USE OF A SEALED SILVER CADMIUM BATTERY ON EXPLORER XII

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Abstract

Because of the fact that silver cadmium cells could be constructed entirely free of magnetic materials, a secondary silver cadmium battery was used on Explorer XII, a satellite launched in 1961 to study radiation and magnetic fields. A program was carried out at Goddard Space Center to determine the feasibility of using the battery in this space application. Major points of interest of this program are brought forth. The operation of the power system on Explorer XII is outlined and cycling data, telemetered from the satellite, are presented. The first application of a silver cadmium battery on a satellite was very satisfactory. While in flight, no deterioration of the battery power supply was observed.

The initial interest in the silver cadmium couple was brought about at Goddard Space Flight Center during the design phase of Explorer XII. The prime purpose of this satellite was to measure radiation and magnetic fields in space. This satellite, because of its magnetometer, required components on board with minimum magnetic background signal. At that time, the possibility of a nonmagnetic silver cadmium battery was feasible. However, little data were available which would warrant the operation of this system for a one year period at one cycle every 26.5 hr, the orbital time of the satellite.

During the first half of 1961, a program was carried out at the Goddard Space Flight Center to investigate the various parameters of the sealed silver cadmium system. This program resulted in the design of a battery as shown in Fig. 1. It consisted of 13, 5 amp-hr, Yardney silver cadmium cells connected in series and potted in Epon 834. The outer case was aluminum. The battery weight was 6.3 lb. A current sensor

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Presented at the ARS Space Power Systems Conference, Santa Monica, Calif., September 25-28, 1962.

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was included to provide a readout in flight of the charge and discharge currents. Calibrated thermistors were used to monitor battery temperature. Charge and discharge voltages were telemetered. The duty cycle during flight was approximately a 1-amp discharge for thirty minutes followed by a 26-hr charge from the solar array. A block diagram of the Explorer XII power system is shown in Fig. 2.

The solar array was capable of 16 w nominal. The voltage regulator maintained a 19.6 voltage input across the battery and load during sunlight. As the battery became charged, the excess current was dumped through the regulator thereby regulating the solar array near its maximum power point. The battery was capable of operating the payload between the temperature of -10°C to +50°C. Actual battery temperature during the orbital lifetime ranged from +10°C to +28°C.

The discharge voltage of the battery was from 16 to 13 v at the payload power requirement of 14 w. During flight, the battery was discharged about 10% of its nominal 5 amp-hr capacity. A circuit was on board that sensed the battery discharge voltage and if the battery showed a low state of charge, the load would be taken off the line for 8 hr to allow the solar array to recharge the battery. The cutoff voltage was 12 v over a temperature range of -10°C to +50°C.

Typical charge characteristics, after a discharge during shadow time, are shown in Fig. 3. Note that the ampere-hour capacity, that was removed during shadow, is replaced in about 6 hr and at end of charge the current has decreased to less than 2 ma. It has been found that, during this type of orbit, the battery would operate at an ampere-hour efficiency of 97% or better.

As aforementioned, a program was carried out at Goddard to determine the parameters of the sealed silver cadmium system for use on Explorer XII. The major points of investigation are outlined below.

1. Optimum Charging Voltage

For the type of orbit and depth of discharge of the battery on Explorer XII, a constant potential charge voltage of 1.50 v per cell was very satisfactory. This voltage was not only capable of maintaining cell capacity but also, at this voltage, gassing is negligible. Since the solar array is inherently a current limiting device, the actual charging, either simulated or in flight, was of the modified constant potential type with 1.50 v per cell maintained at the end of charge and during trickle charge.

2. Discharge Characteristics

The discharge characteristics of the silver cadmium couple were investigated over the temperature range of -10° C to +50° C. The range of voltage at the 6-hr rate over this temperature range is from 1.27 v per cell at the beginning of discharge to 1.05 on the second or silver monoxide plateau. A typical discharge of a silver cadmium cell at room temperature is shown on Fig. 4, curve A. About 25% of the capacity is removed at the silver peroxide level while the remainder of the capacity is discharged at the silver monoxide level. A curious phenomena occurs when the silver cadmium couple is either cycled with long trickle charge periods or trickle charged only for long periods of time. As shown in Fig. 4, curve B, the peroxide portion of the curve is depressed and all the capacity can be recovered at the monoxide level. Usually, an increase in capacity is observed. Nominal 5 amp-hr cells can be cycled or trickle charged so that on discharge a capacity in excess of 7 amp-hr is realized at the monoxide level. Note the excellent voltage regulation. This phenomenon, the depression of the peroxide level of discharge, is under further study.

3. Effects of Nonuniformity in a Series String Especially at the End of Charge

During the evaluation program at Goddard, considerable data were taken to determine the degree of nonuniformity or unbalance of cells in series at the end of charge. Even though the Yardney Electric Company was able to select cells that had uniform charge characteristics, occasionally a few cells in a series string would unbalance. Some cells have shown end of charge voltages as high as 1.8 v. Naturally gassing occurs. Fortunately at the end of charge the current is of the order of 2 ma. An investigation was carried out on single cells to determine the pressure rise of the 5 amp-hr cells at voltages greater than 1.50 and low current levels. Typical data are shown in Fig. 5. Maximum pressures of the order of 50 psig were observed. After attaining this magnitude of pressure, the gas pressure either drops off sharply or, in some cases, decreases gradually and no further pressure rise is observed, even at a high charge voltage. This effect is being studied further at Goddard.

4. Thermal Characteristics as a Result of Charge or Discharge in Vacuum (10^{-5} mm Hg)

During a 10% depth of discharge of an Explorer XII type battery at 25°C and in a vacuum of 10^{-5} mm of Hg, the temperature rise of the battery on discharge was less than 2°C. There is no temperature rise of the battery during a charging mode of the type used on Explorer XII.

5. Leak Rates of Epoxy Encapsulated Batteries

One phase of the evaluation program at Goddard was to determine the helium leak rates of epoxy encapsulated batteries. The leak rates of single cells were less than 2×10^{-6} std cc/sec while the leak rates of thirteen cell batteries were less than 3×10^{-6} std cc/sec. Neither vibration nor temperature cycling had any damaging effect on the seal.

6. Ampere-Hour and Watt-Hour Efficiencies at Room Temperature

As aforementioned, the ampere-hour efficiency of the silver cadmium system during the orbital cycle of Explorer XII was 97%. The watt-hour efficiency of the battery, depending on the degree of depression of the peroxide level, is between 80% and 68%. The energy density of the battery was 13.0 w-hr/lb.

In conclusion, the first application of the silver cadmium system on a satellite was very satisfactory. During the 112-day lifetime of Explorer XII, telemetered data showed no deterioration of the battery power supply. The ampere-hour efficiency of the system was 97% or better. Since no overcharge is required, the battery did not present a thermal problem. Laboratory tests showed the epoxy seal to be satisfactory and since the battery showed no deterioration in space, the epoxy seal appears to be a reliable sealing technique in space applications. At the present time, three more satellites are scheduled to use the silver cadmium system as its battery power supply.

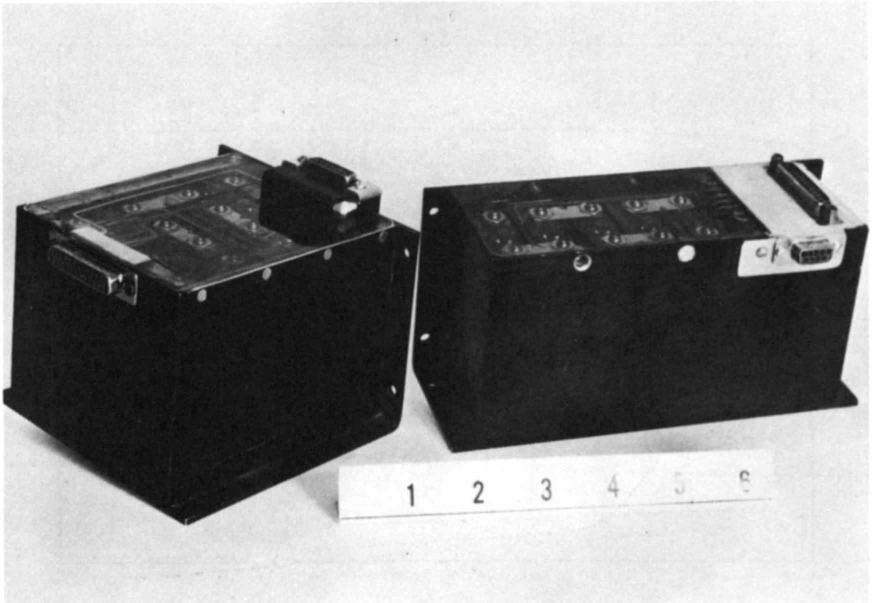

Fig. 1 Explorer XII silver cadmium battery

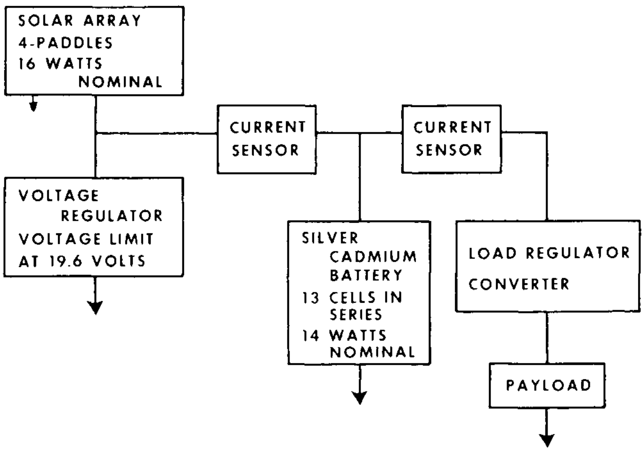

Fig. 2 Block diagram of Explorer XII power supply

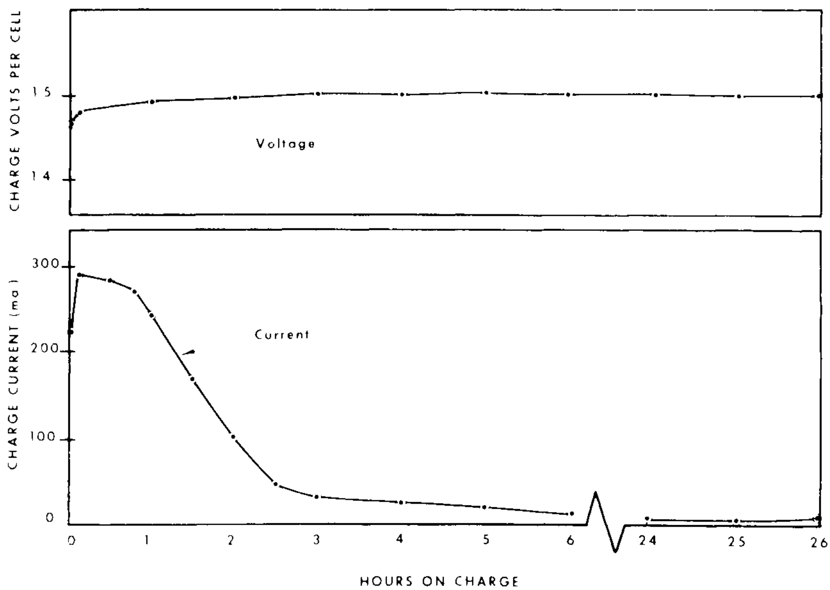

Fig. 3 Explorer XII silver cadmium battery typical charge characteristics after discharge in Earth's Shadow

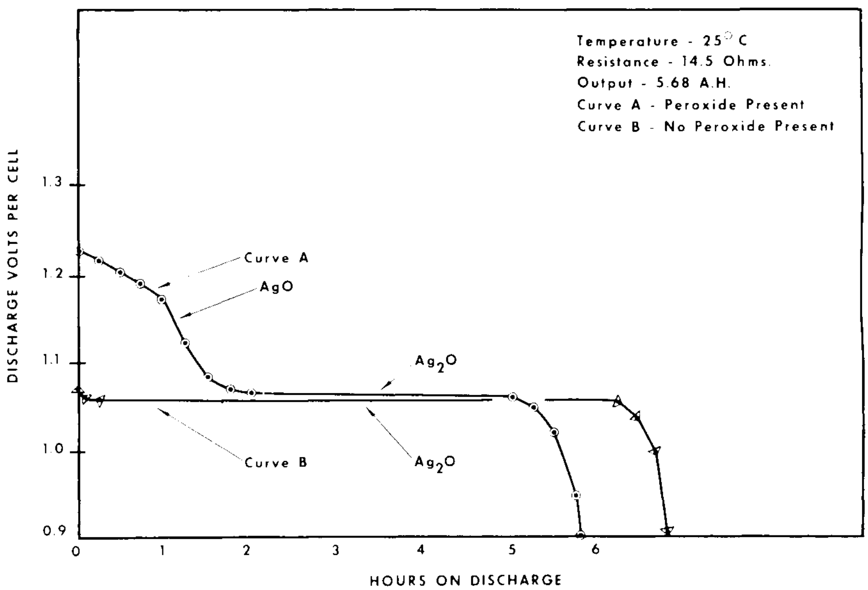

Fig. 4 Explorer XII silver cadmium battery typical constant resistance discharge

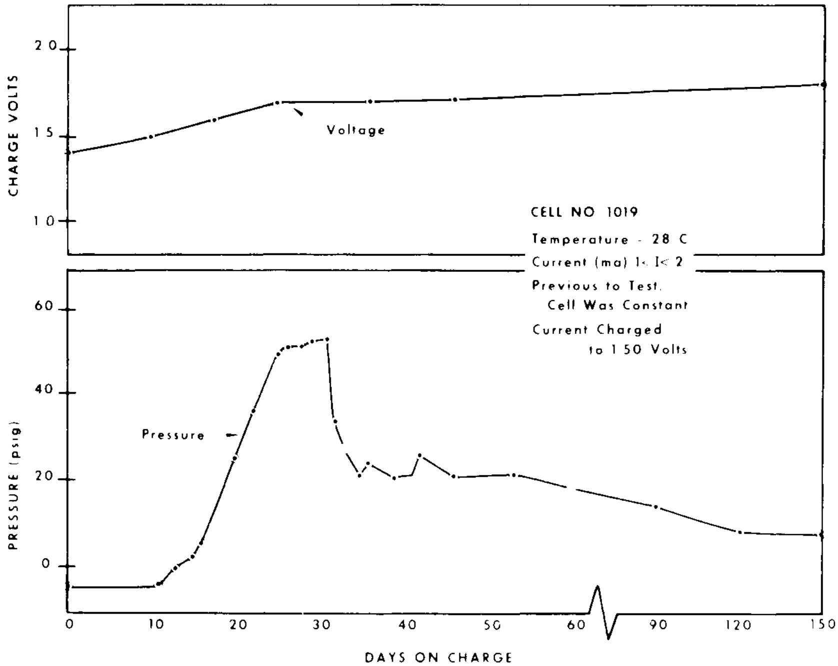

Fig. 5 Variation of internal pressure of a sealed silver cadmium cell continuously charged at E.>1.50 v