TROJAN BATTERY COMPANY

WHITE PAPER

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Comparison of Tubular and Flat Plate Lead Acid Battery Technologies

This white paper outlines the differences between Tubular and Flat Plate lead acid battery technologies and how specific applications should be the bases of technology selection.

Clean energy for life.™

Introduction

Since the introduction of the lead acid battery by Gaston Plante, in 1860, battery manufacturers have relentlessly sought better methods of storing greater amounts of electrical energy. Between 1881 and 1892, rapid development occurred in the area of grid design and active material formulation. In addition, technological advances in machinery and charging equipment resulted in improved, more efficient manufacturing processes.

It is generally accepted that tubular plate technology developed along a similar timeline as did the flat plate. It is interesting to observe, however, that tubular plate lead acid batteries seem to have gained wide acceptance within the European community, as well as those Asian countries which were tied to the great empires of Europe around the turn of the century.

The purpose of this white paper is to compare and contrast the features and benefits of both flat and tubular plate, lead acid batteries. We will look at construction and structural differences, as well as performance and life cycle characteristics. Finally, we will point out differences regarding charging characteristics and maintenance.

Positive Plate Construction

An electrolytic cell, by definition, is two dissimilar metals submersed in an electrolyte. In the lead acid cell, the positive electrode or anode, is comprised of lead dioxide (PbO2) and is the work horse of the battery. The negative plate is sponge lead (Pb). In both tubular and flat plate batteries, the negative plate is identical in appearance and function. It is the positive plate that differs in design and construction.

Figure 1

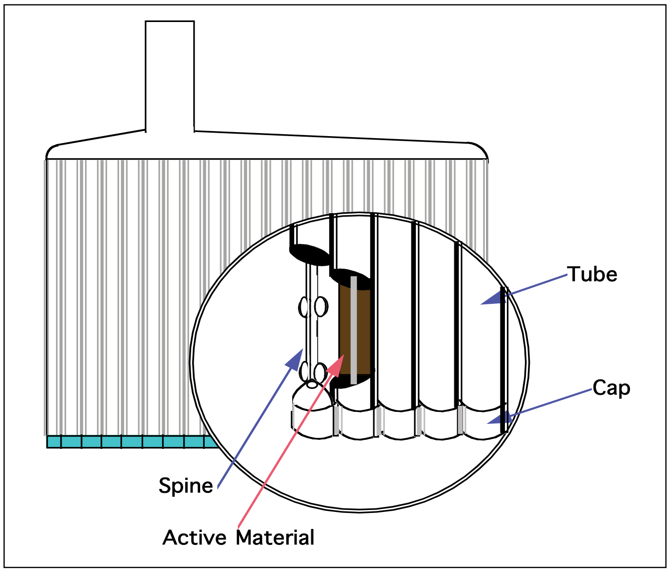


Figure 1 shows typical tubular plate construction. The current collector consists of a series of spines that extend down from the top bar and is called a **comb**. The parallel tubes, or **gauntlet**, which surrounds the spine and retains the active material, are made of a porous, inert fabric. Once filled, a cap is placed over the opening at the bottom of the tube to prevent active material loss.

The flat plate positive is constructed of a grid and active material. The grid is cast from an alloy of lead and antimony. The horizontal and vertical members are called **wires** and are connected to the **frame**. As shown in ***Figure 2***, the active material, when pressed into the grid, results in a mechanical interface at the grid wires and frame. This extrusion process also yields flat surfaces on both sides of the plate.

The primary objective in both tubular and flat plate construction is the uniform distribution of the density of the active material throughout the plate. If the density is too high, performance will be reduced. Low density results in premature capacity loss and short battery life.

Figure 2

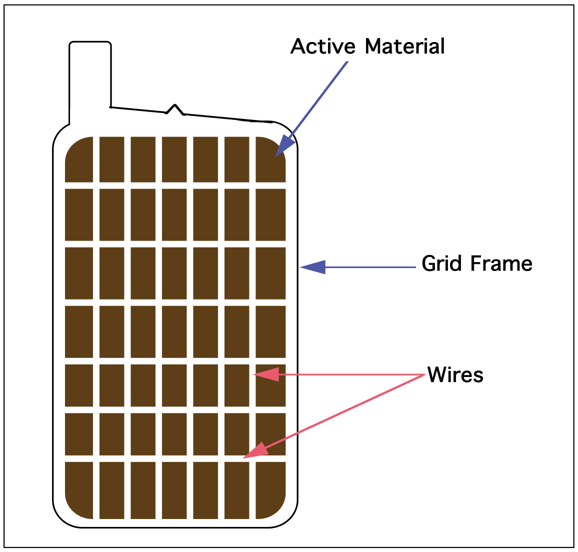
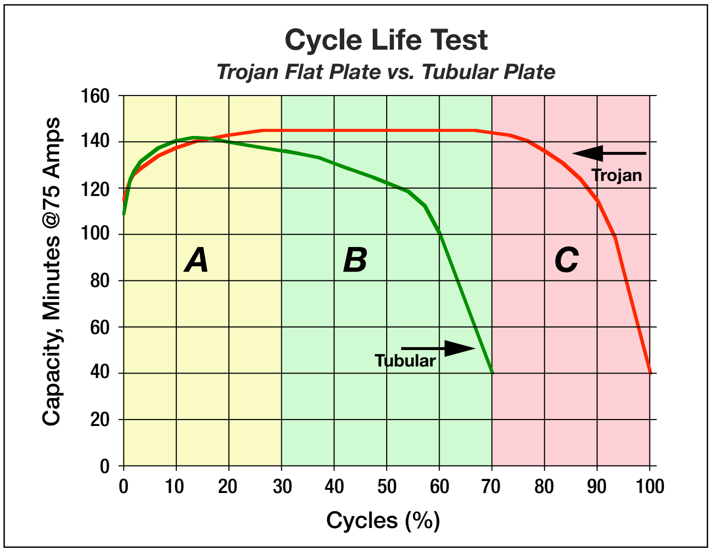


Figure 3



Performance and Cycle Life

Battery performance can be characterized by a variety of criteria, none of which taken singularly should be viewed as a basis for making a buying decision. The following graphs comparing capacity against life cycles visually demonstrate the differences between flat and tubular plate batteries.

When a lead acid battery is formed, the active material in the positive plate is converted to lead dioxide (PbO2). Lead dioxide exists in two forms, **Alpha** and **Beta**. The ratio of Alpha and Beta PbO2 in the formed plate is due in large part to the active paste formulation and plate curing processes.

Section A of ***Figure 3*** shows the gradual increase in capacity over many cycles which is characteristic of a high concentration of Alpha-PbO2. The tubular plate battery graph shows a sharp, rapid increase in capacity within a few cycles, and is typical of an active material formulation high in Beta-PbO2 content. It should also be noted that after achieving its maximum performance, a gradual decline in capacity begins in the high beta, tubular plate battery. This decline in capacity continues through the section B of the graph, whereas in the flat plate battery, full performance is maintained throughout this period.

The flat plate battery begins to experience age-related capacity loss in section C, at about the time the tubular plate battery has reached the end of its useful life.

The typical end-of-life failure mode of a deep cycle, flat plate battery is (1) the deterioration of the structural integrity of the active material resulting from the consumption of the Alpha-PbO2 and (2) grid failure which results from the continuous corrosion process due to charging. Although the spines of the tubular plate battery are subject to the same corrosion forces as the flat plate grid, normal failure in the tubular battery is related to the shedding of active material. At the end of charge, gassing causes the loose positive active material to come in contact with the negative electrode resulting in the formation of a mossy, sponge lead. Mossing usually results in short circuiting and premature failure. Due to the physical stress placed on the tube from discharging and charging, eventually the tubes rupture and active material is lost from the positive plate. This is why tubular plate batteries may have up to twice the sediment space as a comparable flat plate battery.

Charging and Maintenance

Optimum battery performance and life is in large part dependent upon proper charging and maintenance. As previously discussed, the active material in the positive electrode of either battery type is lead dioxide, a corrosion product, similar to rust which is iron oxide. The rate at which corrosion occurs in a lead acid battery is related to the end-of-charge current required to restore the battery to a full state of charge.

The most obvious benefit of the tubular plate battery design as compared to the flat plate is the higher **specific energy**. Specific energy is the relationship between watt hour capacity of the battery relative to the weight of the battery.

Such benefits are not without cost, however. Small diameter spines and reduced active mass result in greater internal resistance. This means more watt-hours of over-charge are required to restore the tubular plate battery to a full state of charge. Furthermore, the greater sediment space in the bottom of the tubular plate cell requires more watt-hours of charging to facilitate the mixing of the electrolyte during recharge after a discharge. If sufficient over-charge is not accomplished, a condition known as stratification will result wherein the sulfate ions concentrate in the bottom of the cell during recharge. Gassing, which increases toward the end of charge, causes the highly concentrated acid solution to mix uniformly throughout the electrolyte solution.

When recharge time is critical, a higher end of charge voltage may be required to bring the tubular battery to full charge. Lab tests demonstrate that full performance of the flat plate battery was achieved when the end of charge voltage reached an average 2.58 volts per cell. Whereas in the tubular plate battery, the end-of-charge voltage had to reach 2.68 volts per cell, in order to achieve optimum performance. This higher over-voltage potential in the tubular plate battery, coupled with higher current flow, generally results in a greater rate of corrosion to the lead alloy comb and increased water loss from the electrolyte solution.

Generally accepted routine maintenance practices do not differ greatly between flat plate and tubular plate batteries. It is good practice to check cell voltages and specific gravity values periodically, in addition to verifying proper operation of the battery charger. Also, the batteries should be cleaned periodically to remove any acid-saturated dirt and debris which might accumulate on the top of the battery.

Laboratory tests confirm that water consumption in the tubular plate battery was significantly greater than in the Trojan flat plate battery - almost twice as much over the battery's life. This in turn would suggest that maintenance cost would generally be greater for the tubular plate battery.

Conclusion

Proponents of both designs have debated the virtual benefits of their favored technology for decades. Granted, tubular plate batteries tend to excel in specific energy characteristics. Meaning, the watt-hour per kilogram ratio is greater in tubular plate batteries than in flat plat designs.

Flat plate designs are more robust. That is there is a greater reserve of grid metal and active material, resulting in a heavier battery for the equivalent watt-hour capacity. Heavier grids and more active material enhance the life cycle characteristic, thereby reducing the costs associated with frequent replacement. Lower water consumption reduces maintenance costs. Furthermore, experience has shown that flat plate batteries are superior at sustaining their voltage under high rate discharges, such as a forklift raising heavily loaded pallets during the course of a normal work shift. This is due to the greater active material mass and larger current conductors of the flat plate.

The selection of a battery best suited for a specific application should be based in large part on considerations as previously discussed. But first and foremost, the application requirements and proper sizing analysis should be performed prior to evaluating a battery's design and construction.

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