Journal of Power Sources, *28* (1989) 173 - 180

DEVELOPMENT OF SEALED LEAD/ACID BATTERIES FOR SOLAR POWER SYSTEMS

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Introduction

In many countries, there is growing concern over the deterioration of the environment on a global scale. To ameliorate this problem, increasing efforts are being made in the research and development of renewable (or oil-alternative) energy sources. In particular, solar power generation — the cleanest source of energy and one that is derived directly from the sun — is attracting considerable attention and is already being used in various parts of the world, especially in remote areas.

Photovoltaic cells used for solar power systems can only generate electricity when the sun shines. The electricity cannot be stored in the cells themselves and, therefore, solar power systems use rechargeable batteries so that power can be supplied continuously, both day and night. Lead/acid batteries are the popular choice of energy storage media.

In the early stages of the development of solar power systems, the cost of the solar panels was as high as JY 5000 (U.S. $ 35.17) per peak-watt (W_p), see Fig. 1. By contrast, the cost of the storage batteries was less significant. Since then, however, the cost of solar panels has been decreasing (technological innovations have caused advances in performance and manufacture), whilst that of the storage batteries, as a proportion of the

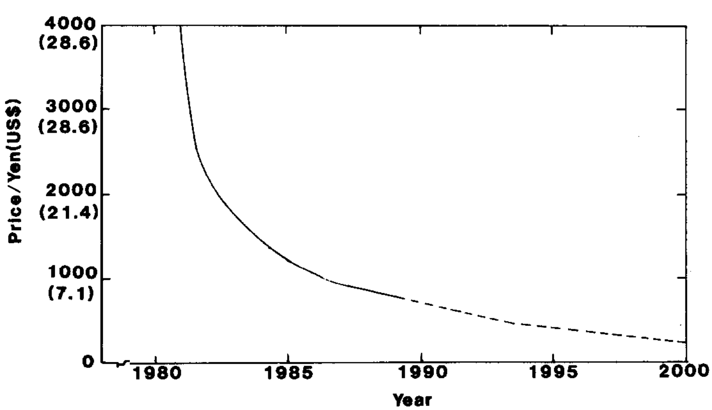

Fig. 1. Price of photovoltaic (solar) modules.

0378-7753/89/$3.50

TABLE 1

Lead/acid batteries for various solar power systems

Battery type	Development/production period	Application
PS-TL	1979 - 1989	radio station railway station
CS-L	1980 - 1989	power generation station
12CT	1981 - 1989	street lights small power systems
Sealed (12CTE)	1984 - 1989	radio station, buoys, small power systems

total system cost, has been increasing. Thus, it has become important to reduce the system cost component associated with the batteries.

By and large, the characteristics of solar power systems are easier to maintain than those of other power-generating systems. This feature encourages the use of solar power systems in remote areas such as mountains, islands and deserts. In these applications, it is essential that the storage batteries require minimal maintenance throughout their service life. Since 1979, the Furukawa Battery Co. Ltd. has developed specialist and fully-sealed (*i.e.*, 'maintenance-free') lead/acid batteries for various solar power systems (Table 1). The general design and performance characteristics of these batteries are discussed in this paper.

Required characteristics of batteries for solar power systems

The specific characteristics required by batteries for solar power systems depend upon the given application, environmental conditions, load profile, etc. In general, however, the following criteria are important:

- long service life
- easy maintenance
- low self-discharge
- low price

Each of these factors is addressed separately in the following discussion.

Service life

Storage batteries used in solar power systems can only be charged during the daytime; they supply electric power during periods of inclement weather and at night. In other words, the charge/discharge pattern is irregular. Furthermore, the batteries may undergo long periods in a less than fully-charged state. Battery service life under such conditions is somewhat similar to that experienced under other cycling applications. To cope with this demand, batteries for solar power systems must have good low-rate discharge characteristics. In general, a service life of 5 years, or longer, is required.

Maintenance

Solar power systems are particularly appropriate for generating electricity in remote areas, *i.e.*, in locations where routine maintenance and inspection are difficult to perform. It is therefore very important for the interval between inspections to be made as long as possible. Among the major components of a system, the solar panels and controllers are relatively trouble-free. Conventional batteries, on the other hand, require periodic attention, particularly in terms of water addition and equalization charging. There has been pressure, therefore, to develop maintenance-free (or fully sealed) batteries for solar applications. Such batteries are not expected to require any maintenance throughout their anticipated service life.

Self-discharge

During the early development of solar power generation, the reserve capacity of the battery system was necessarily set at a high value, *i.e.*, it was assumed that there would be instances of zero sunshine for a large number of consecutive days. Such a strategy placed extra significance upon the self-discharge rate of the batteries. The level of reserve capacity is much lower in present systems because the reduction in the cost of solar panels has allowed more panels to be included in a given design, *i.e.*, there is now a better match between the supply of, and the demand for, power. Self-discharge of batteries has correspondingly decreased in importance. Nevertheless, the phenomenon does constitute a waste of energy and should be kept to as low a rate as possible.

Price

Reduction in system cost is the key to expanding the use of solar power supplies. The target in the case of solar panels is to halve the 1986 price by the early 1990s. A similar cost-cutting exercise is being applied to the batteries. It is difficult, however, to make significant savings on conventional batteries. Thus, efforts are being directed towards developing cheaper, purpose-built batteries for solar systems. Other benefits will be obtained by having batteries operate successfully to deeper depths of discharge and by improving the efficiency of utilization of the active material in the plates.

Present status of Furukawa sealed batteries purpose built for solar applications

For some years, Furukawa Battery Co. Ltd. has been supplying non-sealed batteries with a water-maintenance interval five times longer than that of other batteries. At the same time, the development has taken place of fully-sealed units that are designed specifically for solar power service. The

TABLE 2

Comparison of lead/acid batteries produced by Furukawa Battery Co. Ltd.

Item	Battery type			
	PS-TL	CS-L	12CT	12CTE
Application	shallow discharge	deep discharge	small systems	small systems
Plate construction	pasted	tubular	pasted	pasted
Grid material				
positive	Pb–low Sb	Pb–Sb	Pb–Sb	Pb–Ca
negative	Pb–Sb	Pb–Sb	Pb–Sb	Pb–Ca
Life (years)	10 (10% DOD)[a]	10 (25% DOD)	5 (30% DOD)	5 (30% DOD)
Maintenance	good	medium	medium	maintenance-free
Self-discharge (% per month)	5 - 6	8 - 10	8 - 10	<2.5
Energy density[b] (W h kg^{-1})	29	18	40	42
System adaptability	large	large	small-medium	small-medium
Discharge rate (h)	500	10	100	100
Capacity range (A h)	50 - 2600	130 - 2000	40 - 200	40 - 200
Price	medium	high	low	low
Application	radio station for railway signals	power generation	street lights and clocks; small power systems	street lights and clocks; small power systems; buoys

[a]DOD = depth of discharge.
[b]From tests on 200 A h batteries.

types and characteristics of the various storage batteries produced by Furukawa Battery Co. Ltd. are listed in Table 2.

As mentioned above, the characteristics required by batteries for solar power applications are complicated and are strongly load-dependent. The approaches taken by Furukawa Battery Co. Ltd. to meet these requirements are as follows.

Charging

Battery charging must be carried out using a small current, even after a deep discharge duty. This criterion requires suppression of passivating films that form at the lead–calcium grid/active-material interface on positive plates; this is achieved by the use of certain proprietary additives. Further additives are used to suppress the dissolution of lead sulphate into the electrolyte.

Service life

The major causes of failure in sealed batteries are growth of the positive plate (which results in internal short-circuiting) and shedding of active material from the positive grid. The first of these two problems has been overcome by including a saddle-shaped construction at the foot of the grid to absorb the plate growth (see Fig. 2). The second problem — shedding of active material — has been restricted by using tight plate-group assemblies.

Self-discharge

The rate of self-discharge has been lowered to a minimum by the use of special lead–calcium alloys in both the positive and negative plates. The present level of self-discharge is 0.1% per day, or 20 - 25% of the normal rate.

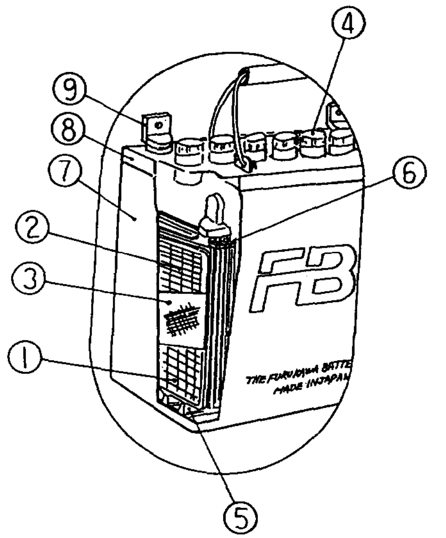

Fig. 2. Schematic of sealed lead/acid battery design: (1) positive plate; (2) negative plate; (3) separator; (4) safety valve; (5) plate growth absorbing saddle; (6) shorting prevention comb; (7) container; (8) cover; (9) terminal.

TABLE 3

Design criteria for sealed lead/acid batteries (type 12CTE)

Positive plate	pasted (Pb–Ca grid)
Negative plate	pasted (Pb–Ca grid)
Separator	glass-fibre unwoven fabric
Container	ABS resin
Electrolyte	dilute H_2SO_4
Capacity range	40 - 200 A h (*C*/100 rate)
Capacity (%)	
C/100	100
C/48	100
C/24	95
C/10	90
Self discharge	<2.5% per month
Water addition	not required
Expected life	~5 years at 30% DOD

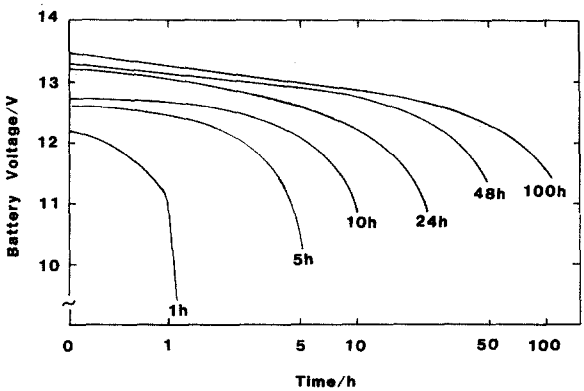

Fig. 3. Discharge characteristics at 25 °C for sealed lead/acid battery.

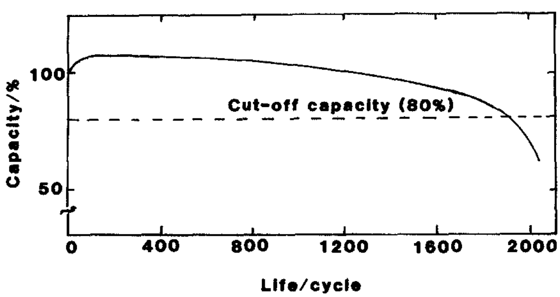

Fig. 4. Cycle life at 30 °C and 30% DOD for sealed lead/acid battery.

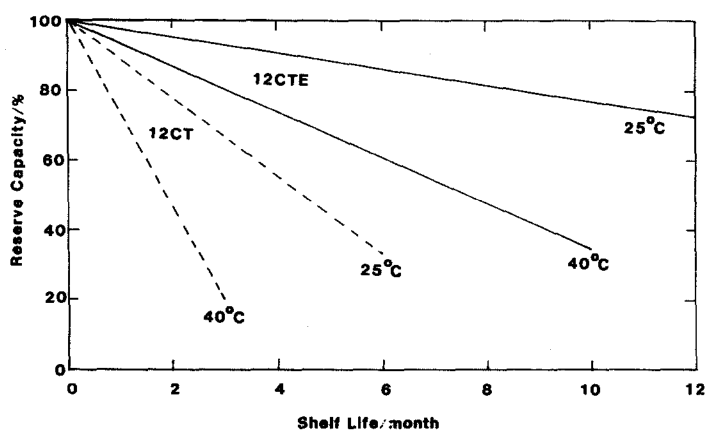

Fig. 5. Self-discharge characteristics for sealed (12CTE) and unsealed (12CT) lead/acid batteries.

Maintenance

With the adoption of a sealed design, the batteries do not require any water addition until the latter stages of their expected service life.

Cost

As the sealed batteries are still at an early stage of development, it is difficult at present to draw firm conclusions on the cost comparison with conventional units. It is expected, however, that the current price of the sealed batteries will fall as better materials are found (*i.e.*, for containers and separators) and productivity is improved by increase in the numbers produced (*i.e.*, mass production techniques).

Cell design

Details of the construction and specifications of the sealed batteries are given in Table 3 and Fig. 2.

Operational characteristics

The performance of the sealed batteries in terms of discharge characteristics, cycle life, self-discharge, gas-recombination efficiency and temperature is given in Figs. 3 - 7, respectively.

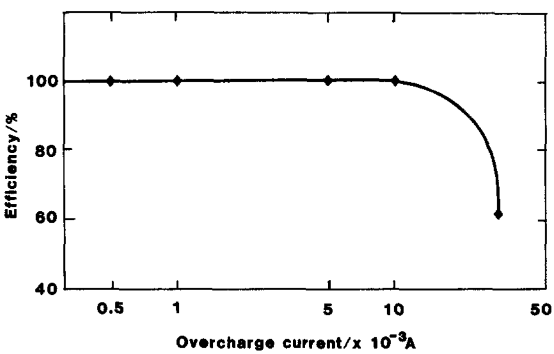

Fig. 6. Gas-recombination characteristics of sealed lead/acid battery.

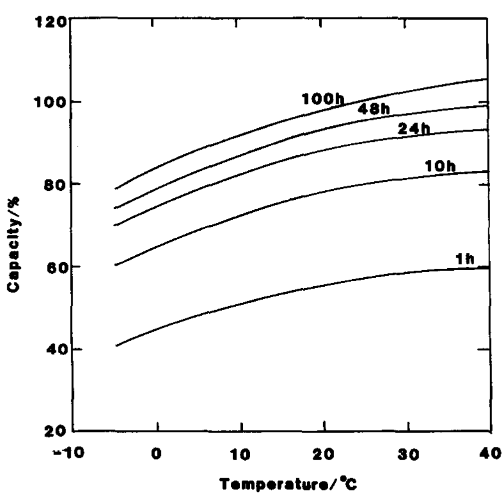

Fig. 7. Influence of temperature on capacity of sealed lead/acid battery.

Conclusions

The suitability of sealed lead/acid batteries, developed by the Furukawa Battery Co. Ltd., for solar power application has been demonstrated by both laboratory and field tests. With increasing concern over environmental problems emanating from the use of fossil fuels in power generation, it is anticipated that there will be a strong demand in the near future for solar power systems incorporating sealed lead/acid batteries for the storage of energy.