Journal of Power Sources, *31* (1990) 35 - 42

GAS-RECOMBINATION BATTERIES: FROM BASICS TO BATTERIES IN SERVICE

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Trends in the use of standby power

Trends in standby power are towards decentralized power installations and reduced ownership costs. The component batteries are installed integrally with, or near, the power equipment and are required to have minimal gas emission, a high energy density, and a service life commensurate with that of modern electronic equipment.

In the quest for reduced ownership costs, there is also an acceptance of shorter life to reduce capital costs; hence, there is a trend away from products such as nickel/cadmium and Planté-type lead/acid batteries. The great benefit of decentralized installations is elimination of the need for special battery rooms and associated buildings, and therefore associated electrical installation costs. The other advantage is, of course, the 'maintenance-free' (or more correctly described, 'minimal-maintenance') concept.

Lead/acid battery types can be categorized by service-life requirements based on their market-sector application. Thus, shorter-life batteries, normally of the gas-recombination type, satisfy alarm, small UPS (no break), PABX, and emergency-lighting duties. Longer life (10-year-plus) products would normally be specified for telecommunications, large UPS systems, switch-operating facilities (especially in the power generation industry), and central emergency lighting systems. There is a residual demand for long-life conventional products in large telephone exchanges and utilities, especially for replacement in countries using less modern equipment. In summary, the trend is towards lower capacity with shorter life. These aspects are summarized in Fig. 1.

Development of the Powersafe battery

Design criteria

The Chloride range of 'Powersafe' products was developed in recognition of market requirements, and was specifically aimed at the 10-year-plus life requirement with a capacity range from 20 to 1000 A h. With periodic testing during the seven years already achieved in service, operating results indicate that the design life of 10 years will be achieved in practice. The construction details of the Powersafe battery are given in Fig. 2.

0378-7753/90/$3.50

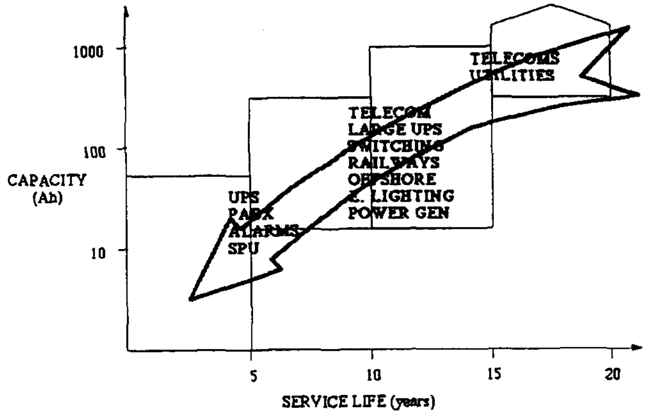

Fig. 1. Battery trends in standby power.

Powersafe has been designed using a lead–calcium–tin alloy that has been proved in service with conventional lead/acid cells. No antimony is present in the lead components and problems such as corrosion at the plate-lug/group-bar interface, which have been experienced by other manufacturers who chose to use antimony, have not been encountered.

The use of low-resistance microfibre-glass separation imparts very high-rate capability, of which full advantage is taken by careful design of the top lead and terminal components. Particular consideration has been given to safety, and the all-plastic components are flame retardant (UL94 VO rated). Other major features include integral insulation, controlled valve regulation (UO924, 2 psi), and robust current-carrying capability. All Powersafe batteries will withstand their own short circuit, and the current obtained at, for example, 0.5 s is at least twice that of the equivalent conventional product.

Gas-recombination efficiency

The gas-recombination reaction has been well documented [1, 2] and it has been shown that the evolution of a minimal amount of gas occurs [3]. As a result, there is no necessity to provide environmental or equipment ventilation for installations. For stationary applications where the float current is small, determination of gas evolution by weight loss is not sufficiently accurate.

Previous work [3] has measured and analyzed the gas evolved over a period of time. Over 95% of the gas evolved is hydrogen, the conclusion being that the remaining nitrogen and oxygen present is due to air contamination. Table 1 summarizes the volumes of the gas evolved from gas-recombination batteries with regulated float currents of 2.27 V/cell and 2.40 V/cell, and compares these volumes with those from conventional low-maintenance technology. Cells with the facility for gas recombination are normally at least 98% efficient. Observation of the average float-current levels in the sealed

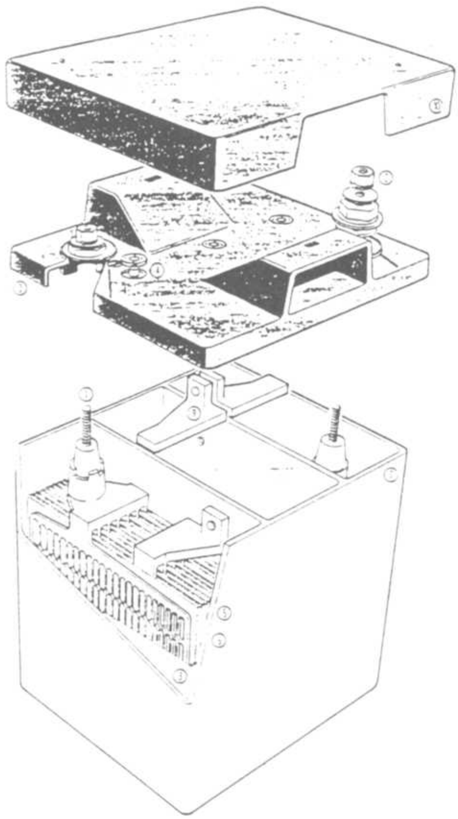

Fig. 2. Components of Powersafe battery.

cells for the two float-voltage levels demonstrate clearly the reason for the carefully regulated charging conditions always recommended by manufacturers of gas-recombination batteries. Indeed, experience at Chloride shows that a gas-recombination battery on permanent float at 2.40 V/cell will fail within 18 months to 2 years [4].

Operating conditions and chargers

For the operation of Powersafe batteries the following conditions are recommended:

(i) constant-potential charging;

(ii) float voltage 2.27 - 2.30 V/cell, 20 °C, no current-limit;

(iii) maximum boost voltage 2.40 V/cell to stable current, 24 h max.; typical 5 mA per A h of battery capacity;

(iv) float voltage should be adjusted for continuous average ambient temperatures below 15 °C or above 25 °C;

(v) low voltage cut-out at 1.60 V/cell;

(vi) no limit on cells in series connection;

(vii) for parallel banks of batteries, the external circuit resistance should be within ±5% for each parallel installation (4 max. preferred);

(viii) recharge within 5 days of discharge, also when the open-circuit potential of a battery in storage reaches 2.11 V/cell;

(ix) ripple current (a.c.) limited to 7% of 3 h capacity in frequency range 100 ⟶ 300 Hz; (it is possible that interaction between the components in some types of system can lead to high-frequency, shallow cycling);

(x) operating conditions based on 1300 sp. gr. acid at top-of-charge (obviously, it is not possible to take acid gravity readings for gas-recombination standby cells).

System 2000

Appreciating the requirement of some operators to have information concerning batteries while in service, Chloride has introduced a sophisticated battery monitoring system. The system offers a cost-effective solution for installations such as central telecommunications exchanges, back-up to computer main-frame equipment, offshore oil- and gas-rigs, and for monitoring remote-area power-supply installations. The equipment consists of an integral battery racking system accommodating Powersafe 1000 A h cells. The cells are arranged with front facing terminations to allow easy access and to optimize the use of space, and there is a fully automated battery monitoring system with facility for remote operation and data storage. All interconnections and cosmetic insulating panels are provided.

Each cell is monitored individually by a microprocessor-controlled unit. The unit records cell voltages and currents during discharge, recharge, and float operation. Cell condition is indicated by an LED mimic panel and the

TABLE 1

Relationships between gas volume and float current

Float voltage (V/cell)	Average float current (mA)	H_2 gas evolved[a] (litres)
2.27 (Powersafe)	25.2	0.20
2.40 (Powersafe)	487	1.17
2.27 (Conventional)	95	40.70 ($+20.35\ O_2$)

[a] Over a continuous 6-week period.

parameters checked include:

- high/low cell voltage (relative to module average)
- high/low rate of change of cell voltage
- 'time to go' during discharge, updated at 5 s intervals
- high/low module temperature (remote sensor in battery module)
- imbalance of parallel string currents (if appropriate).

The information can be stored for later analysis and an optional autodial modem will be available to facilitate remote initiation and data collection. The display/control unit can support up to 256 monitoring stations and can carry out an automatic 'check', cell by cell, that displays details of suspects or faults on the battery. It can also be used to initiate alarms.

Installation is very simple and the electronic system is supplied fully configured for the battery layout and cell type. A single multipin plug connects the module wiring loom to the monitor. Voltage measurements are made via connections on the cell terminals and current measurements are obtained from a special bus bar.

The battery racking system is designed for easy assembly and later extension, if required, thus promoting the concept and cost effectiveness of modular, decentralized power. The racking must be substantial and is constructed from 2 mm-thick rolled sections of mild steel. Shelf cross-sections have location guides for the battery monobloсs to ensure accurate alignment. One module, containing 24 monoblocs, weighs about 1000 kg and if point floor loading is restrictive, custom-designed spreader plates are available.

Standards and approvals

Powersafe conforms both to British Standard 6290, Part 1, which defines test methods, and to Part 4, 1986, which relates particularly to valve-regulated, gas-recombination, stationary lead/acid batteries. BS 6290 sets out criteria concerning life in service, short-circuit capability, gas emission, flame retardancy, and environmental and electrical test parameters. Powersafe also conforms to BS 2011 (Mechanical Stress) and BS 6334 (Flame Retardancy).

The above standards are important in that they identify and quantify the physical characteristics and performance of the product against published parameters, thereby providing a basis of expectation for the user. It should be noted that Powersafe is designed to operate in the gas-recombination mode as soon as it is commissioned and that process control in the factory ensures conformance.

Many gas-recombination products purport to be designed to, or conform with, BS 6290, Part 4, without any evidence of design capability or published data. Any purchaser in doubt as to the fitness for purpose of a product should request a written statement of test results, demonstrating conformance to BS 6290, Part 4, from the battery manufacturer. Note, as yet there is no European or IEC Standard.

Benefits of gas-recombination technology

One of the major benefits of gas-recombination batteries is their high energy density, especially at high rates of discharge, when compared with conventional lead/acid products.

Table 2 shows four major types of lead/acid standby battery, each of 300 A h nominal capacity, and compares the 5 min current with the amount of space taken up by each type of cell. Owing to the low internal resistance of gas-recombination cells, as well as the much smaller size of cell for equivalent capacity when compared with conventional cells, the energy density of gas-recombination cells is much higher, especially at high rates of discharge. Table 3 compares the nominal capacity (10 h rate) required of each of the four types of battery to meet a constant power duty of 160 kW for 5 min.

The space required above gas-recombination cells can be limited to that required for the installation. For example, it is quite easy to put six Powersafe cells in a vertical stacking arrangement, thereby making considerable savings on floor space when compared with conventional products. Figure 3 demonstrates this particular feature. The comparison of space required for 160 kW/5 min using 180 cells shows that Powersafe requires only 46% of the floor space of, for example, tubular products (see Fig. 4).

Other benefits of gas-recombination cells are:

- excellent resistance to environmental vibration and shock, owing to tight assembly and robust design
- cost effectiveness of the modular system: capital is required only for present-day duties, but the system is capable of being extended in the future
- minimal maintenance and long life once installed
- safety and reliability in use, with flame-retardant components, no free acid, minimal gassing, integral insulation, and full short-circuit capability
- convenience in service with provision for lifting; threaded terminals and front facing facility, if required, for ease of installation and monitoring

Apart from being installed on stands or in cabinets, or even within the system for which the batteries are providing power, gas-recombination batteries may be used in confined surroundings or hazardous areas where the gases evolved from conventional cells would be unacceptable. Typical of such installations are:

- containerized equipment, such as remote telecommunication installations
- underground locations — either for security or because of above-ground space limitations
- wall-mounted shelves or racks where floor space is limited
- underfloor, where retro-fitting often allows more power to be obtained in the existing space available
- mobile equipment or trolleys for ground starting duties
- mining or chemical process industries
- oil rigs for all standby duties, including eddy-current breaking, process control, SOLAS regulations and generator starting
- seismic installations

TABLE 2

Battery comparison — high rate performance

Battery type	10 h capacity to 1.85 V (A h)	5 min rate to 1.62 V (A)	Overall box volume (litres)	Energy density (A min litres^{-1}) (5 min rate)
Powersafe	300	916	9.3	493
Planté	300	714	24.6	145
Tubular	300	448	11.6	154
Pasted	300	606	14.8	205

TABLE 3

Nominal capacity under high-rate duty (160 kW/5 min, 10 h rate) for different types of battery

Battery type	
Powersafe	160
Planté	250
Pasted	255
Tubular	420

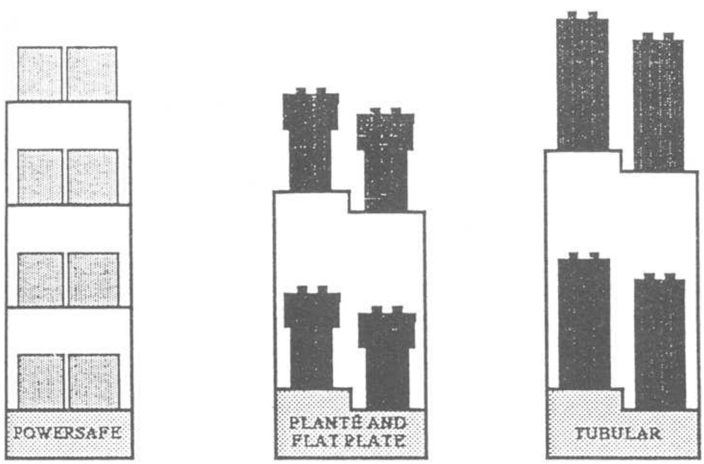

Fig. 3. Height needed for different battery types. Duty: 160 kW/5 min/180 cells.

A full range of engineered accommodation including racks, cabinets and wall shelving can be provided, seismically qualified designs are also available. In high-current applications, such as uninterruptible power supplies, special termination boxes, to support and connect cabling up to cross-sectional areas of 600 mm^2, are available.

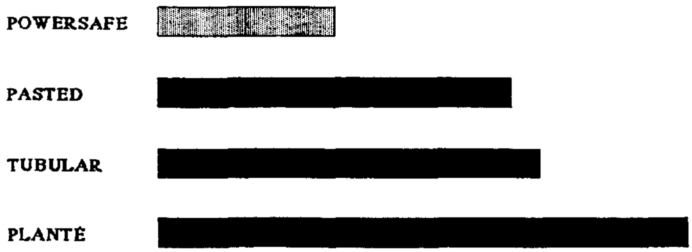

Fig. 4. Floor area required for different battery types. Duty: 160 kW/5 min/180 cells.

In conclusion, Chloride now has seven years' service experience with Powersafe in a variety of installations. This work has proved beyond doubt the satisfactory performance and reliability of gas-recombination lead/acid batteries.

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