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Valve-regulated lead/acid batteries: they are not all the same!

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Abstract

It has become popular and widespread, both in symposia and battery magazine articles, to refer to valve-regulated lead/acid (VRLA) batteries as if they are a single entity and generic in nature. Sweeping conclusions have been drawn about the reliability and life of VRLA batteries but, usually, little is published alongside of these conclusions that can give the reader much insight into the nature of the alleged non-reliability, or indeed the failure modes associated with the apparent shortage of life. Consequently, there is a danger that the performance of VRLA batteries will become branded as a serious problem. The purpose of this paper is to present facts which demonstrate that VRLA batteries are most certainly not generic in nature. The batteries are designed differently, and they are manufactured in different ways from different materials. Moreover, the various producers make different claims with respect to the likely service-lives of VRLA batteries. When considered against this background, it should not be surprising that there is considerable variation in the life of VRLA batteries in their many and varied applications and environments. Nor should conclusions be drawn about all VRLA batteries by a consideration of a few.

Keywords: Lead/acid batteries; Valve-regulated lead/acid batteries; Lead sulfate; Dry charge; Compression

1. Introduction

Valve-regulated lead/acid (VRLA) batteries have become the subject of a great deal of discussion in recent years. There have been many articles, panel discussions and meetings that have focused attention on published data which suggest that VRLA batteries are inherently unreliable [1–5].

The purpose of this paper is to examine some of the factors that are important to the reliability and longevity of VRLA batteries, and to demonstrate that such batteries are not generic in nature and, therefore, should not all be judged to have similar properties.

2. Experimental/discussion

The published literature from 12 manufacturers of VRLA batteries was surveyed and the design features from each manufacturer were catalogued. When available, the catalogue data sheets were supplemented by factual data gathered from competitive analysis on actual production units. What follows is a list of the features that the author's company considers to be significant when designing a VRLA battery and choosing the materials and methods of manufacture. The 12 manufacturers are listed in Table 1.

Table 1
Manufacturers in the VRLA battery survey

C&D	Exide	Power
GNB	JCI	Powersonic
Gates	East Penn	Yuasa
Chloride	Douglas	AT&T

2.1. Cover and jar

Two items of considerable importance when choosing the cover and jar materials are the oxygen index and the oxygen and moisture permeability. These properties are summarized in Fig. 1 and Table 2.

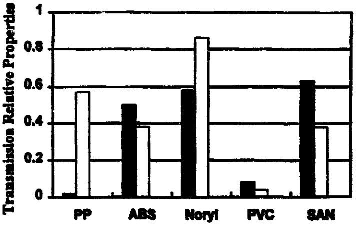

Fig. 1. Oxygen and moisture transmission of common plastic materials.

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Table 2
Cover and jar plastics used for VRLA batteries

Material	Polypropylene	Flame retardant polypropylene	ABS	PVC
a) *LOI (%)* [a]	18	28	29	>32
b) *Manufacturer*	GNB [b] East Penn [b] Douglas [b] Powersonic Power	AT&T Exide/Yuasa JCI Gates	Chloride Yuasa	C&D

[a] LOI: limiting oxygen index.
[b] Flame retardant optional.

Table 3
Positive grid alloys used by various VRLA manufacturers

Pb–Sn–Ca–Al	Pb	Pb–Sn	Pb–Sb–Cd
C&D	Gates	AT&T	GNB
Yuasa/Exide		East Penn	
JCI			
Douglas			
Powersonic			
Yuasa			
Chloride			
Power			

2.2. *Grid alloys*

The choice of alloys influences the corrosion and growth characteristics of the grid. Calcium-based, i.e. non-antimonial, alloys are generally used because they provide stable float characteristics and lower internal operating pressures. The use of tin as an aid to grid casting and improved corrosion resistance is further enhanced by the addition of aluminium. The aluminium acts as a quality-control agent; it helps to maintain a stable calcium content by preventing calcium oxidation. The various alloys widely used today in the manufacture of lead/acid batteries are listed in Table 3.

2.3. *Technology for grid production*

Several technologies exist for grid casting, i.e., punched sheet, expanded metal, continuous cast, and gravity cast. Good quality castings can be obtained with either of the two casting technologies. Expanded metal and continuous casting are more prevalent in the manufacturer of automotive batteries. Gravity casting is still the most common technique used to fabricate grids for VRLA batteries.

2.4. *Positive grid thicknesses*

As a first approximation, the thickness of the positive grid reflects its intended design life. Assuming that positive-grid growth and corrosion are the life-determining factors, the thicker the grid, the longer the battery will last. Thinner grids are usually cast with the technology used for automotive-battery grids. This equipment is heavily automated. Thicker grids are usually cast using industrial battery technology. Here, the type of casting method (gravity cast) is very important in influencing the quality of the grid castings. A minimum grid thickness of 0.2 in is required for a 20-year life. Grids with a thickness of less than 0.15 in are indicative of a 5- to 10-year design life. A comparison of positive-plate grid thicknesses is shown in Tables 4 and 5.

2.5. *Known process variations*

Typical materials employed in the manufacture of battery plates are grey oxide, red lead and tetrabasic lead sulfate (4BS). The advantages of 4BS in extending the longevity of the positive-active material are well documented. Formation of 4BS is associated with a high-temperature/high-humidity cure, and is normally reserved for industrial batteries. Automotive batteries usually receive a low-temperature cure that provides easy plate formation and gives good initial capacity. C&D is the only battery company that manufactures and uses pure 4BS.

The formation procedure seriously affects battery capacity. There are two types of formation: tank formation and jar formation. During the former, a plastic tank is lined with raw plates and filled with dilute sulfuric acid, then a forming charge is applied. This process has the advantages of allowing visual inspection by the operator and assuring a complete formation that leads to better capacity and more uniform float characteristics. When the formation is complete, the plates are rinsed, dry-charged, and assembled into a cell. This entire

Table 4
Positive-grid thickness (in) in a 20-year VRLA product

C&D	Yuasa/Exide	East Penn	GNB Ver. 1	GNB Ver. 2	GNB Ver. 3
0.235	0.190	0.205	0.200	0.200	0.235

Table 5
Positive-grid thickness (in) in a 5- to 10-year VRLA product

Power	JCI	Exide/Yuasa	C&D	Yuasa	Gates
0.105	0.116	0.95	0.136	0.136	0.040

Table 6
VRLA battery processing technology adopted by different manufacturers

Manufacturer	C&D	East Penn	GNB	Exide/Yuasa
Battery	LS 2000	Unigy II	Absolyte IIP	Dynacel
Jar/cover seal	T&G	Butt seal	Butt seal	Butt seal
	Epoxy seal	Heat seal	Heat seal	Heat seal
Pre-formed 4BS	Yes	No	No	No
Formation type	Tank	Tank	Jar	Jar
Float matching	Yes	?	?	?
Capacity testing	Yes	?	?	?

procedure is more costly than jar formation, but is much more reliable. C&D makes all its VRLA batteries by the tank-formation process.

Jar formation involves assembling the element into a battery container, filling the container with electrolyte, and applying the forming charge. This process is inherently more variable. Indeed, C&D evaluations of competing products have found capacity shortfalls that can be traced directly to jar formation. Nevertheless, jar formation has found favour with several manufacturers, mainly for economic reasons.

The jar-to-cover seal is another important area that is often overlooked. In its 20-year battery production, C&D uses an epoxy seal with a tongue-and-groove cover. This assures complete reliability of the jar-to-cover seal. Most other manufacturers, employ a butt seal that is heat sealed and more prone to leakage.

Acid filling is a further critical variable in the manufacture of VRLA batteries. At present, three methods of acid filling are used by the industry, i.e. fill-by-weight, fill-by-volume, fill-and-dump. Of these techniques, fill-by-volume is the most reliable. Fill-and-dump is common with smaller VRLA cells.

After formation is completed, discharge testing should be performed to verify the capacity. All C&D cells are capacity tested prior to shipment to the customer. After testing, the cells are segregated into groups with similar float-voltage characteristics. This insures uniformity within the battery string while on float.

The above process variables are summarized in Table 6.

2.6. *Known design variations*

Use of monobloc designs is rather common with VRLA cells. This is due to the advantage afforded in a smaller battery footprint. The disadvantage of this technique is that, in the event of failure of a single cell, the entire monobloc must be replaced. Heat dissipation can also be a problem.

Grid design should be optimized for the intended battery application. The C&D Liberty LS 2000 battery is specially designed to minimize positive-plate growth and, thus, extend battery life. An element support system provides many benefits, e.g. it relieves stress on the post seal and helps to maintain plate-group compression throughout the cell. Compression is vital to insure electrolyte contact with the plates. In the C&D design, compression is assured for the entire life of the cell through a unique, adjustable pressure plate. This also enables easy accessibility in order to exchange a cell should this ever become necessary.

Horror stories abound about batteries that have been placed in high-temperature operating environments, or have suffered charger malfunctions that resulted in thermal runaway and complete loss of the battery. C&D has recognized this potential problem and designed a proprietary ribbed jar with module air channels to provide a system approach to facilitate thermal control. East Penn has also taken high-temperature operations of VRLA batteries into consideration. The East Penn design, however, results in an increased footprint and no attempt has been made to optimize air flow through the steel tray.

The importance of the design of the post seal is often understated. The post seal used by many manufacturers is the motive-power battery type and tends to leak and is inadequate to the needs of VRLA batteries. C&D has extensively tested different post-seal designs. That used in the Liberty LS 2000 battery is a modification of the seal that has operated successfully for over 25 years in C&D's flooded-electrolyte product line.

Table 7
Variations in VRLA design

	C&D LS 2000	East Penn Unigy II	GNB Absolyte IIP	GNB Absolyte I	Exide/Yuasa Dynacel
Element support	Yes	No	No	No	No
Controlled compression	Yes	No	No	No	No
Thermal management	Yes	No	No	No	Yes
Individual cell installation and removal	Yes	No	No	No	No
Post seal	Isolated	Non-isolated	Automated	Motive power	Machined
	Heliarc weld	Heliarc weld	Welder	Hand burn	Epoxy
Plate wrap	C-wrap	U-fold	U-fold	U-fold	U-fold

Table 8
Battery life claims made by VRLA manufacturers

Battery	Life (years)	V/Cell	Temperature (°C)
Gates Cyclon	8	2.35	23
Gates Genesis			
(H&D)	5	2.27	25 (15 min rate)
	8	2.27	25 (5 h rate)
(CyD)	6.5	2.27	25 (15 min rate)
	10	2.27	25 (5 h rate)
(ExD)	6.5	2.27	25 (15 min rate)
	10	2.27	25 (5 h rate)
Yuasa N.P.	4–5	2.25/2.30	20
Chloride Powersafe	10 (design life)	2.27/2.30	25
Powersonic	6–8	2.25/2.30	20
	4.5–6	2.25/2.30	25
Guardian	4+ on float		
Absolyte			
I&II	20	2.25/2.28	25
IIP	20	2.23/2.27	25
Liberty 1000	10	2.25/2.27	25
Liberty 2000	20	2.25/2.27	25

Another significant feature of VRLA design is the deployment of the absorbent glass-mat separator. The common practice is to use a 'U-fold' wrap in which the glass mat is wrapped vertically around the plate. The inadequacy of this technique is evident should the glass mat be misaligned during assembly and the edges of adjacent plates become exposed to possible shorting. C&D employs an 'alternate C-fold' separator that is wrapped horizontally across the plate with the open end of the glass staggered to make plate-to-plate shorts an impossibility.

The above design variables are summarized in Table 7.

2.7. *Life claims*

The data given in Table 8 show that the longevity of VRLA batteries is conditional upon many different variables. These include float voltage, temperature and discharge rate.

3. Conclusions

The life of the lead/acid battery is critically dependent on the choice of positive grid alloy, positive grid thickness, processing parameters, and design variables. Each battery manufacturer exercises conscious decisions as to the design life of the product. Consequently, to paint all VRLA batteries as being deficient with regard to promised design life is to ignore the facts and to deny the advances in the state-of-the-art that have taken place within the past ten years.

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