NICKEL CADMIUM SPACECRAFT BATTERY CHARGE CONTROL WITH AUXILIARY ELECTRODES

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The need for charge control in these batteries is associated with the requirement to limit internal pressure rise within hermetically sealed cells. Whenever a cell becomes fully charged, the internal pressure rises due to gas evolution. The positive electrode becomes fully charged before the negative electrode; therefore, oxygen is generated during overcharging. Manufacturers are incorporating a third (control) electrode to detect the oxygen and thereby produce a difference in potential between the control and negative electrodes for signal purposes. Two types of control electrodes have been developed. These electrodes are known as the adsorption hydrogen electrode and oxygen fuel cell electrode. Emphasis is placed on the adsorption hydrogen electrode because of its early availability and the large amount of data accumulated at Goddard.

The following aspects of the control electrodes have been studied: (1) Instrumentation required for control circuitry; (2) The performance characteristics of the adsorption hydrogen electrode in five-cell batteries operating at depths of discharge of 10% to 40% and temperatures of -20°C to 40°C; (3) The function of the external impedance in producing the control signal between values of 150 to 300 millivolts; (4) The relationship between the control electrode signal and the internal pressure rise of the cells; and (5) The relative characteristics of the adsorption hydrogen electrode and the oxygen fuel cell electrodes under identical conditions, i.e., with both electrodes operating within the same (common) nickel cadmium cell.

All batteries used were five-cell assemblies. One battery contained six ampere-hour cells equipped with the adsorption hydrogen electrodes, and a second battery consisted of twelve ampere-hour cells with oxygen fuel cell electrodes. In each case, each cell contained an auxiliary electrode. The auxiliary electrodes were connected externally to the

~~to the~~ negative (cadmium) electrode terminal through selected resistance values based upon the performance desired. A solid state scanner was designed to sense the electrode voltages and control the charging of the battery.[1] When the auxiliary electrode generates current to develop the preset voltage, the solid state scanner adjusts the conductance of a series transistor to a preset trickle charge rate. The system remains in this condition until the highest auxiliary electrode voltage falls below the preset trip point.

A most important characteristic of the adsorption hydrogen electrode was noted in the fact that the output voltage signal is a linear function of the oxygen gas pressure within the cell. This characteristic enables one to adjust the percentage recharge desired from 90% to 140%. Some tests indicated an optimum amount for recharging from 110% to 115%. These measurements were made by varying the third electrode external resistance while holding the voltage trip point constant and by varying the trip point while holding the resistance constant.

A most difficult problem with the adsorption hydrogen electrode relates to the critically small voltage difference between the end of charge and the beginning of charge. Cases are noted wherein the voltage is higher than the trip voltage at the beginning of the charge cycle, causing a five to ten minute delay before the commencement of charging. In a conventional 90-minute orbital regime, there is not enough time during trickle charge and discharge to recombine the gas generated at the end of charge. Gas generation is inevitable, since it is considered necessary to recharge a cell at 25°C an amount in excess of 110%.

The behavior of the adsorption hydrogen electrode voltage with resistance values from 1 to 25 ohms has been examined in detail. The percent recharge of the battery was held constant at 120% and the temperature at 27°C. It was observed that the ratio of the control electrode trip voltage to the minimum control electrode vs. cadmium voltage during charge increases as the resistance decreases, indicating that the control electrode supplements reduction of the oxygen pressure in the cell. It was also observed that the maximum power point occurs at 7.5 ohms and the maximum value of the above ratio occurs at 1.3 ohms.

Another problem of some concern was observed in that there was about 75 millivolts' variation between adsorption hydrogen electrode voltages of cells in series. All these cells had the same internal gas pressure, environmental temperatures and auxiliary resistance values. Instrumentation for that condition suggests the application of different trip voltage values and different resistance values for each cell in a series string.

Work performed on the application of the oxygen fuel cell control electrode has been somewhat limited. However, it has been observed that the signal produced is not linear with respect to the internal gas pressures. In fact, the onset of oxygen evolution produces and accelerated trip voltage which prematurely signals the charge controller before the battery has attained the fully charged state. As experienced with the adsorption type electrode, the selection of the external resistance of the control electrode becomes critical. The oxygen recombination rate of this electrode exceeds the recombination rate of the adsorption type by at least a factor of ten.

1. Marine Engineering Laboratory R&D Phase Report 283/64, "Solid State Circuit Development," by P.P.M. Liwski, dated April 1965.