Review

The Secondary Battery Industries in Japan

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Received July 1, 1965

1. Brief History and Recent Situations of Japanese Secondary Battery Industry

1.1 Brief History

The definition of secondary batteries in this report is limited in the field of lead-acid storage batteries and alkaline batteries including Edison-type, Jungner-type and sintered-type. The silver-zinc batteries are used for particular applications. However, they are excluded since their history is short and their production and applications are limited.

1.1.1. Industry of lead-acid storage battery

The industrial research of lead-acid storage battery in Japan was initiated in 1895 by Mr. Genzo Shimazu. During the period of 1912 to 1918, Japanese major battery manufacturers were established. Therefore they have the history over 50 years. However, the actual commercial production started in 1930. The progress in the production in Japan is shown in Fig. 1. It is classified into five periods. The industrial characteristics for each period are briefly explained as follows.

(1) Before World War II The procurement of batteries for military and railroad use was most active and the automotive batteries except for military applications were merely employed only for the replacement of batteries of imported vehicles.

Fig. 1 Progress in production of Japan's lead acid battery

(2) During World War II The consumption of batteries were almost limited to military applications.

(3) The period of resuscitation after the War For the restoration of equipments & facilities damaged by the war, the demand for industrial batteries (stationary use or electric vehicles) rapidly increased. The diligent investigation of putting into practice the enclosed type batteries in hard rubber jar was started to replace the former open type using "Tudor" plates.

(4) Special procurement period In the following period, the trend of nation's economic conditions has notably been improved with gradual gain of production. A solid foundation of the manufacture of automotive batteries was established. The U.S. Military specification was technically applied in the production of automotive batteries for the special orders by the American Procurement Agency in Japan. Especially, the great effort has been paid in improving cranking ability for the military use.

(5) The Period of Automotive Industry With the rapid expansion of automotive industries, the ratio of automotive batteries has risen to 80% of total production of lead-acid storage batteries. The quantity of battery production has marvelously increased.

1.1.2 Alkaline battery industry

Nickel-Cadmium Type (Jungner-Type) batteries appeared in this country after the War. Formerly, Nickel-Iron Type (Edison-Type) ones were only employed. The trend of production is shown in Fig. 2. Before the War, the amount was very small and the application of alkaline batteries was limited for safety mine lamps only. After the War, especially in 1954, the practical production of nickel-cadmium alkaline type batteries with improved performance was

established. The characteristic application of the batteries has been sharply developed. As a result, the demand has remarkably risen for the power source of trains, electric cars, marine and telecommunications etc. In recent years, the practical use of sintered-plate nickel-cadmium alkaline batteries has been activated. The demand of this type is expected to become appreciable in the future.

1.2 The Trend of Production and Demand

As mentioned before, with a sharp growth of Japan's economy, the battery industry has also notably increased its production after the War. The modernization of production facilities or expansion of equipment have resulted in a marvelous change in manufacturing methods in comparison with those before the War. Moreover, the quantity of production of various types of batteries has also changed. In the field of lead-acid batteries, the ratio occupied by automotive batteries has increased at the same rate as the European countries' consumer demand. On the contrary, the ratio occupied by safety mine lamps in the field of alkaline battery has declined. Other fields of battery applications have widely spreaded.

1.2.1 Lead-Acid storage battery

Table 1 shows the record of production of batteries of different types in the last seven years. The production in 1964 is approx. 3.2 times larger than that in 1958. For the production of automotive batteries including those for motorcycles and three wheel vehicles, the consumption of 152,000. tons of lead in 1958 has sharply increased to 586,000. tons in 1964. The ratio of occupancy of automotive batteries to the total battery manufacturing quantity has increased some 8.9%, and the tendency of dependence of the batteries upon the automotive industry was obviously deepened in this period. The progress in automobile

Fig. 2 Changes in production of Japan's alkaline battery.

Table 1 Production Types of Lead-Acid Storage Battery (From 1958 to 1964)

	1958		1959		1960		1961		1962		1963		1964	
	Lead (t)	Amount (\$)	Lead (t)	Amount (\$)	Lead (t)	Amount (\$)	Lead (t)	Amount (\$)	Lead (t)	Amount (\$)	Lead (t)	Amount (\$)	Lead (t)	Amount (\$)
Automobile & three wheels batteries	13,786	18,242	18,333	24,708	23,486	28,561	31,111	38,419	37,027	46,068	46,008	58,041	52,584	66,322
Motorcycle batteries	1,428	3,171	3,146	7,186	5,134	10,471	4,797	9,843	51,59	10,594	5,464	11,234	6,014	10,017
Stationary batteries	1,672	2,192	2,127	2,837	2,689	3,198	3,529	4,198	3,232	3,858	3,646	4,364	3,428	7,558
Portable batteries	369	668	504	925	457	769	615	1,027	610	1,027	809	1,367	1,025	1,951
High vol- tage	49	137	76	175	90	149	101	153	87	148	94	149		
Marine use	216	373	311	538	312	480	428	649	308	477	327	506	353	732
Electric cars	1,105	1,641	1,386	2,120	1,561	2,103	1,553	2,147	1,422	1,937	1,603	2,154	1,631	2,963
Train batteries	553	739	714	908	718	848	1,055	1,246	851	968	758	921	883	1,077
Fishing lamps	90	669	453	803	447	709	470	750	334	531	352	561		
Lead-Acid safety lamps					19	66	7	89	13	58	14	43		
Others	348	1,137	286	855	300	892	220	459	482	1,042	441	1,276	723	1,866
Total	19,616	28,969	27,336	41,055	35,243	48,246	43,876	58,980	49,525	66,708	59,516	50,616	66,641	92,486

Table 2 Export Record of Lead-Acid Storage Battery
(from 1958 to 1963)

Unit: Quantity: Kg.
Amount: \$1,000.

	1958		1959		1960		1961		1962		1963	
	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount
South East Asia	440,848	352,972	456,682	337,561	636,413	500,036	1,237,323	878,261	1,853,691	1,306,278		1,854,475
Middle East	116,324	143,825	94,373	66,439	164,149	105,881	237,016	152,214	277,954	168,364		365,567
Europe	6,707	3,936	215	614	3,361	4,569	8,341	20,392	41,418	114,219		230,692
North America	10,031	10,489	25,099	46,856	64,759	109,847	25,688	51,631	75,021	117,372		201,028
South America	1,350	1,556	2,232	6,686	89,350	49,258	5,143	9,022	35,213	50,064		277,817
South America	50,980	21,647	7,958	10,939	19,386	22,017	48,777	83,228	32,443	73,431		47,450
Africa	1,416	2,350	63,824	70,639	25,891	21,508	104,416	79,275	81,908	60,244		118,397
Oceania	857	911	1,037	1,394	19,025	16,417	13,914	13,794	29,501	35,647		40,656
Others	54	281										
	628,567	537,967	651,420	541,128	1,022,334	829,533	1,680,618	1,287,817	2,427,149	1,925,619		3,136,082

production after the War is shown in Fig. 3. It is noted that the production ascending curve is just as that of Fig. 1. As to the battery for communication use, keeping abreast of economic development, the manufacturing quantity has increased remarkably and during the last 10 years from 1946 through 1956, the consumption of lead has increased from 26,000. tons to 47,000. tons. But the ratio of manufacturing quantity has decreased from 21.7% to 10.6%. This tendency is also seen in the production of electric car batteries and train lighting batteries. This is because the batteries for automotive use have increased sharply.

The record of Japan's battery export during last 6 years are shown in Table 2.

Fig. 3 Progress in production of automobiles in Japan

1.2.2 Alkaline battery

The alkaline batteries of which demand were mainly occupied by the safety mine lamps have expanded their applications in various ways since 1954. The change from Nickel-Iron to Nickel-Cadmium type is due to the improvement of performance. In recent years, sintered-plate type alkaline batteries have been introduced. This type of battery is used not only for aircraft use but also for various uses as a new type of batteries so called "completely sealed type", just as dry cell, with no

needs of adding any electrolyte or water. They are now marvelously expanding their sales in such fields as electronic equipments, cigarette lighters & etc. The growth of demand is expected in the future. The production of all types of alkaline batteries is shown in Table 3 and Table 4.

Table 3 Production of Alkaline Battery (1958 - 1961)

(Unit: $\times 10^3$ Dollars)

	1958	1959	1960	1961
Safety mine lamps (Alkaline Type)	752	690	913	1,643
General alkaline battery	463	584	1,083	1,410
Total	1,215	1,274	1,996	3,053

Table 4 Production of Alkaline Battery (1962 - 1964)

(Unit: $\times 10^3$ Dollars)

	1962	1963	1964
Safety mine lamps (Alkaline Type)	835	582	540
Pocket Type	1,357	1,805	2,412
Sintered-Plate type	371	1,130	1,662
Counter cell	64	45	34
Total	2,627	3,562	4,648

1.3 The Secondary Battery Manufacturers in Japan

The following is the list of the names and addresses of head quarters of Japan's major battery manufacturers.

Japan Storage Battery Co., Ltd., No. 3-2 Inobaba-cho, Kishoin-Nishinosho, Minamiku, Kyoto, Japan.

Yuasa Battery Co., Ltd., No. 61, Shiroume, Takatsuki-shi, Japan.

Kobe Electric Machinery Co., Ltd., No.

5-15, Urae-kita, Oyodo-ku, Osaka, Japan.

The Furukawa Battery Co., Ltd., No. 246, 2 Hoshikawa-cho, Hodogaya-ku, Yokohama, Japan.

Matsushita Electric Industrial Co., Ltd., No. 1006, Kadoma-shi, Osaka, Japan.

Nippon Storage Battery Mfg. Co., Ltd., No. 2034-9, Mikawashima, Arakawa-ku, Tokyo, Japan.

Honda Denki Co., Ltd., No. 190 4-chome, Kamiosaki, Shinagawa-ku, Tokyo, Japan.

Yokohama Battery Co. Ltd. (Totetsu Kogyo K.K.), No. 87, Kaminoki-cho, Kanagawa-ku, Yokohama, Japan.

1.4 The Association of Secondary Batteries in Japan

The association of secondary battery in Japan is as follows:

The Storage Battery Association of Japan, No. 2, 2-chome, Nishi-shinbashi, Minato-ku, Tokyo.

2. The Progress of Technique

2.1 Lead-Acid Storage Battery

It is said that quality of Japan's lead-acid storage batteries is not inferior to European and U. S. A. makes. The present technical problem is to increase their capacity and cycle life miniaturization and lightening of weight. The research is being carried out under a keen competition among manufacturers. On the other hand, the forthcoming freeing of all import restrictions on foreign batteries into Japan, the battery industry now faces a rationalization program in order to meet the approaching competitions with foreign products and the price emulation for the international market. The manufacturing process of manual operation has been changed to fully automatic operation system which requires casting machines, pasting machines, drying equip-

ments, and assembling machines with a container-formation system. The manufacturing process has been curtailed. The transportation of products between process to process has also been remarkably improved.

High performance fiber-clad type lead-acid batteries having long lives of operation have appeared and were recognized widely and applied in a very wide ranges not only for electric vehicles, but also for stationary batteries or other low rate discharging applications. The plate of "Tudor" type or "Planté" type for stationary uses are still in production, but the usage has been declining. Major technical developments in each classified types of batteries are mentioned as in the followings:

2.1.1 Automotive and motorcycle batteries

The major trends of automotive and motorcycle batteries in past 10 years are

- The change from 6V to 12V system (gasoline cars), and the change from 12V to 24V system (Diesel cars).

- The use of low cost resin bonded cellulosic separators in place of wooden separators.

- The practical application of dry charged batteries.

- By the evaluation of hard rubber materials, the new application of thin wall cheaper container or synthetic resin container and parts.

- The progress of cranking performance.

Remarkable improvements have been made on the above items. On the other hand, for export of automotive batteries, and of batteries for multitude automobiles, cost cutting problem are brought up. For this reason, the unification of types of batteries and the establishment of new specifications are earnestly required. The Society of Automotive Engineers of Japan became a leader of the establishment of types

with simplified specification. Japanese Industrial Standards (JIS) was revised as regards batteries. According to the adoption of AC alternation in 1962, it became possible to charge batteries fully even when cars were driven slowly in the town. In passenger cars, especially, stress has been laid on the cranking performance rather than the low rate discharging capacity, which resulted in the development of thinner plates and light weight batteries.

a) Plates and plate elements: It was recognized about 15 years ago that thick plates (approx. 3 mm) were preferable for automotive batteries as 3 mm plates are especially sturdy and durable for driving along bad roads even without applying glass mats. Since 1950, in order to meet the requirement of cranking performance batteries using 2 mm plates were developed so that more plates could be assembled in a container. Moreover, to prevent shedding of active materials from positive plates, glass-mats were applied as the retainer together with separators. These batteries have been loaded in new cars. In special passenger cars, along with the improvement of casting technique, the thickness of plates have been changed from 2 mm to approx. 1.5 mm or less and the distance between two adjacent positive plates were narrowed from 8 mm to approx. 7 mm. Some batteries have a pitch of 5 mm to 6 mm. Wet wooden separators have long been used, but since 1954, the practical application of resin bonded cellulosic separators were realized. Since they are low in cost and simple for handling, the mass production has been in success.

The double insulated system in which separator and glass mats are applied together, has been generally used in automotive and motor-cycle batteries. Since this separator is used in dry conditions, this is useful for the preservation of bat-

teries and also suitable for the production of dry charged batteries. As another material for separators, microporous rubber is partly used. Owing to the adoption of stacking machines, the assembling process of plate elements were now effectively rationalized.

b) Posts and connector: The method of fabricating posts and connectors has been changed from hand casting to automatic machine casting. As regards their shape, the former posts in mono-block batteries were welded and connected at the upper part, penetrating through the perforated cover. However, the position of connectors has been gradually changed from the upper part of the cover to the lower part. Shortening the terminal not only prevents the voltage drops in the terminal, but also decreases the quantity of lead. This would also help the leakage current in the upper part of batteries.

c) Materials for containers Hard rubber has been used as the material of containers. As the sharp increase of production, the hand moulding which had poor efficiency, was replaced by the machine moulding. Blend of synthetic rubber shortened the vulcanization, and increased the number of shots. A plan for making the container with partition thinner is also under way. Miniaturization & lightening of weight for automotive batteries have been developed and the synthetic resin container such as Acrylonitril Styrene, Acrylonitril Butadiene Styrene and Polypropylene are widely used.

The efficiency of injection moulding has been greatly improved. Physical properties, such as tensile strength and impact strength, of resin containers are generally superior to those of hard rubber. It is, therefore, possible to make the container thinner, smaller and lighter in weight by using resins mentioned above which have the very small specific gravity.

In photograph 1, the comparison of a new battery with an old one is shown. If 100 is taken for the older one, the new battery is 55% in weight and 50% in volume.

Photo 1. Old and new passenger car batteries

Basis of figures

1. Low rate capacity is to be obtained under 20 hr 25°C.
2. High rate capacity is to be obtained under 20 hr (12V battery), 300A (6V battery) at -15°C
3. Cycle life per unit ampere hour is to be obtained by dividing the 20 hr capacity accordance with S.A.E. cycle life test.

Fig. 4 Progress in performance of automotive battery

Thus, automotive and motorcycle battery production has been bouncing ahead in their performance of plate, the progress of production technique and the improve-

ment of materials. Small sized and light batteries for those uses with such high performance are notably recongnized. The outline of the changes of characteristics are shown in Fig. 4.

2.1.2 Industrial Batteries

As stationary batteries for industrial use, the pasted enclosed type in hard rubber jar or the fiber clad type in glass or hard rubber jar have been introduced to substitute the open type using "Tudor" plates. New synthetic resin is used as a mould material for jar in place of glass or hard rubber. Not only the changes of plates or jars, but also "enclosed explosion-proof technique", and new designs of automatic recording for temperature and for specific gravity, are also in practical application. In transparent type batteries, a ball is put inside of jars to indicate the specific gravity of the electrolyte which shows the condition of charging or discharging. One of the most major changes is the practical use of fiber clad type plates both in stationary and portable batteries. The previous ebonite clad type of which active materials were filled in finely slitted ebonite pipes, has been replaced by the type with knitted glass fiber tube. This new type of plates was at first applied to the electric car batteries as being vibration-proof but now it has a very wide range of use including that for telephones. The fiber clad batteries of which capacities are up to 7,500 A.hr are now in practical application. The fiber clad batteries are also used for all the submarines for which demand has grown after the War. With the industrization of this type of batteries, their plates have also been exported to the U.S.A. have not yet been in practical application in this country.

With the application of fiber clad plates, the transparent synthetic resin jar have been in practice. They tightens the space

for battery room and battery maintenance is carried out easier. The typical fiber clad positive plates are shown in photograph No. 2.

Left: 60 A. hr. (6 hr.) per plate
Right: 300 A. hr. (10 hr.) per plate

Photo 2. Fibre clad positive plates

The enclosed stationary battery using pasted plates with hard rubber jar, which has been used in telephone exchange since 1957, is shown in photograph No. 3. An enclosed stationary battery using Tudor plates with synthetic resin jar, which has been employed in power stations since 1960, is shown in photograph No. 4.

With the progress of technical development, the performance of each type of batteries has been improved and is shown in Fig. 5 and Fig. 6.

Completely enclosed lead-acid storage batteries of small size (less than 10 A·hr) have been on the activation, but not yet in the process of practical application.

Photo. 3 Enclosed stationary battery in hard rubber container. (rated capacity 100A.hr/10hr)

Photo. 4 Enclosed stationary battery in synthetic resin container. (rated capacity 1,000A.hr/10hr)

Fig. 5 Progress in performance of stationary battery

Basis of figures

1. Capacity is to be obtained under 5 hr at 25°C.
2. Cycle life test method is to be discharged at 45–50% of its rated capacity and recharged 125% of its discharging capacity 40–50°C. When the capacity drops below 40% of the rated capacity, the test is considered completed.

Fig. 6 Progress in performance of electric car batteries

2.2 Alkaline Battery

2.2.1 Pocket type alkaline storage battery

Pocket type alkaline storage batteries have been applied only to safety mine lamps and subway uses, although the characteristic features such as strong mechanical structure, long life and simplicity of opera-

tion were recognized to be excellent. However, according to the development of low resistant alkaline batteries, with approx. 3 mm thick plates this type of battery has gained wide uses in power stations or industrial facilities. Recently, owing to the success of research, the batteries with plates 2 mm thick capable of high rate discharge were put in practical use so that the pocket type is now approaching to be competitive with sintered-plate type.

2.2.2 Sintered-Plate alkaline battery

The outstanding characteristics of this battery is the plate which can be produced approx. 1 mm in thickness or less. The performance of high rate discharge is much more excellent than other batteries. Aircraft batteries are now gradually employing this type substituting lead-acid storage batteries. The applications are now being underway in diesel starting use, as auxiliary power source which requires high rate discharge, and as the power source for portable electric appliances. The main problem is their price competitiveness. Therefore, the hasty rationalization of production, is now under consideration among the battery manufacturers which have just industrialized this type in this country.

2.2.3 Completely sealed alkaline battery

From the view point of external appearance, batteries are available in disc type, cylindrical type and rectangular type. On the other hand, from the standpoint of plate construction, there are various kinds of types such as pressed type, sintered type and etc. Batteries of Approx. 100 mA·hr to 5 A·hr are now under practical application. The improvement of quick charge, reverse charge or the rationalization of production process are important subject for study.

3. Trend of Research

To show the trend of research on secondary batteries in Japan, the classification of literatures which have been published in "Chemical Abstracts of Japan" during 5 years since 1960 is given in the following.

	Number of papers
General information	2
Lead-acid storage battery	23
Lead alloy	3
Pasting	3
Formation	1
Active material	7
Electrolyte & additives	1
Theory & performance	4
Maintenance	1
Clad type	3
Alkaline battery	28
Pocket type	1
Sintered type	11
Sealed type	2
Positive plate	5
Iron negative plate	0
Cadmium negative plate	8
Particular Storage Battery	9

In recent years, the research of alkaline batteries including sintered-plate type has been very active. It is noted that the publication of research papers for exceeded those on industrial developments. Comparative studies on the power source including fuel cells have become very important problem for the secondary battery.

However, lead-acid battery having a history over 100 years shall be considered to be the firm and suitable power source from the view point of its economic or characteristic performance even in the future. However, it is forecast that studies on the improvement of detailed matters will still be necessary for the lead-acid battery, especial-

ly, on the problems in production techniques.

As for nickel cadmium alkaline batteries which have greatly developed by the appearance of sintered-plate type or thin plate pocket type, the active expansion is expected regardless of their high costs in other fields than those of lead-acid storage batteries because of their notable characteristics. Especially, the complete sealed type are considered to be worth studied delligently. In Japan, the usage of silver-zinc, siver-cadmium batteries are limited. However, as the performance of these batteries are so remarkable that researches are being carried out with no thought of their price. As the launching of satellites takes concrete shape in this country, it is presumed that researches & trial productions of those extraordinary type of batteries will become active. Table 5 shows the number of patent application on secondary batteries and the number of registered utility models published in Japan in 1964. The number shows straight forwardly how the research is brisk.

Table 5 Number of Patents & Utility Model Published (1964)

	Patent	Utility model	Total
Lead-Acid battery	35	32	67
Alkaline battery	40	40	80
Common Patent	79	139	218
Total	154	211	365

1) Including 15 foreigner's applications.