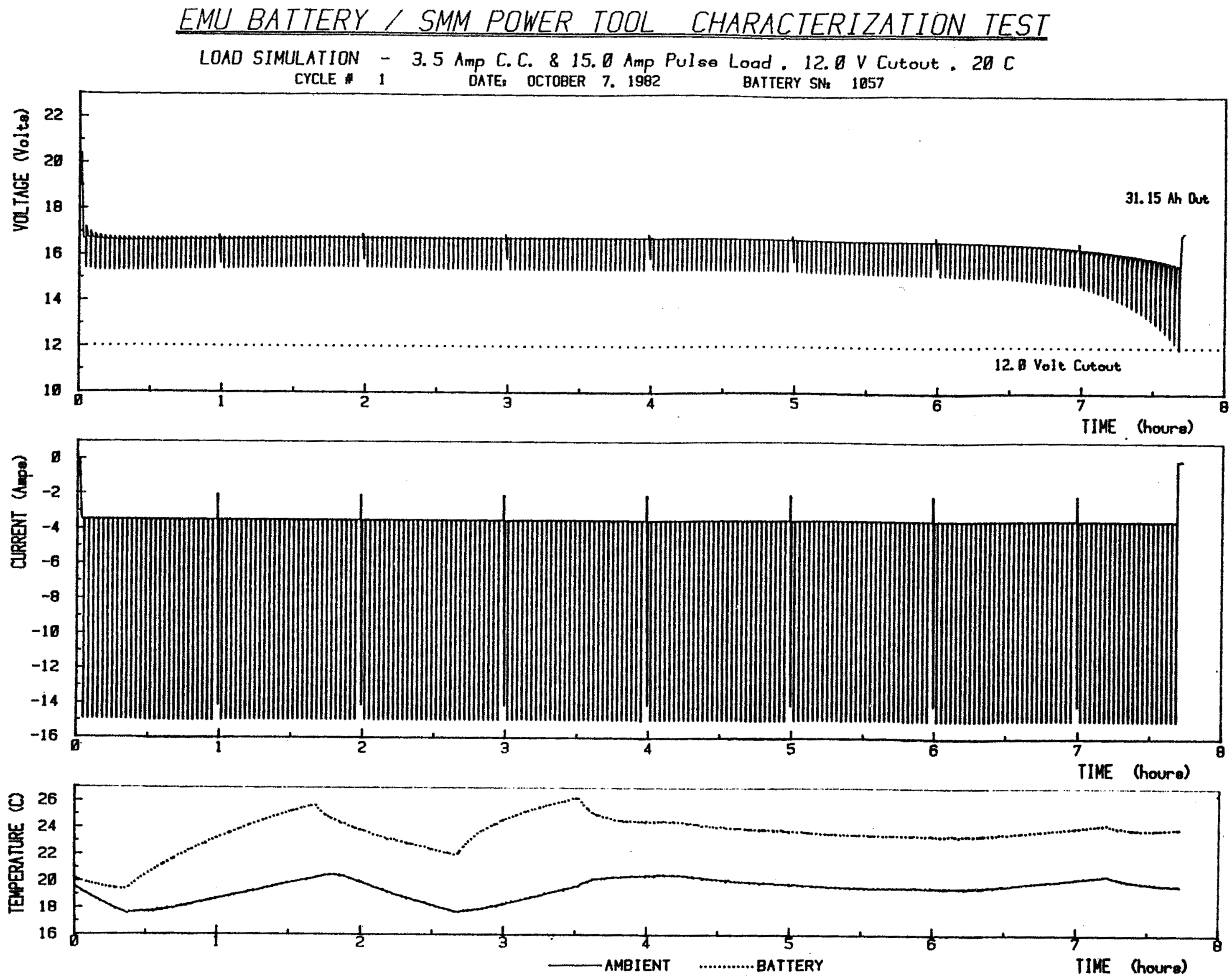


Figure 5. 20°C discharge characterization test.

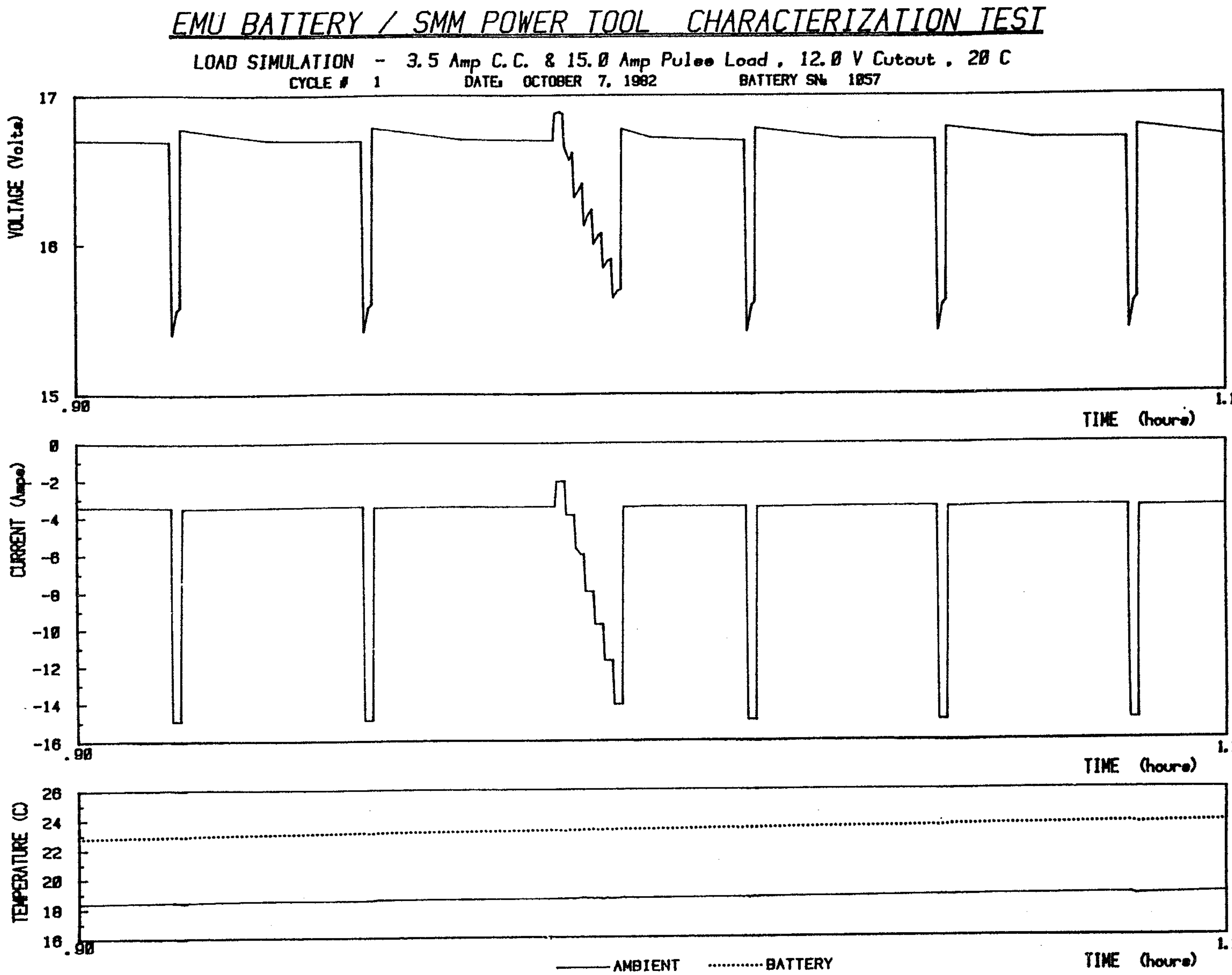


Figure 6. First sequential pulse regime at 20°C.

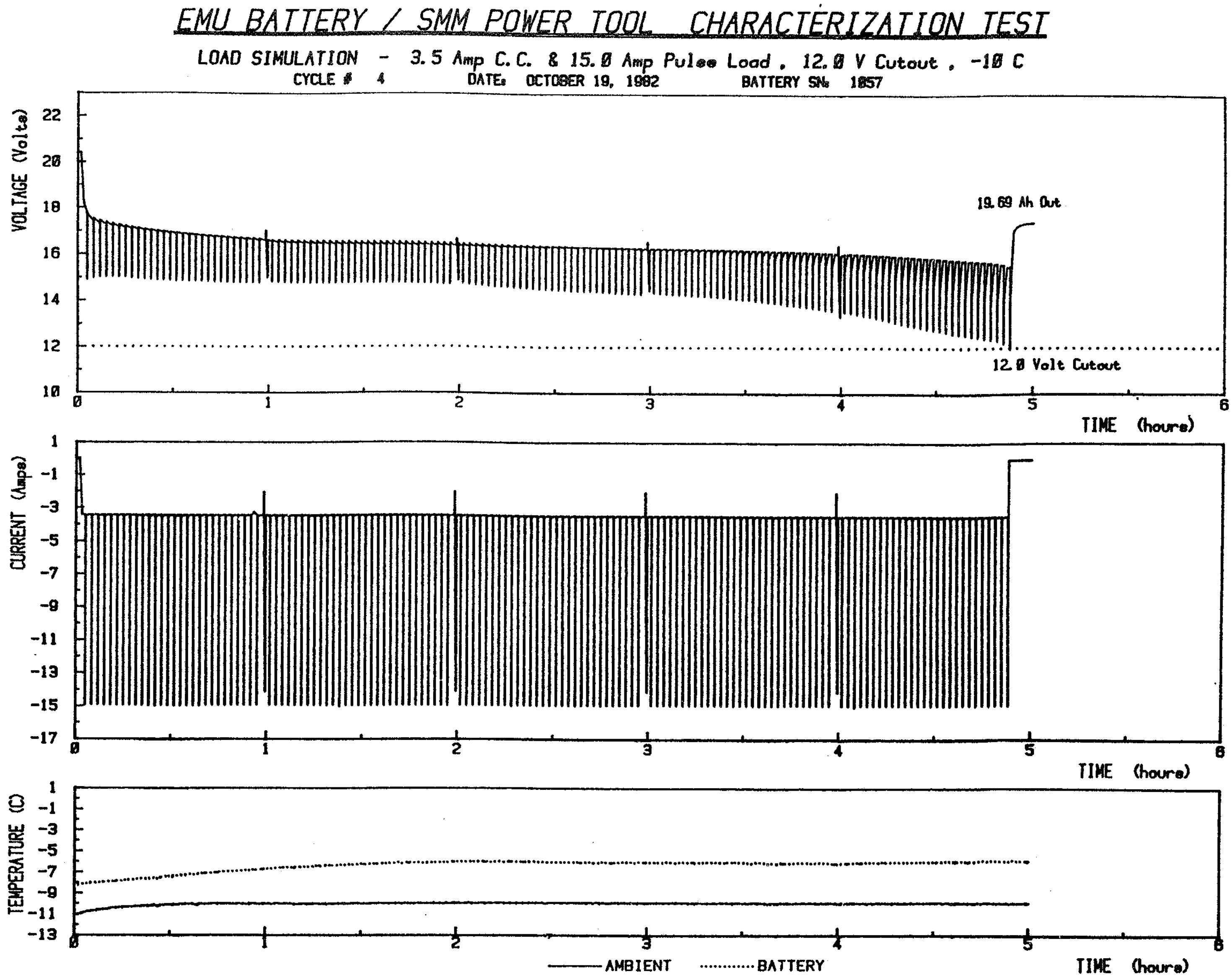


Figure 7. $-10^{o}C$ discharge characterization test.

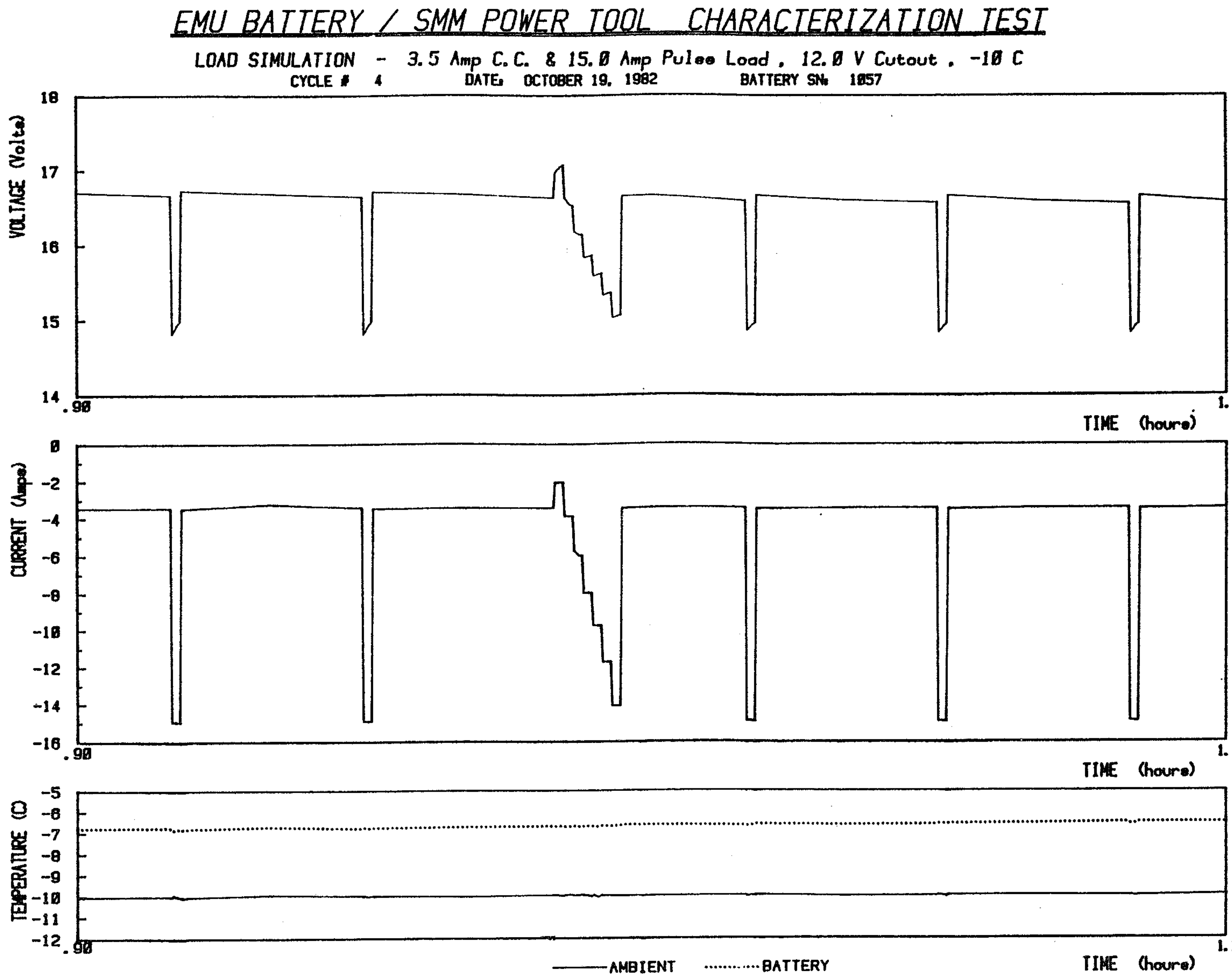


Figure 8. First sequential pulse regime at -10°C.

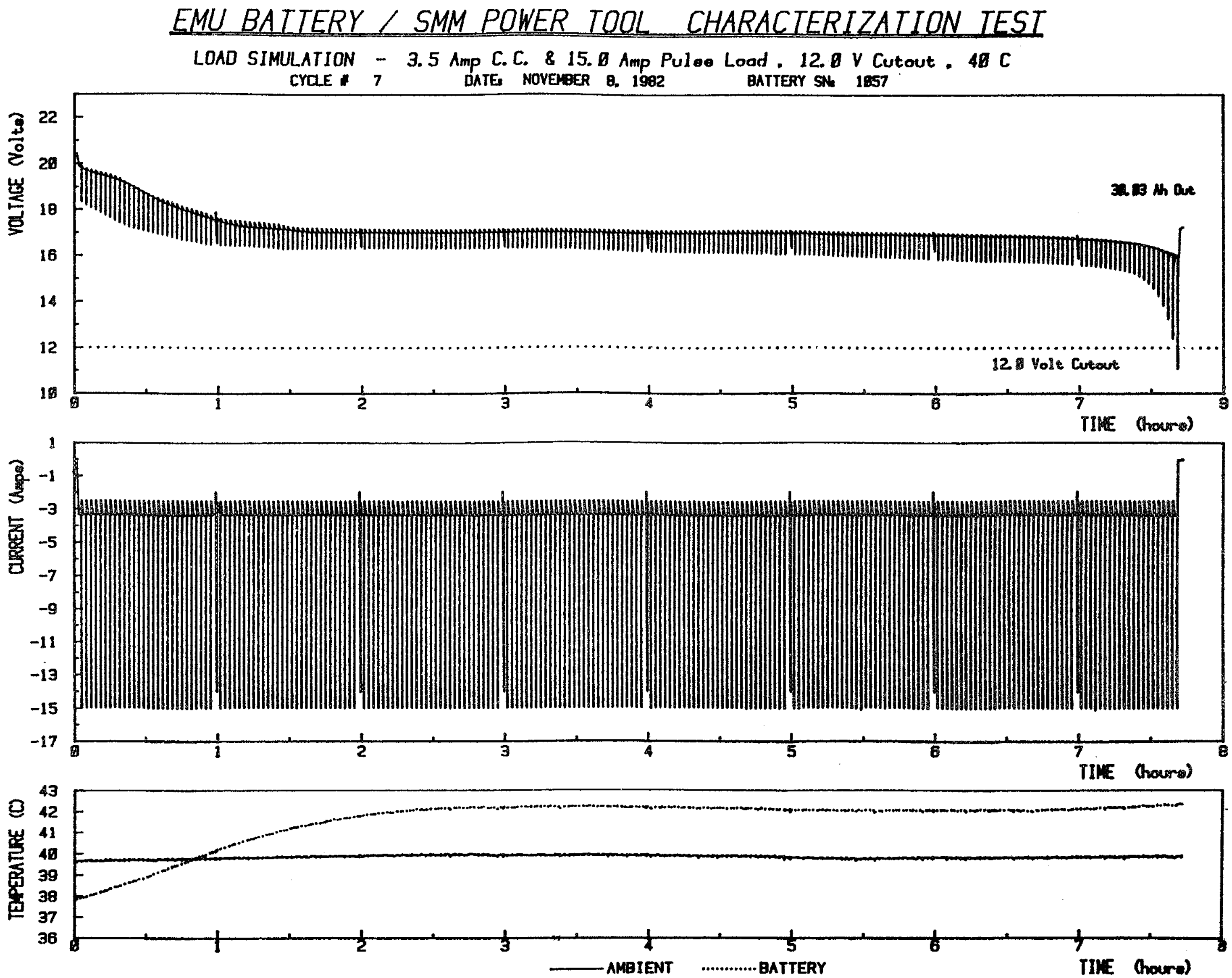


Figure 9. 40°C discharge characterization test.

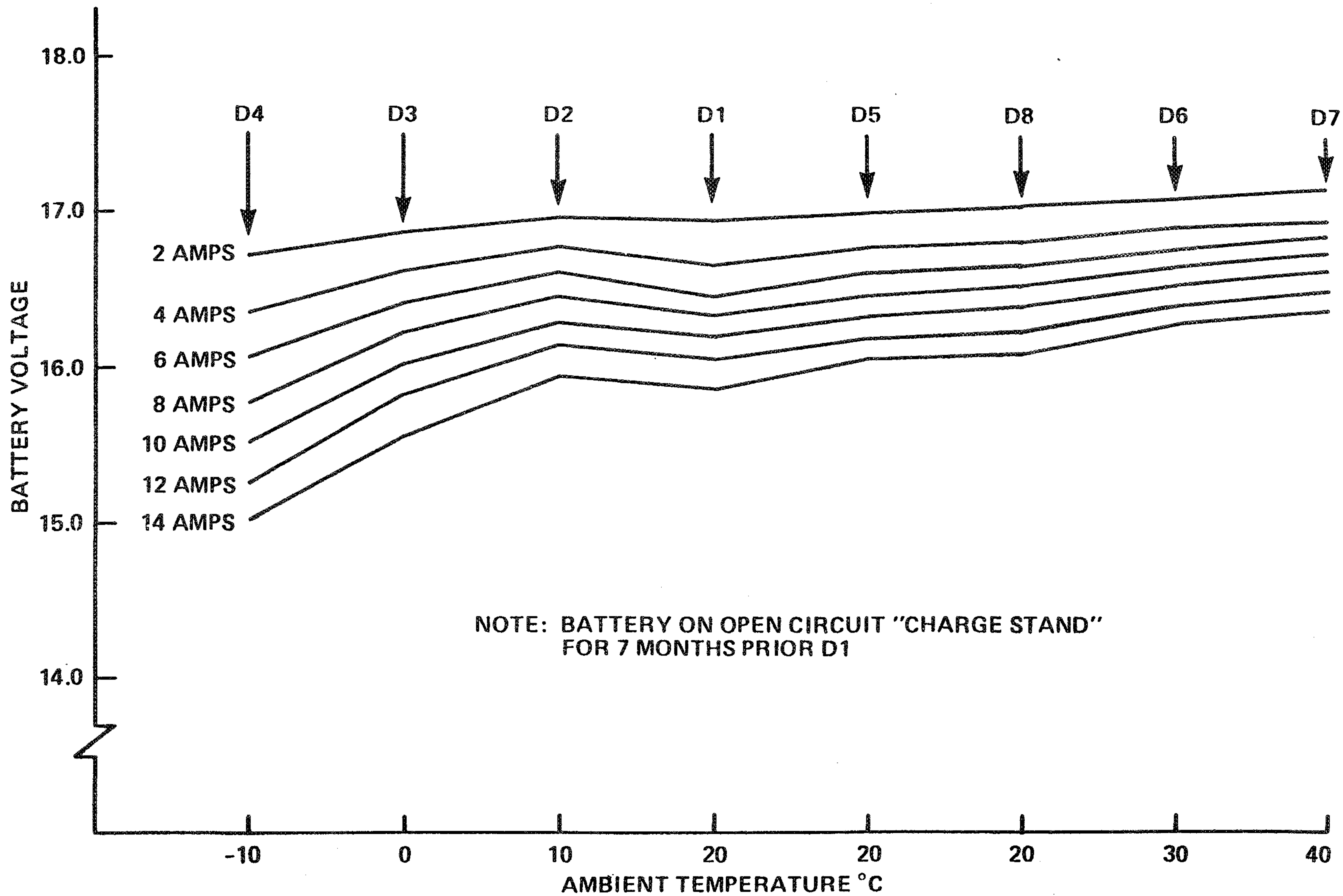


Figure 10. Plateau voltage vs. temperature during sequential pulsing.

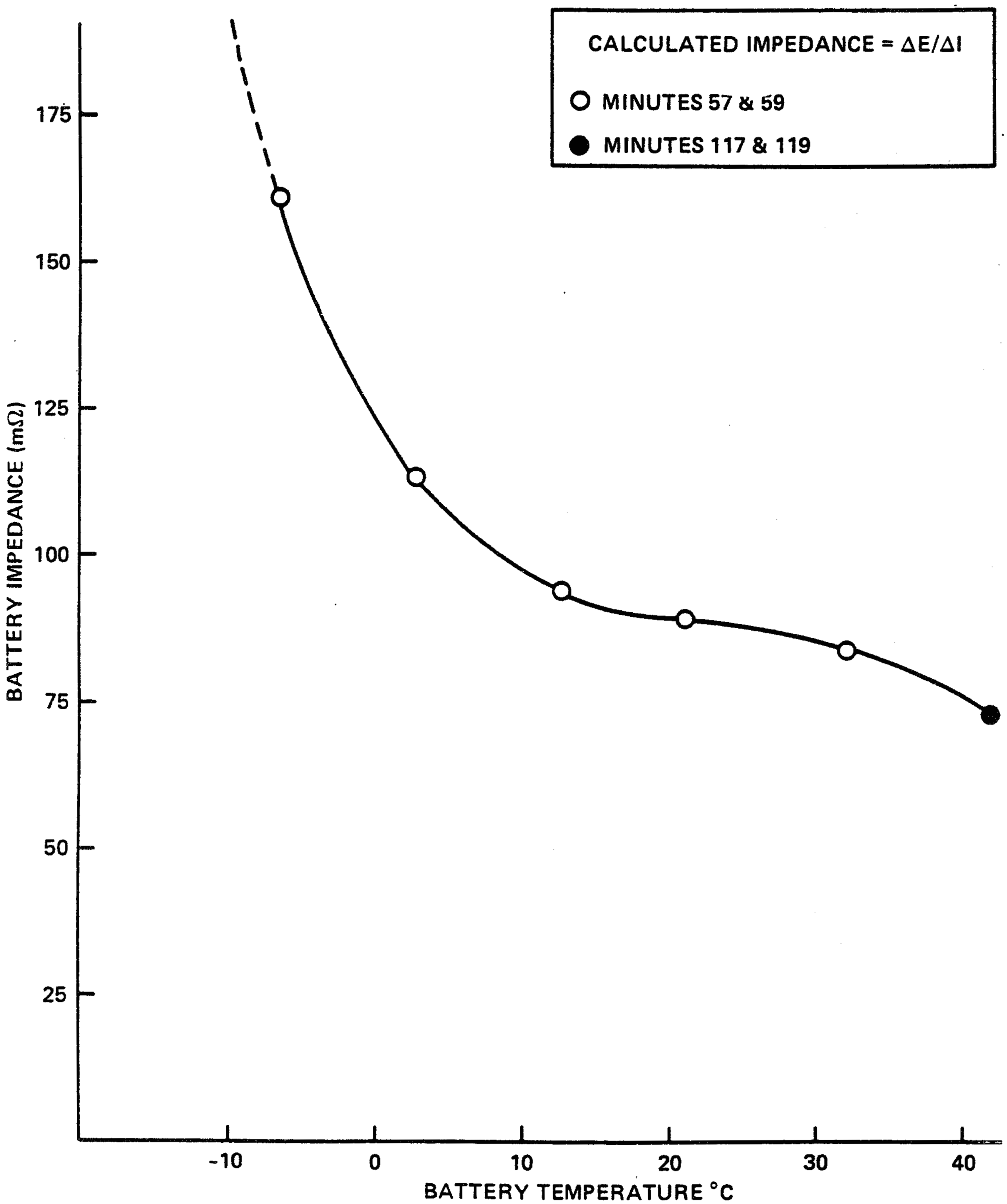


Figure 11. Battery impedance vs. temperature.