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Manufacture and application of valve-regulated lead/acid batteries in China

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Abstract

This paper introduces the manufacture and application of valve-regulated lead/acid batteries in China. The contents cover the following topics: (i) background development; (ii) materials; (iii) manufacturing technology and equipment; (iv) application and market prospects. © 1998 Published by Elsevier Science S.A. All rights reserved.

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1. Background development

The research and development of valve-regulated lead/acid (VRLA) batteries in China started in the early 1980s. Up to now, the research and manufacture of this technology has had a history more than 15 years. This history can be divided into two distinct periods: the 1980s and the 1990s.

1.1. 1980s—the initial development period of VRLA batteries in China

At the beginning of the 1980s, researchers at various institutes and universities in China commenced the study on VRLA batteries. During the first few years, the research and development programmes focused on small VRLA batteries. Battery manufacturers first produced VRLA batteries around the middle of the 1980s. With the development of the local market for the application of VRLA batteries, domestic and imported products were sold in the late 1980s. By 1990, the total production capability for VRLA batteries increased to 20 000 kWh. Together with 40 000 kWh of imported VRLA batteries, the market for VRLA batteries in China expanded to 60 000 kWh after 10 years of development and 5 years of marketing [1,2]. Small-capacity VRLA batteries (up to 100 Ah) were the main products during this period. These units were used in UPS systems and other electrical apparatus. No VRLA batteries were employed in Chinese telecommunications systems up to the end of the 1980s.

1.2. 1990s—the growth period of VRLA batteries in China

By 1990, standby VRLA batteries accounted for 24 000 kWh. Thus, the application of VRLA batteries in standby power systems, such as those used in the telecommunications industry, promised to be the most important and largest market for the developing VRLA battery industry.

With the rapid expansion of the telecommunications industry in China after 1990, local battery manufacturers started to design and produce VRLA batteries for this industry. In the early 1990s, China imported VRLA battery manufacturing technology from the USA and built the first modern manufacturing line to produce and market large-capacity batteries. Since then, local VRLA battery manufacturers have speeded up the programme of development and marketing of large-capacity VRLA batteries, and more and more plants have been built. At the same time, almost all the major battery companies in the world also started to produce VRLA batteries and to invest in VRLA battery manufacturing in China. Up to 1996, there have been more than 150 VRLA battery manufacturers in China! During

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the 1990s, there has been a tendency for VRLA batteries to replace traditional flooded lead/acid batteries as standby-power sources in Chinese telecommunications and other industries. In 1997, total sales of VRLA batteries in China will increase dramatically to 1.0 million kWh.

2. Materials

The materials used in manufacturing VRLA batteries are very important in achieving product quality. The key materials are lead, lead alloys, and separators. Their present status in China is reviewed in the following sections.

2.1. Lead and lead alloys

There are rich resources of natural lead in China. The annual production of lead has increased from 300 000 tons in 1990 to more than 700 000 tons in 1996 (Table 1). With the development of the lead/acid battery industry, the demand for lead has increased in recent years. This has provided a good opportunity for the development of secondary lead recycling facilities in China. The primary and secondary lead statistics between 1992 and 1995 show that increasing amounts of secondary lead are being used by the Chinese battery industry (Table 2).

In order to meet the needs of VRLA batteries, Chinese battery manufacturers and metal suppliers have developed various lead alloys. Table 3 gives the compositions of VRLA lead alloys which are used commercially [3,4]. The lead alloys for VRLA batteries are usually three systems: lead–low–antimony, lead–calcium–aluminium, and lead–calcium–aluminium–tin. The levels of Sb, Ca or Sn differ greatly between battery manufacturers. Some manufacturers have their own proprietary compositions for VRLA alloys.

Although most VRLA manufacturers normally use lead and alloys supplied by domestic suppliers, some VRLA manufacturers, such as the advanced JV manufacturers, prefer to import lead. The source of lead is mostly influenced by the price differential between the domestic and international metal markets.

2.2. Separators

Research and production of absorptive glass mat (AGM) separators for VRLA batteries began in China in the mid-1980s. With development of the VRLA market, domestic AGM separator production has increased very quickly during the past 10 years. Up to the end of 1996, there have been more than 30 producers of AGM separators in China, and the total annual production capacity of these suppliers is more than 2000 tons of AGM.

In 1995 and 1996, local producers' total annual sales of AGM separators increased from 700 to 800 tons per year. It is clear that there is more than a sufficient supply of AGM separators. It is expected that the total market for AGM separators in China could be 1000 tons in 1997.

With respect to the production technology and quality of the AGM products made by Chinese suppliers, great improvements have been achieved in the past 5 years. Typical technical data of AGM separators made in China are listed in Table 4 [5]. The quality of the AGM products is generally able to meet the performance requirements for VRLA batteries in the domestic market, although the separator suppliers still need to improve some aspects of quality control, such as uniformity in thickness and iron content within the AGM material. It is expected that, in the near future, China will be a supplier of AGM separators to VRLA manufacturers in developing countries.

With the development of the local market, most of the major AGM suppliers in the world started to sell their products in China after 1992. If the VRLA batteries are used for high-quality applications, either in China or in overseas markets, some battery manufacturers have been able to import AGM separators from western suppliers. In

Table 1
Annual production of lead in China during the 1990s (unit: ton×1000)

Year	1990	1991	1992	1993	1994	1995	1996
Lead	296.5	320.0	366.0	411.9	467.9	607.9	> 700.0

Table 2
Primary and secondary lead statistics for 1992 and 1995 (unit: ton×1000)

	Production			Export		Import	
	Total	Mine	Recycled	Mine	Recycled	Mine	Recycled
1992	366.0	317.7	48.3	89.9	1.50	1.75	5.71
1995	607.9	432.6	175.3	185.3	0.59	4.59	5.69

Table 3
Suppliers' standards (wt.%) for lead alloys for use in VRLA batteries

	Pb–low Sb		Pb–Ca–Al	Pb–Ca–Al–Sn	
	Type A	Type B		Type A	Type B
Pb	balance	balance	balance	balance	balance
Ca	–	–	0.08–0.15	0.08–0.11	0.08–0.15
Al	–	–	0.02–0.06	0.02–0.04	0.02–0.06
Sn	0.13–0.16	0.06–0.10	–	0.08–0.14	0.25–0.80
Sb	1.60–1.80	2.50–2.80	< 0.005	< 0.001	< 0.005
As	0.20–0.25	0.12–0.15	< 0.002	< 0.001	< 0.002
Se	0.02–0.04	0.03–0.05	–	–	–
S	0.05–0.08	0.05–0.08	–	–	–
Cu	0.03–0.05	0.03–0.05	–	< 0.001	–
Impurities					
Ag	< 0.002	0.002	< 0.001	< 0.001	< 0.001
Bi	< 0.03	0.03	< 0.005	< 0.003	< 0.005
Fe	< 0.005	0.005	< 0.002	< 0.001	< 0.002
Zn	< 0.003	0.003	< 0.002	< 0.001	< 0.002
Ni	< 0.001	0.002	< 0.002	–	< 0.002
Cd	< 0.005	0.005	< 0.005	–	< 0.005
Total	< 0.06	< 0.06	< 0.03	< 0.03	< 0.03

Table 4
Technical data of commercial AGM separators made in China

Item	Unit	Standard in China	Best in China
Electrical resistance	Ω	< 0.0005	< 0.0005
Maximum pore size	μm	< 28	< 25
Porosity	%	> 90	> 97
Capillarity in H_2SO_4	mm/5 min	> 75	> 120
	mm/24 h	> 580	> 600
Ignition loss	%	< 3.00	> 2.00
Oxidation ($KMnO_4$)	ml g^{-1}	< 5.00	< 5.00
Fe content	%	< 0.008	< 0.005
Cl content	%	< 0.003	< trace
Moisture	%	< 1.00	< 1.00
Tensile strength	KN m^{-1}	> 0.70	> 0.90

most cases, however, VRLA manufacturers usually prefer to decrease costs and thus, imported AGM has not been widely used in China because of its 40% higher price. It is expected that imports could increase if their prices become more competitive. For this reason, overseas suppliers have started to invest or cooperate with local partners for manufacturing or marketing AGM separators in China.

3. Manufacturing technology and equipment

The marketing of western battery manufacturing technologies and equipment speeded up the VRLA battery industry in China. All these marketing activities provided local manufacturers with opportunities to import new technologies and machines to modernize and equip their manufacturing lines. The evolution of VRLA battery manufacturing in China can be appreciated from the following two aspects.

3.1. Manufacturing technology

If the history of VRLA battery manufacturing in China is assessed in terms of technical know-how, three different periods emerge. During the first 5 years between 1986 and 1990, all the technology and technical know-how for making VRLA batteries was developed domestically. In the second period after 1990, battery manufacturers started to purchase manufacturing know-how and equipment from advanced countries after the first technical transfer contracts with GNB in USA. Finally, after 1995, with the development of the market in China, world leaders in VRLA battery manufacturing started to invest or form join-ventures in China. Successful technical transfers and joint-venture programmes are listed in Table 5. The technologies in these companies illustrate the modern technical situation of VRLA battery development in China.

VRLA batteries may be of the AGM or the gel design. AGM technology was the main product in China for a long period. Tubular gel technology is not popular in China; until the end of 1996, there were no manufacturers of gel batteries. In view of this situation, the leading battery manufacturers, such as Shenyang Northeast Battery, started to develop or import tubular gel VRLA technology. Domestic production of such batteries started in 1997.

Up to now, VRLA battery manufacturers in China have been able to supply a wide range of VRLA batteries, from small 6 and 12 V units (capacity from 1.2 Ah) to large 2 V units (capacity up to 3000 Ah).

The quality of small VRLA batteries made in China is acceptable to customers in both Europe and North America. In view of the low costs of production, more and more battery companies have started to export small VRLA batteries. It is expected that China will be one of the main suppliers of such batteries.

As for large VRLA batteries for telecommunications or other standby-power sources, it is clear that manufacturing technology and quality control are much more advanced in Europe, North America and Japan. With the help of technical transfer and joint-venture programmes, however, the quality and types of large VRLA batteries made in China are expected to keep pace with those produced in other countries.

3.2. Manufacturing equipment

The methods used to manufacture VRLA batteries in China can be quite different. Modern manufacturing lines imported from world-leading equipment suppliers, low-cost domestic manufacturing machines, and original manual operation are operated at different VRLA battery manufacturers. Nevertheless, after the experience gained in the past 10 years, more and more VRLA battery manufacturers have opted to purchase advanced manufacturing equipment and machines from domestic and overseas suppliers.

As the active consulting organization for battery industry, the author's company is pleased to have introduced more than 60 overseas suppliers to the Chinese battery industry during the past 5 years. Most of these are the leading suppliers of equipment for the manufacture of VRLA batteries (Table 6).

Table 5
Successful technical transfers and joint-venture VRLA programmes in China

Company	Technical transfer from	Joint-venture with
Shenzhen Hwadar	GNB, USA	Hawker, UK
Shenyang Matsushita	Matsushita, Japan	Matsushita, Japan
Shunde Yuasa	Yuasa, Japan	Yuasa, Japan
Shanghai Johnson	Johnson Controls Battery Group, USA	
Shangdong Huari	Japan Storage Battery, Japan	
Tong Yee Tianjin	Japan Storage Battery, Japan	
Hangzou Narada	Tudor, Spain	
Shenyang Northeast	Hagen, Germany	

At the same time, local suppliers of battery manufacturing equipment have developed different equipment for the market. Nowadays, the local suppliers have been able to provide assembly lines for VRLA batteries at very competitive prices. But the plate-making equipment produced by the local suppliers is still not able to meet the pressing demands of the market. Thus, there are business opportunities in China for suppliers of advanced VRLA plate-making machines.

Table 6
List of suppliers introduced by battery consultants China

Company	Country	Main business		
		Material	Equipment	Engineering
Accunalux	Luxembourg	*		
Accurate Products	Denmark		*	
Amerace	USA	*		
Amer–Sil	Luxembourg	*		
ATI	Italy	*		
Axohm–Lydall	France	*		
Bitrode	USA		*	
Chloride	UK			*
Carlson Tool	USA		*	
Cominco	Canada		*	
Anderson	UK	*		
DAGA	Italy		*	
Digatron	Germany		*	
Daramic	Germany	*		
Eberle	USA		*	
Eirich	Germany		*	
Elbak	Austria		*	
Engite	Italy		*	
Evanite	USA	*		
Engineer System	USA		*	
Entek Int.	USA	*		
Farmer	USA		*	
Floridienne	Belgium	*		
Freudenberg	Germany	*		
HADI	Germany		*	
Hohsen	Japan		*	
H&V	USA	*		
H C Starck	Germany	*		
ITAS	Italy		*	
ICS	Italy	*		
INCO	Canada	*		
Japan Vilene	Japan	*		
JNG Intel.	USA			*
Jungfer	Austria	*		
Johnson Controls	USA			*
Kallstrom	Sweden		*	
Linklater	USA		*	
Leko	Australia		*	
Lorival Plastics	UK	*		
MAC	USA		*	
Metaleurop	France	*		
Mealindustrie	France		*	
NEC	UK	*		
Nippon Sheet Glass	Japan	*		
OSI	USA		*	
O&C	USA		*	
OxMaster	USA		*	
Papeteries	France	*		
Penarroya Oxide	Germany		*	
PIL	Italy	*		
Plastam	Italy	*		
SMS	USA		*	
Singer Products	USA			*
Sovema	Italy		*	
Sorfin	USA			*
TBS	UK		*	
Tekmak	USA		*	
Termar	Italy	*		
Trelleborg	Netherlands	*		
UM	Belgium	*		
Weiler	USA		*	
Wirtz	USA		*	
Witco	USA	*		

4. Application and market prospects

As mentioned above, the wide application of VRLA batteries in China started in 1990. In 1991, the first major VRLA battery manufacturers started to promote their products into the telecommunications industry. After testing for 3 years, the customers became increasingly interested in VRLA batteries. Up to 1993, the government management ministries, such as the Ministry of Machinery Industry and the Ministry of Post and Telecommunications, started to formulate policies on the standards for VRLA batteries and for the application of VRLA batteries in telecommunications systems and other industries. Up to now, a series of government policies about Industry Standards and Network Entry Certificates has been approved. With support, these policies, the statistics of VRLA battery sales in recent years (Table 7) show that the manufacture and application of VRLA batteries expanded very quickly. Clearly, there is a bright future for VRLA batteries in China.

It should be noted that the average growth rate between 1990 and 1993 was very high, viz. $>60\%$. This was the

Table 7
Market statistics and future prospects for VRLA batteries in China

Year		Total sales (in million kWh)		Growth rate (%)
1900		0.06		
1991		0.10		66.6
1992		0.16		60.0
1993		0.28		75.0
1994		0.38		35.7
1995		0.54		42.1
1996		0.73		35.2
1997	forecast	>1.00		40.0
2000	forecast	2.50–2.75	average	35.0–40.0

result of two developments: (i) the replacement of traditional flooded industrial batteries by VRLA counterparts; (ii) the installation of VRLA batteries for new projects in telecommunications systems, power industries, and other applications. After 1995, VRLA batteries became the main choice for stationary and standby battery systems.

Based on the information from government policy, the production ability of the VRLA battery manufacturers, the increasing rate of VRLA battery sales between 1994 and 1997, and the future direction of the market, the following conclusions can be made about the application and market prospects of VRLA batteries in China.

(i) The application of VRLA batteries will become increasingly popular in the telecommunications industry, in the power industry, and in railway systems.

(ii) With expanding VRLA applications, government ministries in China will adopt the rule of Network Entry Licence for VRLA batteries in order to guarantee the quality and safety of the system.

(iii) The government will encourage the increased application of domestic VRLA battery products.

(iv) The market for VRLA batteries in China will maintain an annual growth rate of 35 to 40%. The total sales of VRLA batteries may reach 2.50–2.75 million kWh in the year 2000.

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