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BY THE U.S. GENERAL ACCOUNTING OFFICE

Report To The Chairman Committee On Armed Services United States Senate

Army's Procurement Of Batteries: Magnesium Vs. Lithium

The Army is in the process of moving from magnesium to lithium batteries, a change motivated by the magnesium battery's performance limitation at low temperatures and the operating capabilities of the lithium battery.

GAO concludes that the operational advantages of the lithium battery justifies this move. However, GAO was not able to confirm the validity of the Army's cost comparisons of the two batteries.

UNITED STATES GENERAL ACCOUNTING OFFICE

127984

GAO/NSIAD-85-124
SEPTEMBER 26, 1985

033275

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UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

NATIONAL SECURITY AND
INTERNATIONAL AFFAIRS DIVISION

B-219919

The Honorable Barry M. Goldwater
Chairman, Committee on Armed Services
United States Senate

Dear Mr. Chairman:

In a letter dated July 24, 1984, we were requested by former Chairman Tower to review the military's decision to move from a magnesium battery to a lithium sulfur dioxide battery for many applications. The Chairman questioned this decision because of concerns about the cost effectiveness and safety of the lithium battery.

In a later discussion with the Armed Services Committee staff, we agreed to validate the information contained in the U.S. Army report of October 11, 1984, to Chairman Tower, which responded to the Senator's questions concerning magnesium battery BA-4386 versus lithium battery BA-5598. Specifically, we agreed to document the safety aspects of both batteries and their cost effectiveness, with emphasis on the disposal costs of the lithium battery, which the Environmental Protection Agency and the Army have cited as a hazardous material.

BACKGROUND

The Army currently purchases several types of batteries, including magnesium and lithium--which are used primarily in its radio sets (AN/PRC-25 and 77) as well as in a number of other applications. At the end of January 1986, the Army plans to discontinue purchasing the magnesium battery. This change was motivated by the magnesium battery's performance limitation at low temperatures; this problem was encountered primarily in Alaska. Other rationale supporting this change are that lithium batteries (1) are high current throwaway batteries that are small in size and weight and suitable for manportable equipment and (2) meet the operating current requirements of the most recently developed and planned portable communications/electronics equipment because they exceed 1 ampere. (An ampere is a unit of electrical current or rate of flow of electrons.)

An additional motivator is to reduce battery proliferation and improve battlefield logistics by fielding a minimum family of lithium batteries to replace several existing battery types, such as magnesium and mercury. In addition, the family of lithium batteries provides a minimum set of standardized batteries for new equipment applications.

LITHIUM BATTERY MORE EFFECTIVE THAN MAGNESIUM BATTERY

Lithium battery BA-5598 is one of a family of eight non-rechargeable throwaway lithium sulfur dioxide batteries and four rechargeable nickel cadmium batteries being fielded by the Army for use by all military services. (These batteries come in four voltages (3, 6, 12, and 24) and two ranges of drains (a low range of up to 1 ampere and a medium range of from 1 to 2 amperes). The BA-5598 is a 12-volt battery with a rated current capability of 2 amperes and a capacity of 7.2-ampere hours. (An ampere hour is a current of one ampere flowing for one hour.) It has been designated to replace magnesium battery BA-4386, which is a 12-volt battery with a rated current capability of 1 ampere and a capacity of 5.4-ampere hours, and the only magnesium battery ever mass produced.

Although at 110°F, both batteries provide about the same operational hours of service in the radio sets, the lithium battery provides that service at about half the volume and less than half the weight of the magnesium battery, and operates down to -40°F, a temperature at which the magnesium battery is completely inoperative. At temperatures below 70°F, the capacities (i.e., ampere hours) of both batteries decline. However, Army test reports indicate that the capacity of the magnesium battery declines much more rapidly than the capacity of the lithium battery. For example:

--At 110°F, the two batteries have the same capacities (about 6.5-ampere hours).

--At 70°F, the magnesium battery has a capacity of 14.4 percent fewer ampere hours than the lithium battery (due to the lithium battery's capacity increasing between 110°F and 70°F, as well as the magnesium battery's capacity decreasing).

--At 40°F, the magnesium battery's capacity is 42 percent less than the lithium battery's capacity.

--At 0°F, the magnesium battery's capacity is 72 percent less than the lithium battery's capacity.

--At -40°F, the magnesium battery has a capacity of zero ampere hours, 100 percent less than the lithium battery, which is still operating at a capacity of about 3.4-ampere hours.

Other factors discussed in Army test reports and other Army documents which indicate that the lithium battery is more effective than the magnesium are the lithium battery's superior storage capability and suitability for use with recently developed operating systems. For example, under normal storage conditions, the lithium battery is expected to provide a shelf life of 5 to 15 years without refrigeration, while the magnesium battery requires refrigerated storage to prevent battery deterioration and extend its normal storage shelf life to 10 years. Also, the magnesium battery has a rated current capability of 1 ampere. Consequently, the magnesium battery does not have the operating capability to service the operating requirements of the most recently developed and future portable system applications which exceed 1 ampere. The lithium battery, with a rated current capability of 2 amperes, has the operating capability to service the new systems.

LITHIUM AND MAGNESIUM BATTERIES ARE SAFE

The lithium battery was first fielded in 1977 in Alaska. The initial battery design had a cell chemistry ratio of lithium versus sulfur dioxide which caused cell ruptures. About 39,000 batteries with this design were produced, and over time, 3 battery failures occurred resulting in one personnel injury. The injury incident involved a depleted battery which ruptured during improper load testing. This event caused caustic burns to the hands of the tester and is the only reported lithium battery personnel injury to date. These batteries were withdrawn from field service in April 1983.

In 1980, the lithium battery was redesigned to eliminate the cause of cell ruptures. As of January 31, 1985, about 309,000 redesigned cell lithium batteries had been produced; about 186,000 of these were issued to field users. Two safety incidents related to the lithium battery have been reported since the redesign. One incident involved an in-use battery rupture that was apparently due to inadvertent charging of this nonrechargeable battery in the field; the other involved a not-in-use battery found to be corroded and leaking. No injuries resulted from either of these incidents.

The magnesium battery was first fielded in 1968 in Southeast Asia; over 93 million have been produced since then. During the period November 1968 through September 1971, at least 28 safety incidents were reported. They were primarily due to hydrogen gas combustion in either the equipment or the battery case, which resulted in bulged radio cases. Corrective actions were taken, and since then only one incident has been reported. These 29 reported safety incidents did not involve any reported personnel injuries.

LITHIUM BATTERY DISPOSAL IS MORE EXPENSIVE

Since January 1982, the U.S. Army has considered lithium sulfur dioxide batteries to be hazardous waste requiring disposal through the Defense Property Disposal Service (DPDS). The contents of the lithium batteries were deemed to be potentially flammable and noxious, as well as corrosive, according to the criteria established in the Resource Conservation and Recovery Act (RCRA) of 1976. That act establishes four characteristics of hazardous waste: reactivity, corrosivity, ignitability, and toxicity.

In March 1984, the U.S. Environmental Protection Agency (EPA) declared lithium sulfur dioxide batteries to be reactive waste pursuant to the provisions of RCRA. The EPA classified these batteries to be reactive because of the following properties:

--Lithium, when mixed with water, forms potentially explosive hydrogen gas.

--The battery cells are capable of detonation or explosion if subjected to a strong impact or if heated under confinement.

--The potential exists for battery components (sulfur dioxide, acetonitrile, and lithium) to generate toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment when these components are mixed with water or exposed to certain alkaline or acid conditions.

The U.S. Army Environmental Hygiene Agency, in its hazardous waste study report of February 7, 1985, confirmed the EPA's designation of battery reactivity. The study found that fully charged as well as spent batteries (batteries partially discharged during normal use) were reactive, but that fully discharged batteries were nonhazardous waste. It also concluded that the manual discharge of the batteries by soaking in salt and fresh water was not practical, and recommended investigating other ways to fully discharge these batteries.

As a reactive waste, disposal is authorized only in a secure RCRA permitted landfill as neutralized waste. DPDS in October 1984, cited its current average cost for this type of disposal to be $3.25 a pound per 1,000 pounds and $2.60 a pound per 10,000 pounds of waste. In addition, DPDS collection and retrieval costs are estimated to be about 50 cents per battery.

The magnesium battery was classified by DPDS as having the hazardous characteristics of corrosivity and flammability; however, in its hazardous waste study report of November 21, 1983, the Army Hygiene Agency concluded that the battery was not an RCRA hazardous waste. The study recommended that seven batteries per ton of refuse could be buried at sanitary landfills, and if this is not practical, that large quantities of batteries (over 200) be disposed of by commercial contract through DPDS. Consequently, these batteries are apparently disposed of as nonhazardous waste without any of the costs associated with disposing of hazardous material.

LITHIUM BATTERY MORE EXPENSIVE

For fiscal year 1984, the unit cost for lithium batteries was $34.55 from one of the two existing manufacturers, and $38.53 from the other. The unit cost for magnesium batteries has fluctuated over the years, but for fiscal year 1984, the two manufacturers were charging $12.13 and $13.14. For fiscal year 1985, a winner-take-all competition resulted in a unit cost of $8.55 for the magnesium battery. (Orders can be placed against that contract until January 30, 1986.)

In its October 1984 report, the Army projected that the effective battery output cost (i.e., the battery unit cost adjusted to reflect the fact that the lithium battery has a greater capacity than the magnesium battery) of the lithium battery for fiscal year 1988--$14.25--would be essentially the same as the fiscal year 1984 unit cost for magnesium batteries--from $12.13 to $13.14. This conclusion, however, is based on two sets of assumptions.

First, the Army projected, based on a December 1982 battery price analysis from one of the manufacturers of lithium batteries, that the unit cost would decrease from about $35 to $19 by fiscal year 1988. This cost reduction is based on the premise that the Army would purchase 300,000 batteries per year from that manufacturer during a 3-year period, and that there would be a 75-percent learning curve.

Second, the Army further projected that the $19 unit cost would be offset by 25 percent. The Army based this projection on its determination that the lithium battery has a 25-percent greater operating capacity (7.2-ampere hours vs. 5.4-ampere hours for the magnesium battery) to support the operational requirements of the AN/PRC-25 and 77 radio sets. (See app. II for a cost comparison of the two batteries.)

We believe the second set of assumptions dealing with the 25-percent offset were reasonable, based on the rated capacities of the two batteries. However, we question the first set of assumptions. Based on the Army's procurement plan for batteries, the assumption about the 300,000 annual buy quantity for one manufacturer does not seem realistic. The Army's plan calls for purchasing a total of 510,000 lithium batteries each year for 3 years, but dividing the 510,000 equally among three lithium manufacturers, resulting in a single manufacturer providing 170,000 not 300,000.

Regarding the assumed 75-percent learning curve, the Army reported that this was also based on the assumption that the Army would purchase 300,000 batteries per year for 3 years from one manufacturer. Since this assumption is not consistent with the Army's current procurement plans, the 75-percent learning curve cannot be considered valid.

CONCLUSIONS

The Army presented its justification for the change from a magnesium battery to a lithium sulfur dioxide battery in an October 11, 1984, report to then Committee Chairman Tower. Based on our examination of that report and its supporting documentation, we conclude that, from a safety standpoint, the change is justified in that neither the magnesium nor lithium battery appears to constitute a safety hazard. We also believe the operational advantages of the lithium battery justify the Army's decision to move from magnesium to lithium batteries. Specifically:

--The lithium battery has the capability to service the operating requirements of the most recently developed and future portable system applications which exceed 1 ampere.

--The lithium battery has a greater operating capacity (ampere hours) than the magnesium battery, which means it has a longer life and should result in a smaller number of lithium batteries required to support Army operational needs.

--The lithium battery greatly outperforms the magnesium battery at temperature ranges below 110°F.

--The lithium battery meets the Army's requirement for a high energy throwaway battery of small size and weight, and is about half the weight and volume of the magnesium battery.

We are not able to conclude that the Army's decision can be justified on the basis of cost. First, the EPA and the Army have designated the lithium battery as hazardous waste. As such, lithium batteries will incur disposal costs to neutralize and dispose of them in specially designated landfills. Conversely, the magnesium battery is considered nonhazardous waste and therefore there are no additional disposal costs. Second, we question the validity of the Army cost comparisons in the October 1984 report to then Chairman Tower which concluded that the unit cost of the two batteries are comparable when the lithium battery unit cost is adjusted to reflect greater operational capability than the magnesium battery. The cost comparisons in the October 1984 report were based on assumptions that do not reflect the Army's current procurement plans for the lithium battery.

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The U.S. Army Audit Agency is doing a multilocation audit of power sources with the overall objective of evaluating the Army's battery management. The scope of the audit covers a number of issues, including the lithium battery safety and the battery disposal issues of concern to Chairman Tower. A report is expected to be issued in the fall of 1985.

We discussed our conclusions with agency program officials. However, as requested by your Office, we did not obtain the views of responsible officials on our conclusions, nor did we request official agency comments on a draft of this report. With this exception, our work was performed in accordance with generally accepted government audit standards.

We are sending copies of this report to the Chairmen, House Committee on Government Operations, Senate Committee on Governmental Affairs, Subcommittee on Defense, and House and Senate Committees on Appropriations and Armed Services; the Director, Office of Management and Budget; the Secretary of the Army; the Administrator of the Environmental Protection Agency; and other interested parties.

Sincerely yours,

David A. Littleton

Frank C. Conahan
Director/for

OBJECTIVE, SCOPE, AND METHODOLOGY

The overall objective of our effort was to validate the information contained in the Army's report on the military effectiveness, safety, and cost of the two batteries, as well as the disposal cost of the hazardous waste lithium battery. In addition, we validated the information contained in the Army briefing of August 10, 1984, to the Committee staff, which was the basis for the Army's report to the Chairman. We performed our work primarily at the U.S. Army Electronics Technology and Devices Laboratory (the battery developer) and at the U.S. Army Communications-Electronics Command (the battery item manager and contracting office). We contacted DPDS and the U.S. Army Audit Agency for information on battery disposal costs. Our field work was performed at Fort Monmouth, New Jersey, between January 7 and February 15, 1985.

We discussed the contents and conclusions contained in the Army report and briefing paper with battery developer officials, contracting office representatives, and the battery item manager. We verified the information in the report and briefing paper to its source documents, and we updated the information it contained to account for pertinent matters since their issuance.

We reviewed the documents for all lithium battery safety incidents reported to the battery developer between January 1981 and February 1985, as well as the available data on magnesium battery incidents. We reviewed reports and other documents prepared by the Army, DPDS, and other agencies on the disposal of the two batteries and the associated disposal costs. We also reviewed contracts and other documents to develop the procurement history and future procurement plans for the batteries. Further, we verified the Army's projected 1988 lithium battery unit cost, and we reviewed technical and other data on the comparative effectiveness of the two batteries.

BATTERY COST COMPARISON

	Lithium		Magnesium	
	Unit cost	Quantity	Unit cost	Quantity
1984 cost:				
Contractor A[a]	$34.55	109,000[b]	$12.13	300,000[d]
Contractor B	38.53	148,000[c]	13.14	300,000
1985 cost:				
Contractor A	N/A	N/A	8.55	1,200,000[e]
Contractor B	N/A	N/A	N/A	N/A
1988 cost estimate:[f]				
Contractor A	19.00[g]	300,000	N/A	N/A[h]
Contractor B	Unknown	Unknown	N/A	N/A
1988 cost estimate[f] adjustment:				
Contractor A	14.25[i]	300,000	N/A	N/A
Contractor B	Unknown	Unknown	N/A	N/A
Other costs:				
Collection	0.50[j]	1	Unknown	Unknown
Disposal	3.25 lbs.	1,000 lbs.	Unknown	Unknown
	2.60 lbs.	10,000 lbs.	Unknown	Unknown

[a]Separate manufacturers for each battery—four in total.

[b]Additional buy of 39,000 batteries at $35.05 per unit.

[c]Additional contract for 54,000 batteries at $46.50 per unit.

[d]Negotiated split quantity procurement.

[e]Winner-take-all competitive procurement.

[f]We were unable to confirm the validity of these cost projections.

[g]Estimate based on 3-year procurement of 300,000 per year and assuming a 75-percent learning curve.

[h]No procurements planned beyond 1986.

[i]Effective battery output cost due to 25 percent greater capacity of lithium battery.

[j]Average DPDS costs to collect and dispose of batteries in the continental United States.

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