BATTERY DEFINITION FOR THE MARS ENVIRONMENTAL. SURVEY MISSION (MESUR) PATHFINDER

S. Dawson, D. Perrone, B. Otzinger, S. Di Stefano
Jet Propulsion Laboratory
California Institute of '1'ethnology
Pasadena CA 91109

Abstract

Silver Zinc (Ag-Zn) battery technology has been baselined as the energy . storage system for the MESUR mission. The mission profile will require the operation of this battery in a manner not usually seen for this technology. In particular, the combination of storage time followed by multiple cycles as a function of fluctuating temperatures and charge/discharge rates, and limited available time for charging has not been previously demonstrated. This paper describes ground testing designed to evaluate this technology under the proposed mission profile. Wc also present initial results of these tests. Preliminary results of testing (which do not yet take into account the effect of storage) indicate that a modified constant potential method of charging will be able to maintain energy balance during operation on the surface of Mars.

Introduction

The Pathfinder Mars Environmental Survey Mission (MESUR-Pathfinder) is the first of NASA's low cost discovery missions. The purpose of this mission is to demonstrate a low cost spacecraft that can sustain the cruise, direct entry, descent, and landing on the surface of Mars and operate for onc to twelve months while conducting engineering assessments and science investigations. The results of this mission will be used to enhance the Success of follow-on missions which arc designed to place a network of landers on the Martian surface. launch is scheduled for the two week 1996 window with a 1997 Mars landing. The technical requirements (which must be consistent with a low cost approach) make this a challenging mission. In particular, the preliminary design of the Power and Pyrotechnic Subsystem (PPS) calls for a direct energy transfer system which will usc two solar arrays, onc for the cruise portion of the mission and onc for operation on the Martian surface, a power distribution system with heritage from recent JPL missions and a secondary silver-zinc (Ag-Zn) battery enhanced by thermal batteries during the Mars entry, descent and landing (EDL) pyro events. This paper will focus on a discussion of the Ag-Zn technology baselined for this mission. Although Ag-Zn technology has previously flown on other planetary missions, the requirements of this mission arc particularly demanding. A rough timeline for the battery consists of supplying power during launch (Delta launch vehicle), an approximate 8 month cruise with power support for two to three trajectory correction maneuvers (TCMs) and augmentation of the thermal batteries during the initial descent onto the Martian surface. Power will also be required from the Ag-Zn battery during the final landing phase of the mission and during the initial deployment on the first day. Subsequently the battery will be charged as power becomes available from the solar array. The battery cycling will consist of delivering ~ 10 - 20 AH of capacity during the night period when the battery temperature can dip to as low as -20°C and to replenish this energy during the daylight hours when the temperature is expected to climb to 20°C. The battery is expected to maintain this profile for a minimum of thirty days. To verify that this technology will meet the mission objectives, several characterization and verification ground tests arc underway. These tests arc being conducted on prototype cells which arc considered representative of the Ag-Zn technology. The variables being investigated arc the separation system, storage temperature, battery orientation and charge methodology; Preliminary results of tests currently underway indicate that the Ag-Zn system will meet the requirements. However, these preliminary results do not yet include the effect of the 8 month cruise or the battery orientation during launch.

Experimental

Specific battery requirements as well as a sizing analysis have been previously described[1]. Baseline electrochemical characterization is being performed on Ag-Zn cells of 40 ampere-hour nameplate capacity of available design (SZLR40-3). Table 1, summarizes the characterization tests that will be performed on these cells.

Ag-Zn CELL CHARACTERIZATION TESTING
INITIAL CYCLE LIFE
CHARGE / DISCHARGE CYCLE AT O°C
CHARGE / STAND CYCLE LIFE
8 Month Stand @ 15°C and 30"C with OCV and 1.86 V
CHARGE DEFINITION
MODIFIED CONSTANT POTENTIAL
V=1.910 V to 1.980V, I=4.5 A to 0.4 A, TEMP. 25°C to O"C
DISCHARGE CHARACTERISTICS
RATES-1.5A, 4.35 A, 12.5 A, 15 A,
TEMP. -40°C, -20°C, -10"C, O"C, 10"C
SYSTEM PERFORMANCE
PRE-LAUNCH, CRUISE-TCM, EDL, MARS SURFACE OPERATION

Table 1. Characterization tests to be performed on MESUR Ag-Zn cells.

Results and Discussion

Typical initial electrochemical performance of representative of this cell design is shown in Figures 1 and 2. This data was obtained on two four cell packs wired in series. Four cell packs arc subsequently allocated for further testing as outlined in 'Table 1. The features of the charge curves in Figure 1 arc dominated by the thermodynamics of the Ag-Zn system[2]. These consist of the initial charge at -1.63V characteristic of $Zn/Zn(OH)_2$ (-1.245 V vs SHE) and the initial oxidation of silver, Ag/Ag_2O (+0.345 V vs SHE), followed by the subsequent charge at -1.95 V which reflects the potential of Ag_2O/Ag_2O_2 couple (+0.607V vs SHE). Similarly in the initial part of the subsequent discharge the cell voltages arc dominated by the reduction of

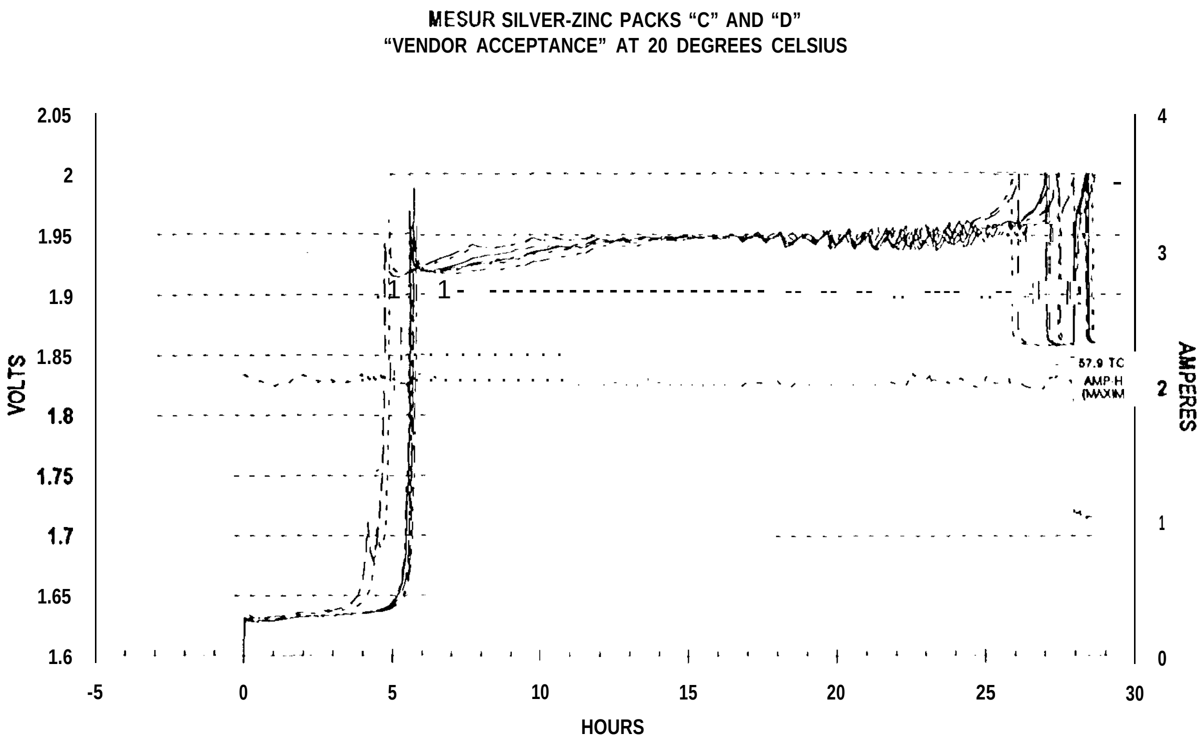

Figure 1. Characteristic 200C constant current charge at 2.0 amperes to a 2.0 V/cell cutoff.

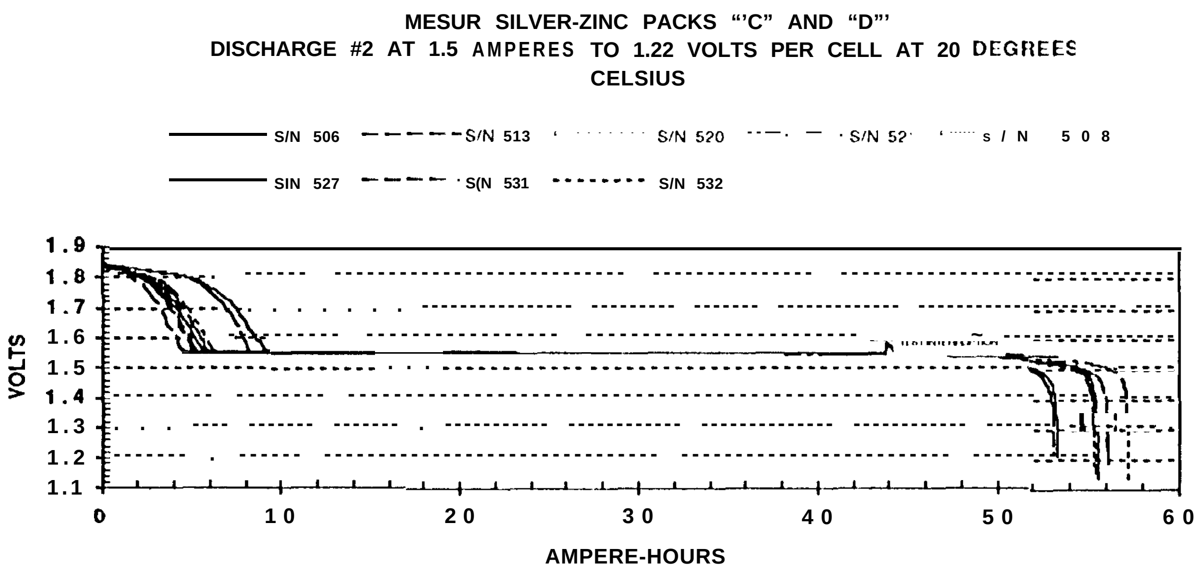

Figure 2. Subsequent discharge also at 20°C at a rate of 1.5 amperes to 1.22 volts.

divalcnt silver (Ag_2O_2/Ag_2O). This pcrformancc is characteristic of the Ag-Zn systcm as moderated by this ccll design.

As part of the initial evaluation a cycling test using a sct of operational parameters within the range of those cxpcctcd during Mars operation was conducted. Test conditions for the Mars surface operation arc outlined below in Table 2. This evaluation was pcrformcd on a single

PARAMETERS

Chamber Temperature	' 1o °C
Charge Period	6 hours
Max, Charge Current	4.5 Amp
Constant Charge Voltage	1.96 V
Discharge Rate	3.0 Amp
Discharge Capacity	20 AH

Table 2. Operational Parameters for energy balance evaluation on the Martian surface.

ccll which had been activated six months earlier and had undergone 14 previous charge discharge Cycles, Figure 3 shows a plot of the data from Cycle 15, the first discharge/charge cycle for this evaluation. Note that the discharge voltage 1.83 V to 1,53 V characteristic of divalcnt silver reduction was available during 4 hours of discharge in the first cycle Figure 3, and for 2.8 hours during the fourth of seven cycles Figure 4. Since the first discharge was started from a fully charged state, the ccl] was only able to accept -13 amperc hours of charge after the first discharge. Subsequent cycles indicate that the ccl] is capablc of maintaining energy balance under this regime as shown in Figure 5. During cycle 19 the charge was terminated in error at 18 amperc hours.

Conclusions

The high energy density of the Ag-Zn battcry systcm make it very attractive for secondary applications with low Cycle life rcquircmcnts. Thc rcquircmcnts of MESUR-Pathfinder mission have not been simultaneously previously demonstrated for the Ag-Zn technology (low cycle life after long term storage under variable tcmpcraturcs and charge/discharge rates). The goal of this program is to demonstrate this capability. Preliminary results of testing indicatc that a Ag-Zn ccl] can bc successfully cycled while maintaining energy balance using a set of operational and charge control parameters within the baseline of anticipated Mars surface operation. These results do not yet take into account the effects of long term storage that will bc cxpcricnccd on the cruise portion of the mission. Thc demonstration of that capability is the topic of on-going tests whose rcsults will bc rcportcd at a later date,

Acknowledgment

The work dcscribcd in this paper was carried out at the Jet Propulsion Laboratory, California Institutc of Technology, under contract with the National Aeronautics and Space Administration.

Refcrcnccs

1, S. Dawson ct. al., 'The 1993 NASA Acrospacc Battery Workshop', NASA Conf. Publication 3254, 1994.

2. S. U. Falk and A. J. Salkind, 'Alkaline Storagc Battcrics', John Wiley and Sons Inc., Ncw York, 1969.

FIGURE 3- Ag-Zn CELL S/N 25 WITH 5 LAYER SEPARATOR SYSTEM
DUTY CYCLE APPROXIMATION AT 10 DEGREES CELSIUS (CYCLE 15)

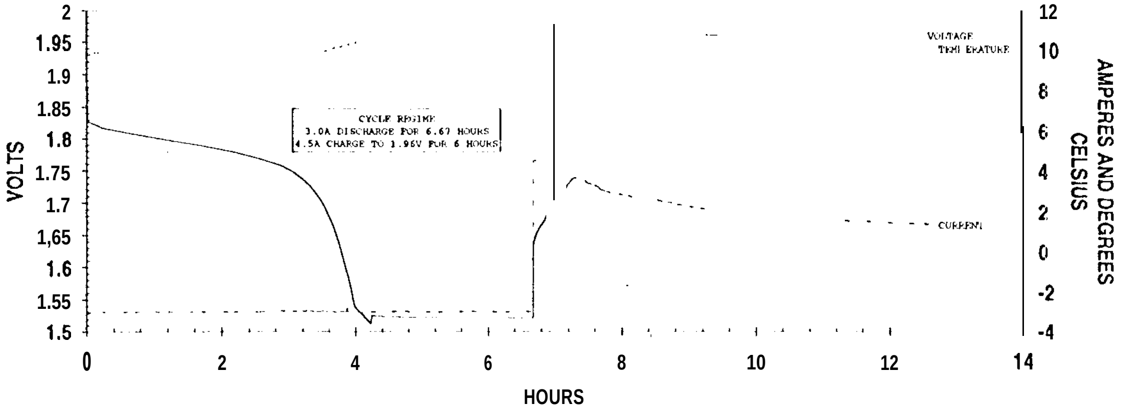

FIGURE 4- Ag-Zn CELL S/N 25 WITH 5 LAYER SEPARATOR SYSTEM
DUTY CYCLE APPROXIMATION AT 10 DEGREES CELSIUS (CYCLE 18)

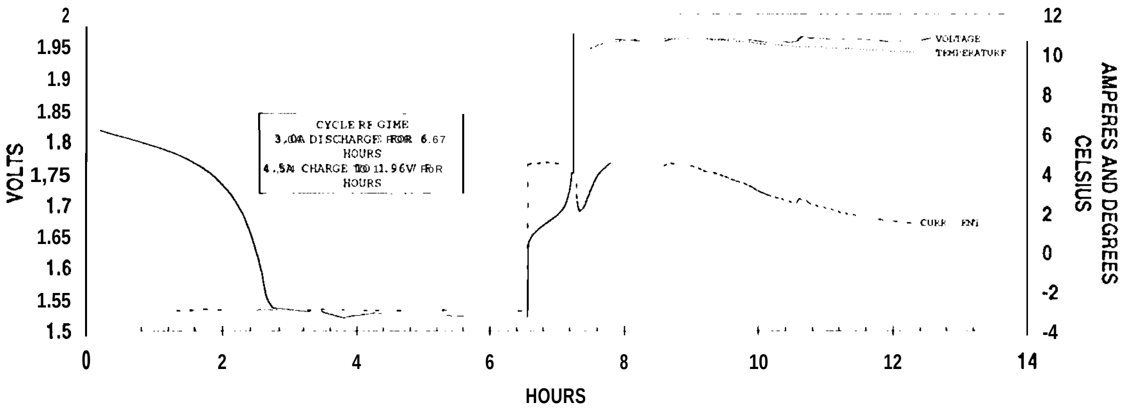

FIGURE 5- Ag-Zn CELL S/N 25 WITH 5 LAYER SEPARATOR SYSTEM
SIMULATED MARS OPERATION AT 10 DEGREES CELSIUS