Gelled-electrolyte lead/acid batteries for stationary and traction applications

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Abstract

The development of new ranges of valve-regulated lead/acid (VRLA) batteries for stationary and traction applications is described. These batteries are gas recombining and use gelled electrolyte, tubular positive plates cast in lead–calcium–tin alloys and a specially-designed pressure relief valve. For stationary service, comparisons are made with VRLA batteries using absorptive glass mat separators. For traction applications, the relative merits of gel technology against alternative approaches to the achievement of lower maintenance for traction batteries are discussed. Operational experience with these batteries is outlined and guidelines indicated for correct application.

Introduction

Sealed lead/acid batteries have been developed over a number of years and for many applications they have become the system of choice, especially for stationary applications. The electrochemical principles that permit the lead/acid system to be operated as a sealed valve-regulated battery are well understood. The key practical requirements are the lowest hydrogen overvoltage for the negative grid alloy to suppress hydrogen evolution at the negative electrode, the correct balance of active materials and a means by which oxygen can diffuse from the positive electrode to the negative where it is chemically recombined.

These requirements can be met with antimony-free alloys for the grids and either an absorptive glass mat separator or a conventional microporous polymeric separator and a gelled electrolyte. Lead–calcium or lead–calcium–tin alloys may be used for grids. The elimination of antimony from the battery has a disadvantage in so far as the beneficial effects of antimony in improving cycle life have to be traded off against the need for sealed operation. There is a substantial effort directed towards improving the cyclability of antimony-free alloys and also to the use of low levels of antimony to obtain the correct balance of properties. Absorptive glass mat separators are designed for operation with the separator only partially saturated with electrolyte and a small amount of connected gas porosity to permit rapid transport of oxygen between the positive and negative electrodes. In gel cells, the electrolyte is mixed with finely divided silica and forms a gel. This becomes fissured on a very fine scale and allows oxygen

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to diffuse rapidly between the plates. Cells can, therefore, operate in a fully-sealed manner without any requirement for routine maintenance. This type of cell is becoming increasingly important for a range of motive power applications and further developments are underway stimulated by the enormous level of interest in electric vehicles.

Stationary applications

The development of valve-regulated lead/acid (VRLA) batteries has proceeded very rapidly over the last several years in Europe, North America and Japan. This has resulted in a large number of different products becoming available needing a variety of requirements. The pace of development has been faster than the introduction of national and international standards for these products but there is currently a draft IEC standard (896–2) which will provide a basis for defining the essential characteristics of this type of cell.

The summary in Table 1 shows a classification of VRLA batteries for stationary applications. There are four categories of cell:

10+ year – 'high integrity'. This type of cell would be specified for applications where the highest level of security is required such as for telecommunications, nuclear and conventional electric utilities and for oil and petrochemical installations. These cells have the maximum attainable design life and the most stringent standards for performance and safety.

10 year – 'high performance'. Cells in this category have a comparable design life expectation to cells in the 'high integrity' group but the requirements for performance and safety are not as severe.

5–8 year – 'general purpose'. The performance of this product group generally falls in the same range as the 'high performance' type but the safety-related requirements and the design life are at the lower level.

3–5 year – 'standard commercial'. This type of battery is very extensively used for consumer applications such as security and alarm systems and also in a large number of nonstationary applications where a sealed battery is required.

Cells with gelled electrolyte generally fall into the 10 year – 'high performance' category but specification requirements often demand that there is compliance with the flammability characteristics of the 'high integrity' group and, under well-controlled conditions, service life should exceed 10 years.

Tubular stationary cells with gelled electrolyte

Figure 1 shows a typical stationary cell with tubular positive plates and gelled electrolyte. Lead–tin–calcium grid alloys are used for both positive and negative plates. Microporous polymeric separators are used and the container is moulded in flame-retardant ABS (acrylonitrile/butadiene/styrene). A high-integrity pillar seal has been developed using a synthetic rubber grommet. The pressure relief valve employs a bunsen valve and incorporates a flame arrestor.

These cells may be installed horizontally or vertically (Fig. 2). For horizontal installation, the plates must be vertical. Intercell connection is by bolted flexible connectors. Cells of this type conform to DIN 40736 Part 3, under the general designation OPzV and are available in a wide range of capacities.

The design of this type of cell makes it suitable for duties where the discharge duration is one hour or more. For shorter discharge times requiring a sealed battery,

TABLE 1

Classification of valve-regulated lead/acid batteries for stationary (standby) applications

Battery type	High integrity	High performance	General purpose	Standard commercial
Design Life (years)	10+	10	5–8	3–5
Capacity	100% at first cycle	95% at tenth cycle 100% at first cycle	95% at tenth cycle 100% at first cycle	95% at tenth cycle 100% at first cycle
Float voltage	User defined	Manufacturer defined	Manufacturer defined	Manufacturer defined
Cycle life	User defined	Manufacturer defined	Manufacturer defined	Manufacturer defined
Gas emission	<10 ml/A h C_{10}/30 days	Manufacturer defined (NTP/A h C_{10}/30 days)	Manufacturer defined (generally as HP)	Manufacturer defined (generally as HP)
Flammability	VO to IEC 707	Manufacturer states rating to IEC 707	Manufacturer defined	Manufacturer defined

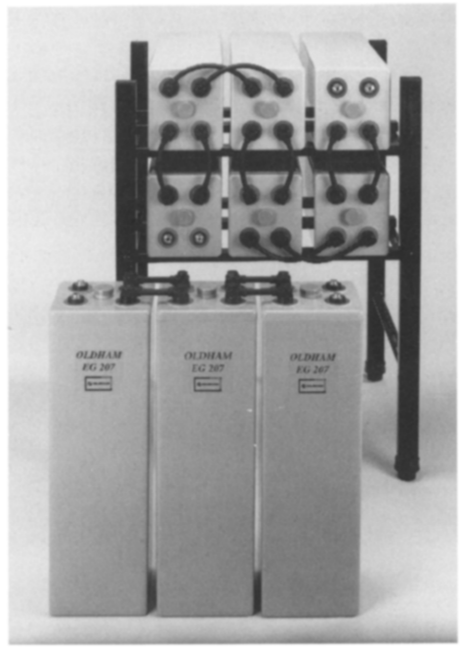

Fig. 1. Gelled-electrolyte stationary lead/acid cell.

Fig. 2. Gelled-electrolyte stationary lead/acid battery installation. Cells may be installed vertically or horizontally.

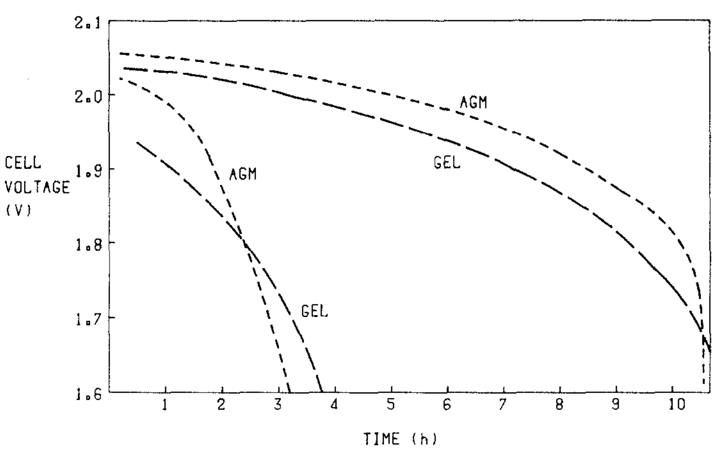

Fig. 3. Comparative performance (schematic) of stationary cells with tubular positive plates and gelled electrolyte and with flat pasted plates and absorptive glass mat separators (AGM).

the use of cells with pasted plates and absorptive glass mat separators is preferred and Fig. 3 shows the comparative performance of the two types of cell in schematic form.

Tubular traction cells with gelled electrolyte

Conventional lead/acid traction cells require frequent servicing in the form of water addition but there are various methods of reducing maintenance. All of these have advantages and disadvantages measured both in initial cost and total life cost. Table 2 summarizes the various methods that are used to reduce maintenance. For flooded batteries, the use of either mechanical or pneumatic pumps to recirculate the electrolyte or short high-current electrical pulses for the same purpose can be coupled with lower levels of overcharge to increase the maintenance internal. Changes in alloy composition can be used to further reduce water losses and as a result, maintenance intervals of up to a year are achievable. In addition, automatic watering systems are available to make maintenance more convenient and more accurate. For many ap-

TABLE 2

Methods of achieving reduced maintenance for lead/acid batteries for traction applications

Battery type	Maintenance interval (cycles)	Degree of overcharge (%)	Recharge time (h)
Flooded, conventional charger	15–20	15–20	8–13
Electrolyte agitation, reduced overcharge	50–75	5	6
Electrolyte agitation, low-maintenance alloys, reduced overcharge	200–250	5	8–13
Gel	Never	<5	11–13
Absorption glass mat separator	Never	<5	6–8

Fig. 4. Traction battery using tubular gel cells.

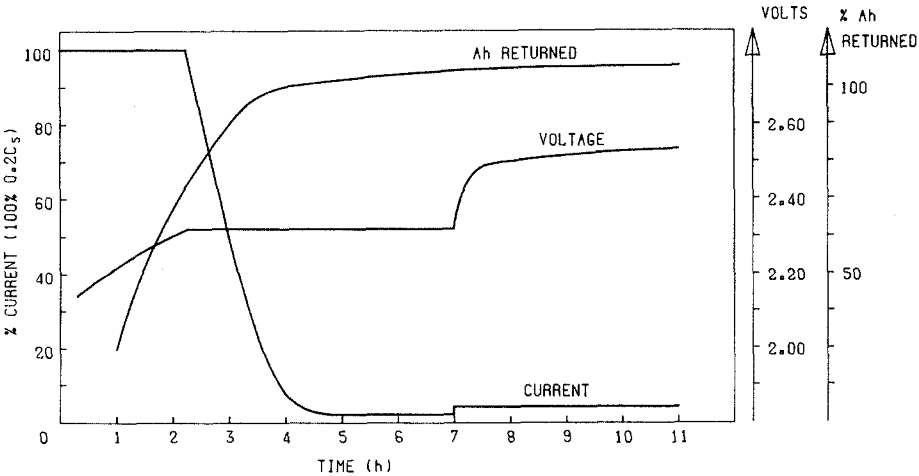

Fig. 5. Schematic charging regime for tubular gel cells.

Fig. 6. Industrial sweeper truck using gelled-electrolyte traction cells.

plications, however, water addition is neither desirable or practical and therefore there is strong interest in VRLA cells for traction service.

Gelled-electrolyte cells for traction service are constructed in a similar manner to their stationary counterparts but there are important changes to the internal design of the cell to optimize cyclability. Cells are invariably supplied in steel trays and so there is no need to have rigid cell containers to withstand internal pressure. As a result, heat-sealed polypropylene cases are used (Fig. 4). Charging must be carefully controlled in order to obtain optimum cycle life. Figure 5 shows a typical charging profile. A constant current of approximately 20% of the 5 h rate is applied until the cell voltage rises to a preset level. Charging is then continued at a constant voltage for a fixed period of time and then a small constant current charge is applied for the remaining time.

The benefits of maintenance-free operation for gel traction cells are not achieved without some disadvantages. The battery and charger are a system and so replacement of existing batteries must always include the charger. Times for recharge tend to be longer than for flooded batteries and cycle life for regular deep cycling is lower. For many applications, however, these are not serious drawbacks. A wide variety of industrial used such as sweeper trucks (Fig. 6), automatically-guided vehicles and pallet trucks can take full advantage of sealed batteries and in many practical situations more frequent opportunity charging is possible.

Conclusions

Gelled-electrolyte cells have become important for both stationary and traction service. For stationary applications, they are complementary to other types of VRLA cell. For traction applications, they form part of a range of alternatives for reduced maintenance but maintenance-free operation will increasingly become the normal requirement.

For electric vehicle applications, sealed operation is a definite requirement and the enormous level of interest in this area will stimulate rapid technological improvements which must be directed in part to improving the cyclability of VRLA batteries and their tolerance to operating conditions.