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Computer formation of sealed lead/acid batteries

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Abstract

The desire of many companies to enter the growing market of valve-regulated batteries (also known as sealed lead/acid) requires a higher level of control in virtually all the stages of manufacture. Formation charging and charge conditioning is a particular case in point. Whether the valve-regulated battery is of the starved-electrolyte or gelled-electrolyte type, the final stages of formation and charge conditioning require careful attention to control the cell voltage. Charge rates that exceed the oxygen-recombination rate will cause excess gassing and thus reduce the available electrolyte. This, in turn, reduces battery life and, in the case of gelled-electrolyte batteries, causes improper cracking of the gell and concomitant reduction in capacity, performance and life. Valve-regulated batteries require charging equipment that can automatically regulate charge/discharge current and voltage. Given the requirement for multiple steps of battery conditioning, computer control provides a totally effective way to control the voltage, current, time, ampere hours and charge/discharge functions without operator assistance.

Introduction

Sealed lead/acid batteries (SLA), more properly known as valve-regulated batteries, require special forming techniques beyond those used for automotive batteries. Two basic formation methods are used for SLA batteries: plate formation and container formation. Both methods are followed by a conditioning charge in order to achieve the desired oxygen-recombination performance and to increase the cell capacity. Generally, the maximum conditioning-charge current is no more than the finish current during formation and is voltage limited. Minimum current rates during conditioning are often as low as 1/100 of the maximum conditioning-charge rate. Minimum current capabilities are particularly important for conditioning of gelled-electrolyte cells. Small-capacity batteries (i.e., 15 A h or less) generally require plate (tank) formation prior to assembly. In fact, some manufacturers form plates prior to assembly for all capacity ratings due to the difficulty of controlling recombination in container formation.

Further to the formation and conditioning-charge requirements, is the need to consider rest periods for formation of thicker plates and to limit the voltage during conditioning charge/discharge steps.

Formation guidelines

The following formation guidelines have been generalized due to the many variations in battery production methods employed by different manufacturers. The values of

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voltage limitations and charging-current rates are approximate and, therefore, should not be considered as absolute values for a particular process. Actual limitations will depend on active-material composition, separator composition, plate thickness, electrolyte volume, temperature, etc.

It should also be noted that the concerns for forming starved-electrolyte (i.e., absorptive glass mat) cells are quite different from those for gelled cells. This arises primarily from porosity differences in the separators of starved-electrolyte batteries compared with gelled-electrolyte types. The latter require lower charging currents to control the gassing to a level that produces the desired cracking of the gelled electrolyte. Excessive gassing will cause voids that reduce both the capacity and the ability for gas recombination.

Generally, for starved electrolyte cells, the porosity of the separators attains a level of about 12–15% of the separator pore volume. By contrast, the porosity may be as low as 1.5% in gelled-electrolyte cells. These differences explain the need for a lower charging current with gelled-electrolyte cells so that the cell voltage is at least 0.1 V less than that used for starved-electrolyte types during the gas-recombination phase of plate formation.

Methods of plate formation

Many companies take the position that tank formation is the only practical method for the plate formation of SLA batteries. This is because of the time required to properly form plates with the voltage restrictions imposed on container formation.

The labour required for plate handling is somewhat more intensive than that experienced with container formation but the process time can be less. When forming plates in tanks, two or three current steps should be provided to follow the conversion efficiency. Generally, formation is made in acid with a specific gravity (sp. gr.) of 1.150 or less. The ampere-hours required are approximately twice the theoretical ampere-hours based on the weight of the active material.

Plates for starved-electrolyte cells are normally formed to approximately 70%, while the value for plates for gelled-electrolyte batteries is somewhat less.

Care must be taken to transport negative plates from the tanks to the drying ovens with minimum exposure to oxygen. This may be accomplished by transporting the plates in mobile water tanks to the washing station, and similarly to the drying ovens.

After drying, the plates are grouped into elements for final assembly in containers. The filling acid usually has a sp. gr. of 1.230. The cells are charged at a rate that produces no more than 2.55 V/cell at 25 °C. This phase of formation is necessary to produce the porosity in the separators that is required for proper oxygen recombination. Finally, the cell is floated at no more than 2.28 V/cell. Preceding the float stage, the cell may be discharged/charged to assist the development of the capacity.

In container formation, the cell is overfilled with acid of 1.230 sp. gr. The latter is dumped after initial formation. The cell is then subjected to a conditioning charge similar to that applied in tank formation and with similar cell voltage restrictions. The resulting electrolyte has a sp. gr. of about 1.290.

Table 1 provides a general guide to forming requirements but should be considered only as a guide. Actual values will vary with process and ambient conditions.

TABLE 1

Plate formation requirements for sealed lead/acid batteries

Parameter	Tank formation	Container formation	Starved electrolyte	Gel
No. of current steps	2–3	3 before final conditioning of cell		
Initial current rate	C/3	C/5		
Conditioning current rate and voltage limit		C/20	2.55 V/cell at 25 °C	2.45 V/cell at 25 °C
Float voltage and current limit		C/20	2.28 V/cell at 25 °C	2.28 V/cell at 25 °C

Approximate forming currents and voltage limits

The values of the conditioning current and the voltage limit will vary with geometry and with the other factors discussed above. It should be remembered that the important function of the charging phase is to create the required porosity for gas-recombination. This will be achieved by controlling both the voltage and the time. The conditions are temperature sensitive and thus some manufacturers utilize water baths to maintain the cell temperature within a narrow range.

Since emphasis has been given to the voltage control, it should be understood that the voltage at the cell terminals is the important value. In order to read this voltage accurately, the cables from the rectifier to the string of cells (or batteries) must have a low voltage drop. Alternatively, a set of sensing leads must be supplied to read directly the voltage of the battery string.

In the float phase of formation, the current will fall to milliamperes to maintain the float voltage. This requirement determines the current control range of the rectifier and, as stated earlier, may be 100:1.

Computer-controlled formation

Charging schedules consisting of multiple steps, as described above, are ideally suited for computer control. The latter provides the means to control effectively the charging process with almost no error. Battery current, ampere-hours, voltage limits, time and temperature may be entered into conditioning programs as control or limit values. Specifications for some SLA batteries require regulation of voltage and current to within 2% of the set point. When regulating at an 0.100 A output, this requires regulation of ± 2.0 mA.

Key features of computer-controlled charging equipment that must perform both conditioning and formation charges are as follows:

- capable of charge/discharge
- accurate voltage limit control
- wide current regulation range (100:1)
- 16-bit accuracy of regulated and monitored values
- fail-safe operation in event of computer malfunction
- distributed control for each circuit
- multiple stages of electrical isolation
- ability to store hundreds of formation schedules and battery types
- battery circuit and system fault detection

A key point of the features listed above is that the computer cannot be used to control directly the regulating functions of the charging circuits. While this approach would be the least expensive, the formation floor would be at the mercy of a computer which is not allowed to fail. This approach is also limited to the number of circuits that can be controlled with high accuracy.

The most versatile and secure method of control for charging circuits is an independent microprocessor-controlled programmer on each circuit that communicates with a host computer. The programmer should also have the ability to select programs locally in the event of a computer malfunction. Usually, microprocessor programmers are provided with a lithium battery to protect memory in the event of a power loss.

It is also desirable to provide each circuit with a manual current control for set up and the checking of charging circuits. Manual control may also be used for charge/discharge operations that are limited to current-regulated operation.

Computer control allows the most effective utilization of charging circuits by providing operators with an overview of the charging status of the formation floor. A summary screen display shows operators at a glance the circuits that are on charge or discharge or are available for new battery circuits to be connected. This same display will also indicate faults of battery circuits, such as open or poor connections between cells or batteries.

Host computer control centre

The host computer control centre may consist of a single computer where all control and monitoring functions are made. Alternatively, the centre may comprise multiple work stations that allow operators to segment floor operations and provide monitoring at an office location.

Computers located on the formation floor require special protection from acid misting, no matter how slight this may be. It is therefore recommended that the computers are located on the formation floors in sealed protective enclosures or in small enclosed cubicles with fresh air available. Keyboards must be protected with covers or use membrane-type keyboards that are resistant to corrosion.

Another possible alternative to computer stations on the formation floor is the use of small portable units carried by operators. These units transmit circuit location and battery type formation to the host computer via a radio frequency signal. This method frees operators from the need to return to an operating station to enter start-up information. Monitors placed on the formation floor provide operators with the current status of the formation activities.

The overall benefits to computerized formation can be summarized as follows:

- maximum utilization of formation circuits
- precise control of formation circuits
- minimum labor in the formation process
- shortest possible formation schedules
- consistent quality of product
- a record of formation results for each group of batteries