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# SMALL-SIZED SEALED LEAD/ACID BATTERIES

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## Introduction

Conventional, flooded lead/acid batteries have higher output voltages than those of other types and are capable of being discharged at higher currents On the other hand, the operation of flooded batteries is accompanied by certain service problems such as acid spray release, electrolyte leakage and the need for periodic water addition. In order to overcome these operational difficulties, considerable effort has been directed [1 - 4] towards the development of sealed lead/acid batteries.

Work at Yuasa Battery Co. Ltd. has resulted in the production of small-sized, sealed, lead/acid batteries. These are sold under the brand name of NP batteries and present models exhibit good performance under both cycling and float conditions. There are twenty-two different designs in production, they have capacities ranging from 0.7 to 65 A h and output voltages between 4 and 12 V The sales of these batteries have shown strong growth (Fig 1), especially during the past two or three years. Applications include· portable appliances; emergency lighting, computer (*e g*, UPS systems [5]) and communications (*e g*, telephone) power back-up In 1981, Yuasa established a manufacturing plant in South Wales, U.K., to serve as a base for European markets [6].

## Development of sealed (NP series) batteries

The development of the NP series of batteries has proceeded in three stages

### *First-generation NP batteries*

The first batteries (NP3-6 type) appeared in 1965 and were designed as power sources for small-sized electrical appliances such as portable TVs, tape recorders, etc. There followed five more models having capacities in the range 1 - 8 A h. The cell design is shown in Fig. 2. It can be seen that the incorporation of very thin, synthetic resin (Yumicron®) separators allowed the use of highly porous glass mats that, in turn, minimized the amount of free electrolyte. The lower portion of the vent plug was filled with glass mat and the upper portion was covered with a reversible safety valve. Acid spray was suppressed by using a specially designed charger that restricted the end-

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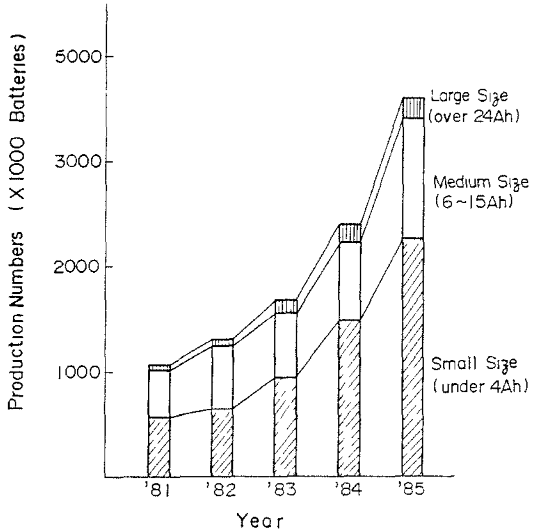


Fig 1 Production of NP-type sealed lead/acid batteries

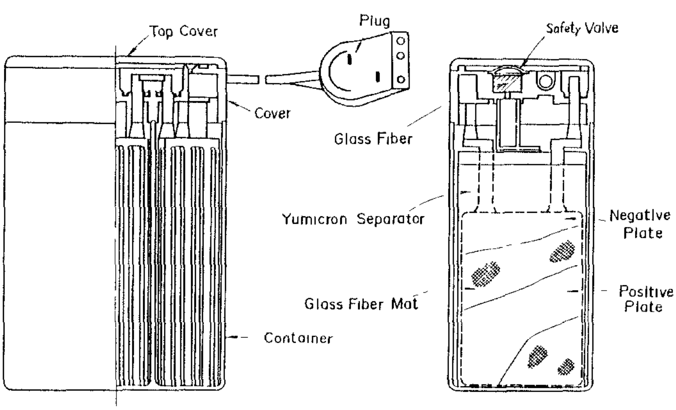


Fig 2 Sectional view of first-generation NP3-6-type sealed lead/acid battery

of-charge current to a low value Sealing the battery and plating the lead–antimony grids with pure lead each served to decrease the rate of self-discharge, and thus allowed batteries to be kept for long storage periods when filled with electrolyte

*Second-generation NP batteries*

The development of sealed batteries for use as power sources for fire alarms, emergency lights, etc , commenced around 1970 In this type of service, the battery is maintained in a charged state (*i e* , "float service") and is required to deliver electrical power in times of emergency The batteries were second-generation NP types and were known as the NP3-6A series [2]

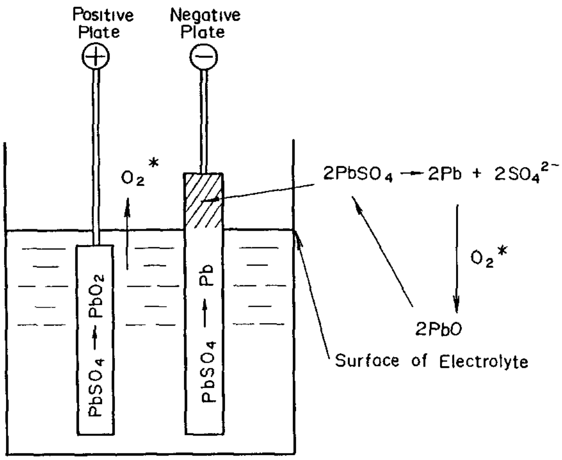


**Fig 3 Schematic of gas absorption mechanism of second-generation NP-type sealed lead/acid batteries**

A total of four models was produced having capacities between 3 and 8 A h. In order to restrict gas generation during float charging, the negative plates were exposed above the electrolyte level so that the oxygen evolved at the positive plate could react with the negative active material (Fig. 3).

The use of a lead–calcium alloy for the grids in place of lead–antimony reduced gas generation. Both factors — new cell design and new grid alloy — eliminated the need for topping up during the operational life of the batteries. Other improvements in design included reduced electrolyte leakage and easier handling

*Third-generation NP batteries*

Whilst second-generation NP batteries gave good service under float conditions, their performance under cycling use was poor This was because a non-conductive layer (*i e* , $PbSO_4$) irreversibly formed on the surface of the lead–calcium grid alloy during deep-discharge operation. Further, repeated charge/discharge cycling resulted in the softening and shedding of positive-plate material Each phenomenon shortened battery life

Third-generation NP batteries have been developed for use under both float and charge/discharge service (Fig 4) Twenty-two models have been introduced into the market and have capacities ranging from 0 7 to 65 A h The grids are made from a lead–calcium–tin alloy which suppresses the formation of the non-conductive layer observed in the second-generation batteries. Microfine glass-fibre mat is used for the separator material and also assists in the retention of the positive-plate material The separators are highly porous and give an excellent absorption of acid Therefore the oxygen gas generated at the positive plates easily migrates to the negatives and is reduced there to water by the gas recombination mechanism. Unlike the second-generation NP batteries, the height of both the positive and negative

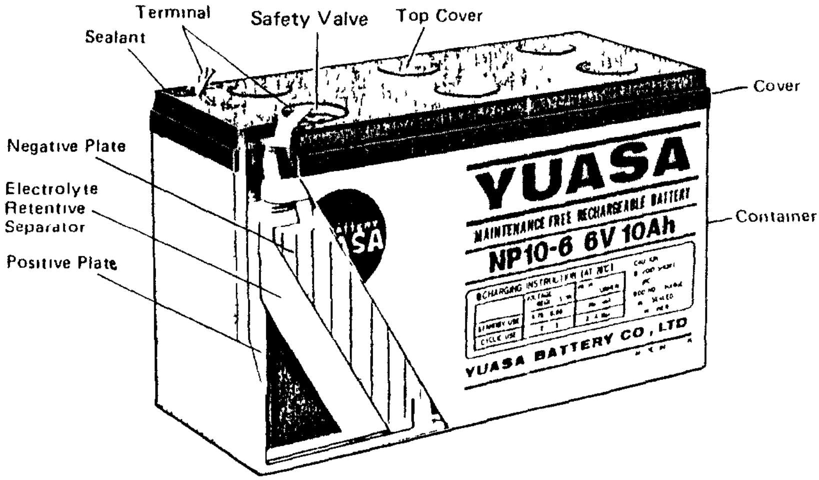


Fig 4 Construction of third-generation NP-type sealed lead/acid battery

plates in the third-generation types is the same This results in an increased capacity per plate and, hence, an increase in the volumetric energy density (W h $l^{-1}$) of the battery

## Performance characteristics of present (third-generation) sealed lead/acid batteries

*Gas absorption*

The ability to absorb gas increases with decrease in the volume of free electrolyte Figure 5 gives the percentage loss of water from the electrolyte (referred to the initial volume) at various overcharge currents It can be seen that the greater is the overcharge current, the greater is the loss of water The relationship between the reduced volume of electrolyte and the battery capacity is presented in Fig 6. The data show that there is no noticeable

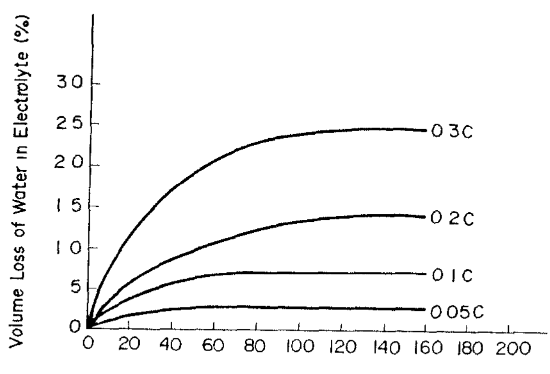


Fig 5 Loss of water from NP-type sealed lead/acid batteries during overcharge at 25 °C

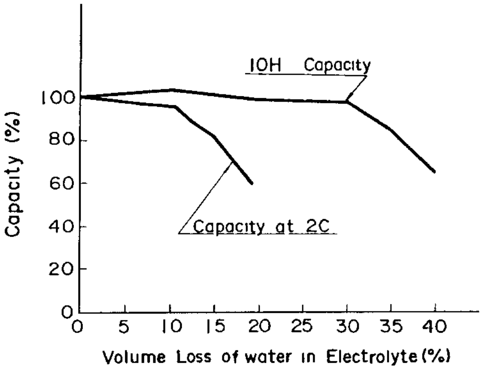


Fig 6 Capacity *vs* water loss of NP-type sealed lead/acid batteries at 20 °C

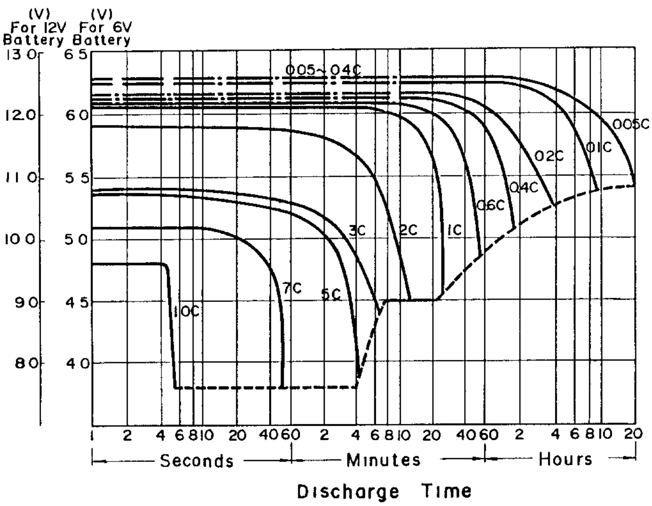


Fig 7 Discharge curves for NP-type sealed lead/acid batteries at 20 °C

drop in capacity at low discharge rates (*e g*, $C/10$) until about 30% of the water has been lost. By comparison, there is a marked fall off in capacity at high rates (*e g*, $2C$) when the loss of water is only 10%. Therefore, batteries undergoing high discharge rates are best operated at small overcharge currents.

*Discharge characteristics*

The discharge performance of third-generation NP batteries at various discharge rates is shown in Fig. 7 Through the use of microfine glass-fibre mats with low electrical resistance and of acid with high specific gravity, the batteries are seen to exhibit superior voltage characteristics and to offer a performance that is satisfactory for a wide range of services involving low to high rates of discharge. Recently, H-type designs have been introduced with even better high-rate discharge performance (Fig 8) For example, whereas a standard NP battery sustains a 13 min discharge at the 2C rate, the corresponding output for an H type is 23 min

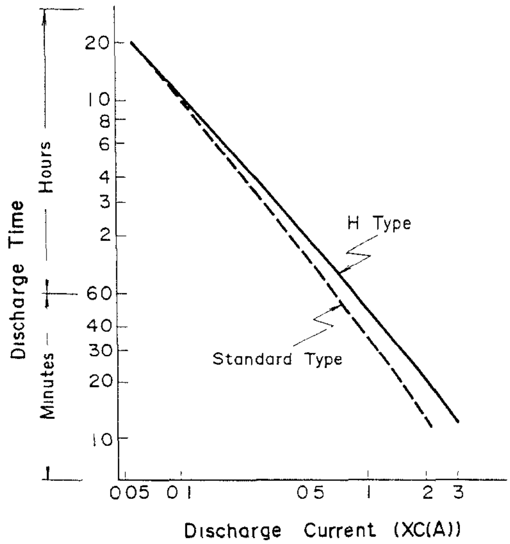


Fig 8 Discharge performances of standard NP-type and H-type sealed lead/acid batteries at 20 °C

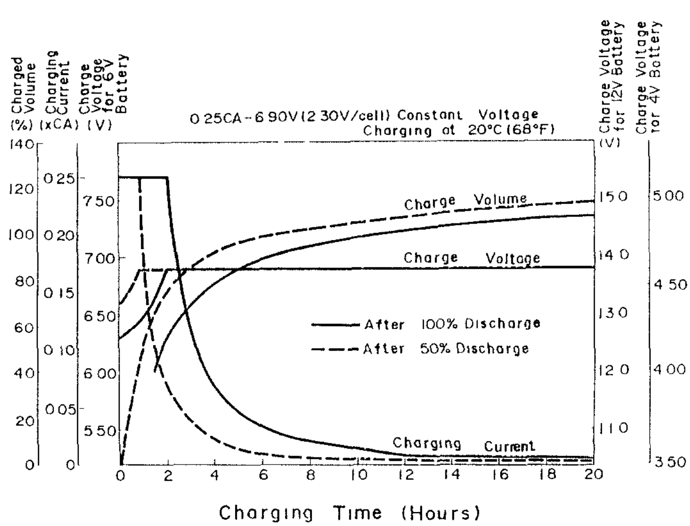


Fig 9 Charge characteristics of NP-type sealed lead/acid batteries

*Charge characteristics*

The current during the final stage of charging NP batteries should be very low so that the evolved oxygen is effectively recombined to water. In order to achieve this condition, a constant-voltage charging method should be applied. Figure 9 shows a typical example of the charge characteristics of NP batteries under float service. It can be seen that the batteries can be fully recharged in about 10 and 20 h from a 50 and a 100% DOD state, respectively. Charging can be accomplished using inexpensive equipment.

*Life characteristics*

In float use, the battery life decreases with increase in the ambient temperature (Fig. 10). In cycle service, battery life decreases with the depth-of-discharge (Fig 11)

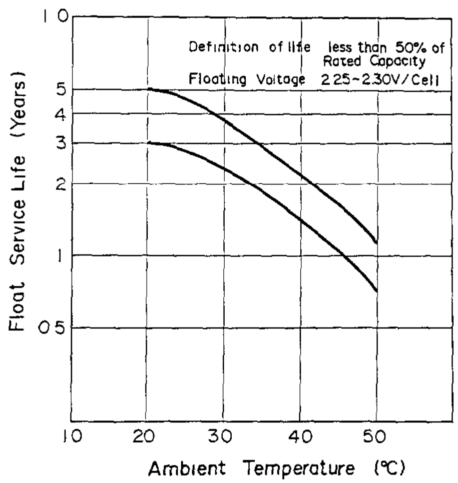


Fig 10 Float service of NP-type sealed lead/acid batteries as a function of ambient temperature

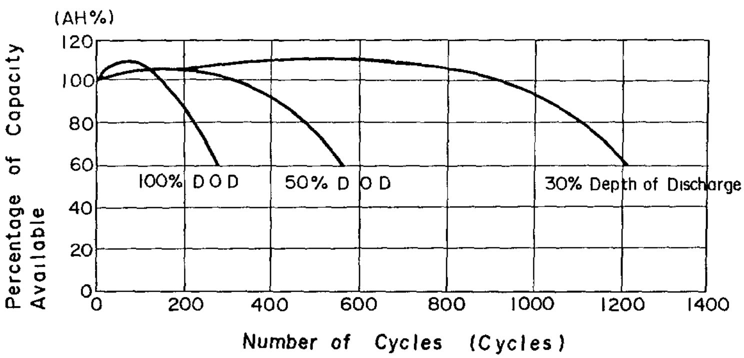


Fig 11 Cycle life of NP-type sealed lead/acid batteries as a function of depth-of-discharge Cycling conditions discharge current = 0 17 *C* A, final voltage = 1 7 V/cell, charge current = 0 09 *C* A, overcharge = 125% of discharge capacity, temperature 20 - 25 °C

## Conclusions

The development of sealed (NP) lead/acid batteries has greatly increased the use of cordless, small electronic appliances This is due to the maintenance-free operation of the batteries and their favourable economics In addition, unexpected applications are emerging, and these demand the further development of such batteries This is the goal of future efforts at the Yuasa Battery Co Ltd

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