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NEW BATTERY TECHNOLOGIES AND THEIR POTENTIAL IMPACT IN THE USE OF ENERGY IN THE TELEPHONE INDUSTRY*

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Summary

The principal use of batteries in the telecommunications industry is to provide standby or emergency d.c. power to telephone exchanges in the event of a failure or breakdown in the utility supply. Batteries are also used for standby power in microwave relay stations, for emergency lighting, and a variety of other minor uses.

Due to its low cost, long life and reliability the lead–acid battery dominates standby applications. Substantial developments are, however, in progress throughout the world to develop secondary batteries for use in electric vehicles and utility load-leveling. In addition, substantial improvements are being made in the development of compact, low-cost primary batteries such as those based on zinc–air and lithium technology.

The characteristics of the lead–acid and nickel–cadmium systems are reviewed and the systems under development are then described together with their predicted characteristics and costs. The possible impact on the telecommunications industry of these new developments in battery technology is discussed.

Introduction

Secondary batteries provide emergency d.c. power to telephone exchanges, microwave stations, computers, and other critical installations. This power is required in the event of an interruption of the power supply from a utility grid, to allow a continuous service to be maintained. Lead–acid batteries are normally installed to provide this standby power, especially in the largest segment of the market, namely, telephone exchanges.

Batteries are particularly suitable as a source of standby power in the telecommunications industry since the loads are primarily d.c. For example, in the normal operation of a telephone exchange the d.c. load is supplied directly from the a.c. mains *via* rectifiers. To ensure that d.c. power is always

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TABLE 1

Types of lead–acid batteries used in telephone plants to provide standby d.c. power

Type	Positive electrode	
	Grid alloy	Plate construction
Pasted Pb–Sb	Pb–Sb	Flat, pasted
Tubular Pb–Sb	Pb–Sb	Tubular
Pasted Pb–Ca	Pb–Ca	Flat, pasted
Bell cell	Pb	Round, conical
Planté	Pb	Swaged Pb sheet

available, batteries are kept connected to the d.c. load of the telephone plant at all times. This arrangement maintains the batteries in a full state of charge since they are kept on float by the rectifier.

The battery is, typically, a 24 or 48 V system which, in addition to supplying emergency d.c. power to the exchange equipment, also serves as a filter by smoothing out the d.c. supply from the rectifier. The battery also supplies additional power to meet peak load demands. Cell sizes range from about 15 A h to 7 000 A h.

The current drain on central exchange batteries varies and can be up to 10 000 A/h and the battery is designed to supply this load for the duration of the outage. The local environment is the main determinant of the duration over which the battery has to provide power. Where a back-up engine generator system is provided and power outages are of short duration, a reserve time of up to one hour is sufficient. Where engine backup is not provided the battery is designed to provide power for up to eight hours or even longer.

This variation in the service requirements of the standby battery has led to the evolution of a variety of different types. They all, however, have one thing in common in that they are variations of one basic system — the lead–acid battery.

Lead–acid batteries

The battery that is almost exclusively used for standby use in telephone plants is the lead–acid system. There are several versions of this battery which differ mainly in respect to:

(i) the composition of grid alloy used in the positive plate, and
(ii) the positive plate construction.

Table 1 indicates the main types of lead–acid batteries. Which type is selected depends partly on service requirements, partly on cost considerations, and partly on historical preference. In general, batteries with lead–antimony (Pb–Sb) positives are still dominant. The flat plate version is preferred in the USA and the tubular version preferred in Europe and Japan.

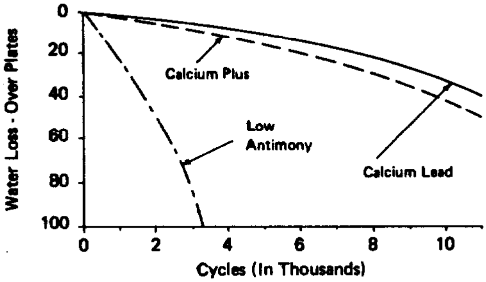

Fig. 1. Water loss observed under shallow discharge conditions (SAE J240 cycle test) with automotive batteries having (i) both grids of lead–calcium alloy, (ii) both of low-antimonial alloy, and (iii) a combination of both (the hybrid "Calcium Plus") (ref.4).

There has, however, been a steady trend away from Pb–Sb to the low-maintenance lead–calcium (Pb–Ca) in the USA while in Europe there are still utilities that prefer the Planté cell.

The Bell Telephone System pioneered lead–acid standby batteries with pasted Pb–Ca grids. This battery was introduced into widespread Bell System use in 1950 to replace batteries with Planté plates. The advantage of the Pb–Ca battery is that it has a relatively high back-emf which enables it to be floated with less gas evolution than in the case of Pb–Sb batteries. Less gas evolution on float means that the battery requires less maintenance in the form of water addition and terminal cleaning.

Although the batteries with Pb–Ca grids generally performed very well some operational problems induced Bell Laboratories to design a battery specifically to meet the requirements of the Bell System. This battery — known as the "round cell" — is unusual in the following respects [1]:

(i) The grids are cast from pure lead to minimize corrosion and growth and are stacked horizontally in a self-supported structure to minimize distortion.

(ii) The grids are conically shaped with grid members designed to grow in such a way as to maintain contact between the grid and active material over the life of the battery.

(iii) A new positive active material, tetrabasic lead sulfate, is used.

Currently, "round cells" are being manufactured by the Industrial Battery Division of Gould Inc. and by the C and D Battery Division of Eltra Corp. for service in the Bell System.

Neither the Pb–Ca nor the "round cell" batteries are suitable for situations where the battery is likely to be deep-discharged since they are prone to lose capacity. In general, their use is restricted to applications where the duration of demand for standby d.c. power is limited to less than one hour. Their low-maintenance characteristics make them the preferred choice in the new electronic exchanges, which are more reliable and require less maintenance than the older exchanges with mechanical switching.

Where a reserve time of greater than one hour is required, batteries with antimonial positive grids are necessary since these can be deep-cycled many times without loss of capacity [2]. Likewise an older version of the lead–acid battery with Planté positive plates can also be deep-cycled [3].

Recent developments in maintenance-free lead–acid battery technology indicate that an all-purpose standby/emergency battery is feasible and, in fact, Gould Inc. is actively working on such a battery. This battery would be all-purpose in the sense of having (i) the low-maintenance float characteristics of lead–calcium standby (and maintenance-free automotive) batteries and (ii) the cycling characteristics of lead–antimony standby and industrial batteries.

This battery would use a hybrid grid system of the type that is being used by Gould in maintenance-free automotive batteries which are maintained on float (2.35 V per cell). These "Calcium Plus" batteries [4] have water losses comparable with those batteries containing calcium grids in both positive and negative plates (see Fig. 1). In addition, Gould recently introduced a low-maintenance, deep-cycle, industrial battery with the similar hybrid grid combination.

Tests are currently being carried out to establish that this hybrid grid combination can be floated at the voltages typical of standby applications prior to the introduction of this battery into the market.

Nickel–cadmium batteries

Apart from lead–acid, nickel–cadmium batteries are the only other secondary batteries in widespread use. These have, however, found only limited application in the telecommunications industry. This is due, in part, to high cost compared with the lead–acid system. The cell voltage of 1.1 - 1.2 V is about half that of a lead–acid cell and twice as many cells are needed to achieve a given voltage, which increases maintenance.

Apart from cost, another disadvantage is that it is difficult to determine the state-of-charge, since the alkaline electrolyte does not change in concentration as the cell is discharged. In the case of a lead–acid cell the concentration of sulfuric acid, and, hence, the density of the electrolyte, decreases on discharge. This variation affords a direct and simple means of state-of-charge indication.

Advanced battery development

In the past two decades a substantial effort has been devoted to the development of new battery systems mainly for use in electric vehicles and for utility standby and load leveling. Some of these battery systems are completely new in the sense of being based on new electrochemical couples (*e.g.*, sodium–sulfur). On the other hand, some are only new in the sense of being an improved version of an old couple (*e.g.*, nickel–iron). This development activity, at least in the U.S., is probably approaching a peak, and within the next few years it will become clear which of the new systems has the best chance of technical and commercial success.

It is unlikely that any of these systems will replace the lead–acid battery for standby and emergency use. However, it is probable that new or improved batteries will find use in the telecommunications industry in areas where batteries are not presently used. Examples could be battery-powered delivery and service vehicles and portable communication devices.

(i) Secondary batteries

A substantial portion of the development work on new battery systems, both in the U.S.A. and overseas, is government funded. The largest fraction of this funding is devoted to secondary batteries where the opportunities for economical energy storage are greatest. In the U.S. in FY 1978 the Department of Energy spent $ 17 million on the development of batteries for electric vehicle and utility load-leveling applications [5].

This government sponsored effort has been categorized as either near-term or long-term with commercialization anticipated within five years and beyond ten years, respectively.

(a) Near-term developments

The near-term batteries are all ambient temperature systems with aqueous electrolytes and are as follows:

Pb/PbO_2	(lead–acid)
Fe/NiOOH	(nickel–iron)
Zn/NiOOH	(nickel–zinc)

All of these are candidates for use in electric vehicles. The thrust for the development of these batteries, none of which is a new system, comes from the need for substantially greater energy and power per unit weight and volume than can be obtained from state-of-the-art secondary batteries.

As the electric vehicle market is in an embryonic stage in the U.S., government funding was considered essential to stimulate the necessary improvements in battery design and performance. The electric vehicle market referred to comprises both the commercial short-haul van and the commuter vehicle markets. In the case of commuter vehicles the minimum performance requirements in terms of range (specific energy) and acceleration (specific power) are more stringent than for commercial vehicles and will probably preclude the use of lead–acid batteries in the commuter market. The status and goals of the near-term batteries for electric vehicle application are listed briefly in Table 2 [6].

The lead–acid battery has a theoretical specific energy of 170 W h/kg whereas that for the Ni/Zn system is 340 W h/kg and for the Ni/Fe system it is 288 W h/kg. Thus these alkaline electrolyte systems have greater potential for achieving a higher practical W h/kg figure. In addition, these systems are more compact than the lead–acid. The main development

TABLE 2

State-of-the-art and goals* of near-term battery development for electric vehicle application

		Lead–acid		Nickel–zinc		Nickel–iron	
		Status	Goal	Status	Goal	Status	Goal
Specific energy**	(W h/kg)	30	40 - 50	70	90	44	60
	(W h/dm^3)	70	70	120	120	90	120
Specific power***	(W/kg)	60	60	90	> 125	90	> 125
Life (cycles)		300	800 - 1 000	300	1 000	> 1 000	> 1 000
Price/energy ($/kW h)		70	40 - 50	–	75	120	60

*Established by Department of Energy [6].
**At C/3 discharge rate.
***At 80% depth-of-discharge.

problems are to achieve adequate cycle life with the Ni/Zn system and a sufficiently low cost with the Ni/Fe system.

The only near-term candidate capable of approaching the development targets for utility load-leveling (10 years life at 70% + efficiency) is the lead–acid battery. However its initial cost of $ 50 - 60/kW h precludes its use in other than a few specialized areas. The Department of Energy plans to fund a 20 MW demonstration load-leveling facility this year to evaluate the benefits of energy storage in the electrical distribution system. DOE is also funding a longer-term program aimed at developing advanced lead–acid batteries with a life of 4 000 cycles over 20 years at a cost lower than state-of-the-art batteries.

(b) Longer-term developments

The main long-term effort in electric vehicle batteries is in the high temperature systems, namely:

Na/S	(sodium–sulfur)
LiAl/FeS$_x$	(modified lithium–sulfur)

Both of these systems are based on low-density reactive elements and have extremely high theoretical specific energies (> 800 W h/kg) compared with the previously discussed systems. These systems have to operate at temperatures in the region of 300 - 500 °C and are capable of high specific power. Also under long-term consideration for electric vehicle application is the ambient temperature zinc–chlorine (Zn/Cl_2) system.

Table 3 lists the present status and the goals of the long-term battery development programs for electric vehicle use. Comparison between the goals for the near-term and long-term batteries in Tables 2 and 3, respectively, shows that the main difference lies in the larger energy storage and power

TABLE 3

Status and goals* of long-term battery development for electric vehicle applications

		$LiAl/FeS_x$		Na/S		Zn/Cl_2	
		Status	Goal	Status	Goal	Status	Goal
Specific energy	(W h/kg)	60	130	88	140	65	130
	(W h/dm^2)	100	300	183	366	–	170
Specific power	(W/kg)	75	160	100	200	60	150
Life (cycles)		1 000**	1 000	200**	1 000	100	1 000
Price/energy ($/kW h)		–	40 - 60	–	60	–	50

*Established by Department of Energy [6]. These goals may change as the scale-up problems become better understood.
**Measured on cells not batteries.

delivery capabilities (on both a weight and a volume basis) of the long term batteries. The cycle life and cost are predicted to be similar in all cases.

The three batteries listed in Table 3 are also considered as candidates for load-leveling application as is the zinc–bromine (Zn/Br_2) battery which is not listed. The Zn/Cl_2 and Zn/Br_2 batteries are similar in concept. In both systems Zn is plated onto an inert electrode substrate during charge and either Cl_2 or Br_2 is liberated. During discharge Zn is anodically dissolved and either Cl_2 or Br_2 is reduced to the anion. The cells differ in the manner in which the molecular halogen is stored external to the cell. Chlorine is stored as chlorine hydrate, which is a yellow solid at 8 °C, whereas Br_2 is stored at ambient temperature by reacting it with a proprietary organic compound to form a stable bromine oil which separates from the aqueous electrolyte.

Both the Zn/Cl_2 and Zn/Br_2 batteries are expected to have relatively low costs and high efficiencies. Because of the complexity of these systems and of their control a large-scale stationary installation such as load-leveling would appear to be the most attractive application.

(ii) Primary batteries

Primary batteries by their nature are more of a consumer item than secondary batteries and, hence, are not likely to find widespread application in the telecommunications industry. However, considerable advances have recently been made in the primary battery area and new batteries are being commercialized. Two systems are of particular interest and will be discussed briefly. These are the zinc–air and the lithium-based systems.

Gould Inc. introduced a zinc–air battery designed for hearing aids earlier this year. This is a button cell designed to replace zinc–mercury cells. The technology is currently being adapted for cells to be used in calculators and electronic watches (with LCD displays). In the longer term, applications are foreseen in long-life, high-reliability equipment such as signaling, computer memory systems and communication devices. Like some of the secondary batteries discussed earlier, the zinc–air battery is not a new system but successful commercialization has been elusive. A better understanding of the physical chemistry of the system and technical innovations were necessary to resolve some of the earlier problems before a practical system could be marketed.

The lithium family of primary cells is being actively developed and cells are now available in small numbers. The common characteristic of this family is that the negative electrode is lithium metal. The cathodes, on the other hand, vary from transition metal halides (CuF_2, AgCl) to sulfides (CuS, MnO_2, V_2O_5) to carbon monofluoride, to soluble species (SO_2, $SOCl_2$). Some cells also have solid electrolytes.

Both the zinc–air and the lithium systems have substantially higher specific energies on both a weight and volume basis than conventional batteries. The lithium systems vary from 200 to 350 W h/kg and from 400 to 1 000 W h/dm^3 (compare data in Table 2). Values for the zinc–air battery are 340 W h/kg and 1 035 W h/dm^3. These figures are approximately twice the energy density of silver and mercury cells and over five times that of alkaline cells.

Conclusions

Despite intensive battery development it is unlikely that the lead–acid battery will be replaced as the prime source of standby power. Improvements in lead–acid technology are expected to result in an all-purpose battery, *i.e.*, one which has (i) the low-maintenance float characteristics of batteries with Pb–Ca grids and (ii) the deep-cycle ability of batteries with Pb–Sb grids. Such a battery would be usable in all types of standby use as well as in regular industrial applications.

The main impact of the advanced battery development programs in the telecommunications industry is likely to be in areas where batteries are not at present used. Battery-powered delivery and service vans is one example. Such vans will have the following advantages: lower life cycle costs than comparable vans with internal-combustion engines; clean, non-polluting operation; quietness; reliability. The development of small, moderately priced primary and secondary cells with higher specific energies than the presently available portable batteries will also probably lead to new applications in portable communication devices.

References

1 D. E. Koontz, D. O. Feder, L. D. Babusci and H. J. Luer, Reserve batteries for Bell System use: design of the new cell, *Bell System Tech. J.*, 49 (1970) 1 253.

2 A. Ausderau, Stationary lead batteries in Switzerland, *Proc. 4th Int. Conf. on Lead, 1971*, Lead Develop. Association, London, p. 12.
3 P. J. Edwards and B. W. Baxter, The use of Planté cells by the British Post Office, *Proc. 4th Int. Conf. on Lead, 1971*, Lead Develop. Association, London, p. 1.
4 A. Sabatino, Update III: new alloy introduces second generation of maintenance-free batteries, *Battery Council International, 1977 Meeting*, London.
5 R. W. Shivers, paper presented at the DOE Electric/Hybrid Vehicle Program Contractors Coordination Meeting, December 6, 1977.
6 U.S. Department of Energy, Second Annual Battery and Electrochemical Technology Conference, June 5 - 7, 1978, Arlington, Virginia.