# CAPABILITY OF THE CADMIUM-SILVER OXIDE SYSTEM

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## Abstract

At the present state-of-the-art, two classes of batteries with distinct operational characteristics can be constructed from the cadmium-silver oxide system. One class operates at maximum capacity obtainable from both the higher and lower oxide states of silver, while a second class can be made to function only at the lower energy level of the positive plate. Each system has important advantages when consideration is given to overall battery performance. Continuous operation of hermetically sealed cells at maximum energy level multiplies problems in obtaining long cycle life, while greater stability is gained through operation at the silver monoxide level. Performance characteristics of vented cadmium-silver oxide cells reveal satisfactory operation throughout the temperature range of -20° F to +120° F. Problems associated with the development of a truly hermetically sealed cadmium-silver oxide battery continue to be troublesome although steady progress is being made towards improvements in hermetic seals, insulation, recombination rates and in alleviating the deleterious effects of overcharging and overdischarging.

## Introduction

At the present state-of-the-art, three secondary battery systems, nickel-cadmium, cadmium-silver oxide, and zinc-silver oxide, appear to be applicable for space and military service. Table 1 presents an estimation of relative performance characteristics that may be expected from each system.

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Table 1 Relative performance characteristics of sealed systems

| Performance factors | Zinc-silver, % | Systems Cadmium-silver, % | Nickel-cadmium, % |
|---|---|---|---|
| w-hr/lb | 100 | 56 | 25 |
| w-hr/in.$^3$ | 100 | 46 | 23 |
| Cycle life | 100 | 2000 | 6000 |

The capacity and life performance attainable from each of the forementioned systems are limited to an extent by inherent physical and chemical characteristics. Most significant, perhaps, is the correlation between energy output and cycle life. It appears fundamental that an inverse function exists between energy output and ability to perform as a secondary system. In addition, it may be stated that a change in design or in plate parameters to improve capacity efficiency normally cannot be made without adverse effects to cycle life performance. Regardless of the inherent problems associated with each of the forementioned systems, it is logical to assume that each one, developed to a reliable state, can be used to advantage in certain space and military applications.

In consideration of both energy output and life expectancy, the cadmium-silver oxide system may be considered best suited of the three. The development of this system has reached a satisfactory state, and sufficient data have been accumulated to estimate the capability of sealed cells constructed in both the cylindrical and rectangular configurations. Sealed cells using the cadmium-silver oxide system are represented photographically in Fig. 1.

## Cadmium-Silver Oxide System

Two classes of batteries with distinct operational characteristics can be constructed from the cadmium-silver oxide system. One class is designed for maximum utilization of the capacity available from both the higher and lower oxide states of silver. A second class of batteries is constructed to operate at the lower capacity output of the positive plate. Each system has important advantages when consideration is given to overall battery performance.

Since a major objective always has been directed towards obtaining maximum capacity per unit weight and volume, the greater portion of investigative work should, and has been, directed towards the maximum utilization of the positive plate. Unfortunately, continuous operation of a sealed cell using silver at its dioxide level multiplies the inherent problems associated with obtaining long cycle life. Of most significance is the observation that a relatively high rate of recombination of oxygen with cadmium is necessary to maintain the positive plate at its dioxide level; otherwise, excessive internal pressures are developed at practical charging rates.

Effort is currently being directed towards the improvement of the performance capability of the cadmium-silver monoxide system, since it has become apparent that working a positive plate at its lower capacity level offers better conditions for achieving long cycle life. A silver positive plate operating near its monoxide level will have an improved matrix structure, and, because of lesser oxidation potential, life expectancy of insulating materials will be increased. Furthermore, the apparent high efficiency of conversion to the silver monoxide level would eliminate to a degree the necessity of achieving a rapid recombination rate of oxygen with cadmium.

Sealed cells constructed to operate at the maximum and lower energy levels of the positive plate have been subjected to cycling tests. Relative performance characteristics are revealed in Fig. 2.

The cycle test consisted of a 100-min cycle, during which the cells were subjected to a discharge of 35% of full capacity at a rate of 0.12 amp/in.$^2$. Periodically, during life the cells were discharged to obtain full capacity data for use in calculating sustained energy in watt-hours per pound. The point for terminating testing was fixed by the time required for the cell to decay in capacity to a value equal to half of its full capacity.

Data in Fig. 2 reveal a rather rapid decay in the silver dioxide capacity of the positive plate, although the energy output available during the early cycling period is noteworthy. It required approximately 500 cycles for the cell to decay to half of its full capacity or to a point representing the capacity available from the lower energy level of silver oxide. To date efforts to regain the dioxide capacity at practical charging rates have been unsuccessful, primarily because of an inability to achieve the necessary rate of recombination.

Sealed cells designed to operate on the lower energy level of the positive plate have been found to be considerably more stable. The stability during cycle life is apparent from comparative data presented in Fig. 2. These cells have completed 1000 cycles with loss of approximately 5% of full capacity. The curve has been extrapolated to indicate the expected performance characteristics with continuation of cycling. The stability of this system is indicated further by the very low rate of self-discharge observed on sealed cells operating at the lower energy level of the positive plate.

Initial design features for construction of both the rectangular and cylindrical sealed cadmium-silver oxide cells using positive plates at both the dioxide and monoxide levels have been established. There remain the problems of achieving the optimum in plate parameters, electrolyte balance, and method of insulation. Based on preliminary data, an estimation has been made of the relative attainable energy outputs of both systems, data of which are presented in Table 2.

Table 2 Relative attainable energy outputs

| Cell type | Cell volume, $in.^3$ | System | w-hr/lb | w-hr/$in.^3$ |
|---|---|---|---|---|
| D | 3.04 | AgO/Cd | 32.0 | 3.5 |
| | | $Ag_2O$/Cd | 23.5 | 2.6 |
| C-6 | 4.69 | AgO/Cd | 33.1 | 3.6 |
| | | $Ag_2O$/Cd | 24.5 | 2.7 |
| C-60 | 26.60 | AgO/Cd | 40.9 | 4.9 |
| | | $Ag_2O$/Cd | 30.2 | 3.6 |

Comparison is made of three units of increasing size. The "D" cell is of cylindrical design, and the "C" types are of the rectangular configuration. Of significance is the comparison of the energy attainable from cells operating on the two energy levels of the positive plate. Although approximately 25% of the attainable energy in watt-hours per pound is lost by working the positive plate at the lower energy level, the sacrifice of this amount of energy will increase cycle life expectance by several times over that obtainable on working at the higher energy level of the positive plate. Also, it is noteworthy to observe the increase in watt-hours per pound with increasing cell volume which is related to the proportional decrease in hardware weight.

Capacity performance characteristics of vented cadmium-silver oxide cells in their initial stage of design have been determined for the purpose of establishing the capability of the system throughout a range of temperature. Cells containing nine plates, weighing 0.53 lb and housed in a container of 7.35 $in.^3$, were constructed for initial capacity and efficiency of charge testing throughout a temperature range of -20° to +120° F. Discharges were conducted at approximately the three-hour rate or 0.127 $amp/in.^2$ of discharge. The energy outputs of vented cadmium-silver oxide cells of this size are presented in Table 3.

Table 3 Initial capacity performance of vented cadmium-silver oxide cells of 7.31 $in.^3$ volume

| Temperature, °F | w-hr/lb | $w\text{-}hr/in.^3$ |
|---|---|---|
| 120 | 29.4 | 2.14 |
| 80 | 27.5 | 1.99 |
| 32 | 23.3 | 1.69 |
| 0 | 14.2 | 1.03 |
| -20 | 11.6 | 0.84 |

It is apparent that the system is capable of delivering appreciable electrical energy throughout the temperature range of -20° to +120° F.

To determine the ability of the system to function at low temperatures, the cells were charged completely at +80° F and brought to -20° F and discharged. The cells then were subjected to a 15% overcharge at -20° F at a rate of 0.025 $amp/in.^2$ and again discharged as before. Charging at -20° F was found to increase capacity by as much as 5% relative to charging at +80° F, disclosing the capability of the system to function at low temperatures.

## Summary

Investigative studies conducted on the cadmium-silver oxide system have demonstrated the feasibility of operating both sealed and vented batteries at the two capacity levels of the positive plate. Operation of a sealed cell at its maximum positive plate capacity over a period of long cycle life presently is limited by the inability of maintaining the silver dioxide level without experiencing excessive internal pressures at practical charging rates.

Operating the sealed cadmium-silver oxide cell at the lower capacity level of the positive plate offers several important advantages in achieving extremely long cycle life; however, it is realized that, to attain long cycle life by this method, a sacrifice must be made in energy output per unit weight and volume.

Construction features of both the cylindrical and rectangular sealed cell configuration have been brought to a satisfactory stage of development using both the cadmium-silver dioxide and cadmium-silver monoxide systems. By subjecting sealed cells of either design to various conditions of cycling, it has been demonstrated that the cadmium-silver oxide system has a potential of attaining greater energy output in watt-hours per pound for longer periods of cycling than other systems currently in use.

Major problems associated with the operation of a truly hermetically sealed cadmium-silver oxide battery continue to be troublesome, although steady progress is being made towards improvement in hermetic seals, insulation, recombination rates, and in alleviating the deleterious effects of overcharging and overdischarging.

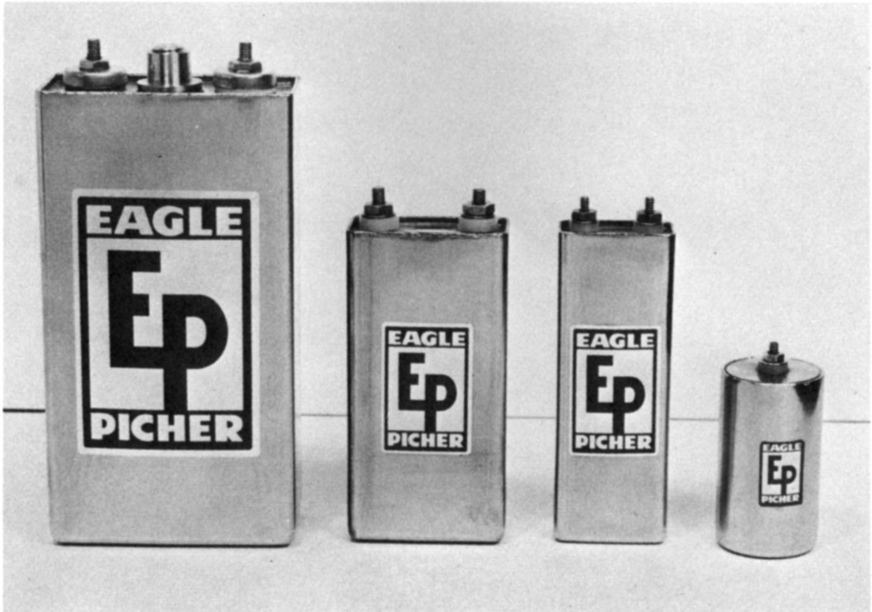


Fig. 1  Sealed cadmium-silver oxide cells

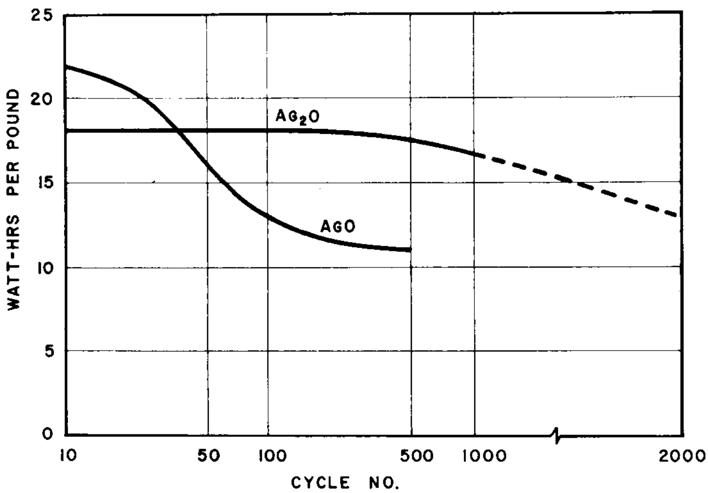


Fig. 2  Relative cycle life performance