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THE LEAD/ACID BATTERY INDUSTRY IN INDIA — MAJOR APPLICATIONS

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Introduction

The world lead/acid battery industry has been in operation ever since Gaston Planté demonstrated the first lead/acid accumulator in 1860. Over the years, the system has found commercial use in various applications such as railways, telephone exchanges, cars and ships. However, more progress has been made during the last 25 - 30 years than in all the previous years taken together. The major factors influencing this activity have been the increasing demand for: (i) higher cranking power for automobiles; (ii) standby power sources for telegraphic services, telex facilities, computers, emergency lights, etc.

The aim of this paper is to highlight some of the important areas of the Indian lead/acid battery industry in the light of the advances made, the present problems, and what needs to be done. Three categories of battery will be considered, namely: (i) motive power (for electric vehicles used in public transportation systems); (ii) automotive (SLI); (iii) stationary (for railways, telecommunications, UPS for computers, power generation, etc.).

The Indian lead/acid battery industry

The Indian industry is a mix of three different sectors:

(i) large-scale sector — approximate sales turnover Rs. 1.60 billion;
(ii) medium-scale sector } approximate sales turnover Rs. 1.15 billion.
(iii) small-scale sector }

Table 1 shows the major large-scale battery manufacturers.

TABLE 1

Major large-scale battery manufacturers in India

Chloride India Limited, Calcutta
Standard Batteries Limited, Bombay
Amco Batteries Limited, Bangalore
Willard India Limited, New Delhi
UB-MEC Batteries Limited, Bangalore
Nicco Batteries Limited, Surajpur; under project stage.

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Electric vehicle (EV) applications

The EV industry for public transportation in India has been popularised in the form of Electravans. These EVs are made by Bharat Heavy Electricals Ltd. (BHEL) at Bhopal. Table 2 presents the basic cost structure for the major sub-systems of the vehicle for a production schedule of 500 per annum. The operational characteristics of the vehicle are given in Table 3. The success of this Electravan depends heavily upon the availability of batteries that have a high energy density and a long service life, as well as being cost effective.

Although efforts have been made at various laboratories towards the development of a high energy-density battery, to date, there has been no significant progress. The present energy density is 32 W h kg^{-1}. The cycle life is over 400 for journeys of average length of 60 - 65 km to 80% depth-of-discharge. However, cell replacements have been made within this period of service.

It should be noted that high energy density is obtained generally at the expense of cycle life, although considerable effort is being made to minimise this dependency. Ambient temperature also has a bearing on cycle life. Therefore, battery life in tropical conditions will be significantly less than that in more temperate climates. These factors are to be considered when drawing up battery specifications.

TABLE 2

Cost analysis of Electravan (1986 budget prices)

Bought in equipment		*(in Rs.)*
Battery		42 500
Chassis		44 500
Charger		9 600
Body		35 000
	Sub-total	131 600
BHEL-made equipment		
Controller		18 900
Traction motor		20 000
Isolator contactor and misc. items		6 100
	Sub-total	45 000
	TOTAL	176 600
Complaint & price variation reserve @ 4.5%		7 900
		184 500
Commercial & administration charges @ 18%		33 200
Ex-works sale price		217 700

TABLE 3

Operational characteristics of Electravan

Unladen weight (kg)	2800
Payload (persons)	15
GVW (kg)	3800
Wheelbase (mm)	3000
Maximum speed (km h^{-1})	40
Range per charge (target) (km)	more than 75 (achieved: 60 - 65)
Energy consumption (kW h km^{-1})	0.5
Traction motor (kW)	15, separately excited d.c. motor
Controller	transistorised chopper controller, 96 V, 200 A
Battery	96 V, 300 A h (*C*/5), lead/acid battery (6-V units).
Battery charger	off-board type
Battery life (target)	1000 cycles (achieved: 400+ but stil continuing with some cell replacements)

The development of a higher energy-density battery would involve the following technology.

(i) Thin, lightweight plastic containers for housing the battery elements. For smaller batteries, the preferred route would be to use 3-cell or 6-cell monoblocs so as to avoid the need for a separate battery tray.

(ii) Thin plates (preferably tubular) to increase the utilization of plate material. This would require corrosion-resistant alloys for the grids/spines and a suitable casting technology for these grids. In addition, the filling of thinner tubes with oxide would require special processes and equipment.

(iii) Thin separators with high porosity and small pore size, but having adequate mechanical strength to withstand stresses encountered during cycling.

(iv) Negative-paste expanders to withstand electrolyte of high specific gravity, *e.g.*, 1.300 - 1.320.

In addition, development work in the following areas would be required to improve (*i.e.*, lessen) maintenance requirements:

(i) lid design compatible with the autofil system for *in situ* topping up of batteries;

(ii) special battery chargers suitable for fast charging (around 8 h) without reducing battery life. An in-built solar charger could prove useful.

SLI applications

Estimates of vehicle demand in India for 1985 - 1990 (Table 4) indicate excellent original equipment and replacement markets for SLI batteries. Of the total market, 41% of the batteries are manufactured in the large-scale

TABLE 4

Vehicle demand estimates (1985 - 1990)

Year	Commercial vehicles		Cars	Jeeps	Total
	Heavy/Medium	Light			
1984 - 1985	75 000	31 000	80 000	28 000	214 000
1985 - 1986	82 000	37 000	91 000	31 000	241 000
1986 - 1987	91 000	44 000	104 000	34 000	273 000
1987 - 1988	100 000	52 000	118 000	38 000	308 000
1988 - 1989	110 000	67 000	135 000	41 000	353 000
1989 - 1990	120 000	75 000	154 000	45 000	394 000

sector, and 59% in the medium- and small-scale sectors. There is only a very limited choice of battery types, but the trend is towards "maintenance-free" systems. The latter batteries have low gassing rates.

Gassing (with consequent loss of water) is primarily caused by impurities, in particular antimony. During corrosion of lead–antimony positive grids, antimony is preferentially dissolved and migrates to, and deposits at, the negative plate. As a result, the hydrogen overpotential on lead is lowered (*i.e.*, gassing voltage is lowered) and the electrolytic decomposition of water commences before the battery is fully charged. Also, as antimony deposits on the negative plate, the cell voltage is lowered. Consequently, the current flowing through a battery being charged with a constant-potential source, increases, leading to further overcharging and premature shedding of the positive-plate material. On the other hand, antimony provides the grid with good mechanical strength and gives better adhesion and cohesion of the positive-plate material during charge/discharge cycling.

Low-antimony alloys. The grid alloy used in India normally contains between 3.5 wt.% and 5 wt.% antimony. The major manufacturers, however, have moved towards reduced levels, generally between 2.5 wt.% and 2.8 wt.%. It should be noted that batteries produced with reduced levels of antimony are categorised as "low-maintenance", and not "maintenance-free". These batteries normally exhibit a service life of 2 - 2.5 years.

Lead–calcium–tin alloys. St Joe Minerals Corporation (U.S.A.) and NL Industries (U.S.A.) have reported the properties of a lead-alloy system having 0.6 - 1 wt.% calcium.

Lead–calcium batteries comfortably meet the maintenance-free criteria as the gassing rates are similar to pure lead grids and the gassing currents do not increase with service life. However, these alloys have disadvantages:

(i) difficult to cast; requires special machines that are currently not available in India;

(ii) special moulds required;

(iii) special separators with pore size 1 - 5 μm to be used;

(iv) cannot be smelted in the same furnace as the lead–antimony alloys for lead recovery;

(v) calcium master alloy has to be imported;

(vi) poor charge-acceptance characteristics;

(vii) overcharge cycling ability low.

Recent research by RSR Corporation (U.S.A.) has shown that castability can be improved and drossing reduced by adding aluminium to the melt. Nevertheless, it is unlikely that lead–calcium alloys will find easy entry into Indian markets. It is possible that lead–calcium batteries could be introduced into newer types of vehicles with modified recharging systems, provided separate smelting arrangements are followed during lead recovery.

Lead–strontium–tin alloy. This alloy was developed by Globe Union in the U.S.A. (now Johnson Controls). The claimed advantages are:

(i) easier to cast and handle with less dross and scrap;

(ii) wider manufacturing tolerances;

(iii) much cheaper than antimony.

However, the technology is not yet available in India.

Lead–cadmium–antimony alloys. A hybrid combination of a Pb–Cd–Sb positive grid (Sb: 1.5 - 1.8 wt.%, Cd: 1.2 - 1.5 wt.%) and a Pb–Sn–Ca negative grid has been popularised as "Calcium plus" by Gould in the U.S.A. However, experience has shown that such Pb–Cd–Sb grids are difficult to cast crack-free. Separate trials with Na and Ag as grain refiners have been made, but with no appreciable success. Further, cadmium is a hazardous material at the lead recovery stage and will not be readily acceptable by the Indian battery industry.

Development work. It is suggested that development work be carried out on an alloy formulated by NL Industries in the U.S.A. This alloy is easy to cast, has low drossing losses and is harder than a 2.5 wt.% antimonial alloy. The approximate composition is: 1.8 wt.% Sb, 0.18 wt.% As, 0.2 wt.% Sn, remainder: lead and small amounts of grain refiners. Use of this alloy would result in low-maintenance batteries for the Indian market.

Stationary batteries

The lead/acid system has maintained its commanding position in the Indian stationary battery market despite competition from the nickel/cadmium system. Lead/acid batteries are preferred for the following reasons:

- initial cost low
- higher residual value at end of service life
- space required less as voltage is 2 V compared with 1.2 V for nickel/cadmium
- greater variety of types and capacities available

- better voltage stability
- lower maintenance — requires less topping up and electrolyte lasts the life of cell; electrolyte of nickel/cadmium has to be replaced periodically and the cost is fairly substantial
- A h efficiency is 91% compared with 80%
- fewer cells to be topped up
- state-of-charge easily determined
- greater W h efficiency
- capable of taking heavy surge currents
- superior low-temperature performance
- easily repairable.

By comparison, the advantages of nickel/cadmium batteries are as follows:

- long life
- mechanically very strong and resistant to damage under extremes of shock or vibration
- may be used for a variety of duties over wide ranges of temperature
- capable of delivering a high proportion of the capacity at markedly diverse discharge rates
- ability to stand idle for long periods in any state of charge with negligible loss of charge
- excellent charge-acceptance characteristics.

The demand for batteries in stationary applications is best seen in context by examining the Indian Plan figures for 1985 - 1990 in telecommunications, UPS systems, power generation and railways (Tables 5 - 9). The data show potentially enormous markets for batteries in these applications.

TABLE 5

Target plan for telecommunication services in India for 1985 - 1990

Item	Target*
Direct exchange lines ($\times 10^5$)	39.98
Switching capacity lines ($\times 10^5$)	46.12
Trunk automatic exchanges	54
TAX stations	51
TAX capacity	173 670
Telex connections	55 457
Long-distance public telephones	30 717
Coaxial cable systems (km)	26 920
Microwave systems (km)	33 698
Fibre optic systems (km)	5 144
Satellite earth stations	93

*Rs 40.1 billion outlay.

TABLE 6

Estimated demand of UPS systems per annum in India

Industry/sector	Ratings range (kV A)	Requirement
Computer installations	1 - 2	100
	5 - 10	50
	> 10	20
Hospitals	1 - 2	100
	5 - 10	30
	10 - 30	250
Defence	10 - 20	250
	50 - 100	50
P&T communications	50 - 100	100
	> 100	20
Process/industry	10 - 50	100
	50 - 100	60
Oil sector	> 100	10
Power sector	5 - 10	30
	10 - 50	20
Railways	1 - 5	30
Nuclear power plants	1 - 5	50
Space	5 - 20	50
Academic institutes and others	1 - 10	100

Note: there are about 800 computers greater than the super-mini types in India of which about 320 have UPS facilities.

TABLE 7

Target plan for power generation (MW) in India for 1985 - 1990

Power type	Installed capacity	Target
Hydro	16 189	20 000
Thermal	32 276	44 293
Nuclear	1 330	1 800
Total	49 795	66 093

TABLE 8

Target plan for substation power in India for 1985 - 1990

Substation type (kV)	Numbers
400	49
220	135
132	1000
66	900

TABLE 9

Target plan for railways in India for 1985 - 1990

(A) Stock

	Target numbers	Present numbers
Locomotives	3500	1 370
EMU	950	500
Coaches	6970	30 000
Diesel engines	1235	n. a.

(B) Signalling and telecommunication facilities available at about 5000 stations each having 60 cells ranging from 16 A h to 400 A h.

(C) Railway electrification

Year ending	Total (km)		Running track (km)		Total track (km)*	
	electrified	total available	electrified	total available	electrified	total available
1985 - 1986	6517	61 836	12 367	77 153	16 086	106 502

*This includes track in yards and sidings.

Research

Unfortunately, very little lead/acid battery research is being carried out by the industry itself in India. This situation arises partly because the industry is highly competitive and cost conscious, which does not encourage research expenditure, and partly because it has been possible in the past to build a product, without extensive research, that has been adequate for most applications. However, it has become increasingly evident that the required increase in performance from modern batteries cannot be expected from engineering changes alone. More emphasis should therefore be placed on understanding fundamental operational processes with a view to developing better batteries.

Conclusion

The Indian lead/acid battery industry has adequately met the growing needs of various power applications. However, the more demanding requirements of high energy and long life, as well as maintenance-free operation, encourage the introduction of newer types of batteries.

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