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Tale of the Tube: Why Tubular Batteries Maximize Fast Charge Benefits

George W. Ayrton
Director of Motive Power Engineering,
EnerSys

Fast Charging industrial motive power batteries have revolutionized the way electric lift truck fleets are managed. Valuable warehouse space and personnel no longer need to be dedicated to battery rooms with spare battery storage, battery handling and changing equipment. Lift truck operators do not need to travel from their work area to the battery room to change out batteries, saving thousands of dollars in lost productivity. No longer do batteries weighing thousands of pounds need to be hoisted in and out of lift trucks, reducing the potential for employee injuries.

Most of the attention in fast charge discussions has been on the fast charger's ability to recharge a battery in a short amount of time. Very little attention has been given to how this affects the performance and life of the battery being fast charged. Interest in fast charging and the number of successful fast charging operations has grown significantly over the past 2-3 years. However, the batteries that have been fast charged in many of these operations have already or are now reaching their operational limits, and because some of these batteries have fallen short of their initial expectations, more and more focus is being put on the batteries used in fast charging.

Traditional thinking in the motive power battery industry has been to size a battery for an application by allowing for one "cycle" defined as 8 hours of work (discharge), 8 hours of charging, and 8 hours of rest or cool down time. Most standard motive power battery warranties limit a battery's use to one cycle per day. Estimates of standard charge times have been based on charging rates of about 14-16 amps for every 100 ampere-hours (AHs) of a battery's rated capacity. Fast charging turns that old rule of thumb on its head by returning 40-50 amps per 100 AHs of a battery's capacity back into the battery. In addition, the battery is now charged many times during a workday in order to provide the power needed for a single battery to last for two shifts or more. This practice is referred to as "opportunity charging" and uses special charge profiles designed to minimize the heat impact by only charging a battery to 80 percent of the rated capacity. Even with an opportunity charge profile, pushing fast charge current rates into a battery designed to only accept standard charging rates will cause heat issues which may shorten the life of the battery significantly. Also, fast charge operations eliminate the traditional 8-hour cool down time during the workday and since the battery may be kept in an enclosed lift truck compartment during charge periods, thermal management becomes a big problem. A few years ago, EnerSys started a project to develop a battery that would address not only the thermal management impact on a battery, but also determine what battery technology would provide the best performance from both a charge acceptance and a lift truck operation point of view. Two areas were looked at: the battery's top construction where most of the heat associated with high charge currents occurs, and cell structure and chemistry design. Since EnerSys markets several types of cell technologies from flat plate, tubular, high gravity, thin plate, thick plate, and various metallurgies, there was no preference for any specific battery design.

The Cell Design

While all cell technologies had advantages and disadvantages for fast changing, it was determined that a high capacity tubular plate was best suited for fast charging. Higher capacity achieved through the use of

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high gravity electrolyte proved to promote higher temperatures because of higher electrical resistance associated with higher electrolyte specific gravities. The standard flat plate batteries have capacities of 85 AH and 125 AH in standard 23-inches height and 31-inches height batteries respectively, while tubular plate batteries in these heights show capacities of 100 AH and 140 AH respectively. That's 17 percent more capacity in the 23-inches and 12 percent more capacity in the 31-inch high battery. The main benefit of a higher capacity battery is more available energy in the battery "box". This allows operators to run longer and or harder between charges, and allows some capacity leeway for peak operating times, or neglecting charging opportunities. Also, higher capacity allows discharged amps to be replaced faster than in lower capacity batteries. As stated earlier, fast chargers are typically set to charge anywhere from 40 to 50 amps per 100 amps of a battery's capacity. Using a charge rate of 50 amps/100 amps of battery capacity (50 percent charge rate), higher capacity tubular batteries can accept more amps in a shorter time then flat plate batteries as outlined in figure 1.

Conversely, if recharge time is not an issue, a tubular battery's capacity advantage allows a charger to replace the same amps at lower charge rates. In this scenario, lower charge rates mean less heat is generated, less stress on the battery, and therefore longer battery life can be expected. (Figure 2)

Battery Type	Battery Height	Battery Capacity	Max Amp Input @ 50% Charge Rate
Flat plate: 85-17	23”	680 AH	340 amps per hour
Tubular: 100-17	**23”**	**800 AH**	**400 amps per hour**
Flat plate: 125-17	31”	1000 AH	500 amps per hour
Tubular: 140-17	**31”**	**1120 AH**	**560 amps per hour**

Figure 1

While charge impedance at the plate surface of a tubular plate will be slightly higher then a flat plate, the "mummy-like" plate insulation that is designed to keep active material from falling off the flat plate grid actually causes a flat plate's electrical impedance to become greater than the tubular plate. Tubular batteries typically use a porous woven or non-woven polyester or braided fiberglass around the active material instead of the four to five layers of insulation wraps commonly used to encase positive flat plates.

Battery Type	Battery Height	Battery Capacity	Charge Rate
Flat plate: 85-17	23”	680 AH	50% @ 340 amps per hour
Tubular: 100-17	**23”**	**800 AH**	**43% @ 340 amps per hour**
Flat plate: 125-17	31”	1000 AH	50% @ 500 amps per hour
Tubular: 140-17	**31”**	**1120 AH**	**45% @ 500 amps per hour**

Figure 2

Another advantage to higher capacity fast charge batteries is a concept called "the sweet spot". As a battery is discharged and battery voltages decrease during a work shift, a typical DC lift truck will experience a gradual slowing of lifts and run speeds, which become more pronounced as the battery falls below 50% state of charge. Given the same discharge rates, a higher capacity battery will sustain higher voltages between charges and allow for a more productive lift truck. Considering a fast charge battery is operated in a partial state of charge due to the opportunity charge profiles used with fast charging, this extra capacity can have a significant impact on truck performance. *(See figure 3 on opposite page.)*

AC lift trucks also will benefit from high capacity tubular batteries in fast charging. One of the advantages of an AC lift truck over a DC lift truck is their ability to maintain constant lift and run speeds throughout the battery's discharge cycle. However, to maintain lift and run speeds as a battery's voltage drops, an AC motor will draw an increasing number of amps to compensate for the falling battery voltage. In a standard charging scenario, higher amp draws associated with AC trucks will discharge the battery faster and shorten battery run times, however the overall productivity of the AC truck per battery can be higher due the trucks ability to maintain run and lift speeds throughout the battery's discharge cycle. Similarly, a high capacity tubular battery will ensure there is adequate capacity in fast charge applications as well.

The "top construction" of an industrial battery is critical to the thermal management capability of the fast charge battery design. On a standard industrial battery, the top construction consists of the lead post strap which connects the positive or negative plates in a cell with a post through the top of the cell's cover, lead intercell connectors, lead charging cable termination connectors, charging cables, and the method of assembling these components. Several design concepts to improve the current carrying capacity of these components were tested. The combined impact of the design improvements resulted in a 10 percent decrease in battery temperatures during fast charge cycling. The post strap was increased in size from a

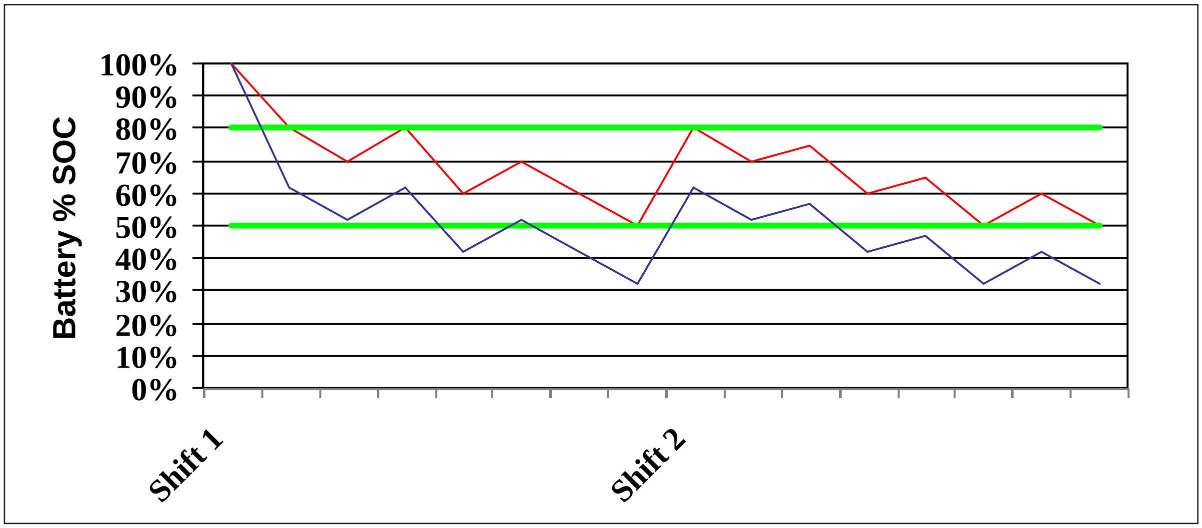

Figure 3

standard ¾-inch diameter to a 1-inch diameter providing 78 percent more cross sectional area. Also, since copper is much more conductive than lead, a copper core was cast into the lead post. Similarly, new molds were designed for the lead intercell connectors in order to double the thickness of the connectors and allow for a thicker copper core. Because batteries exceeding 600 ampere-hours in capacity require two sets of positive and negative cables, a new dual cable termination connector was developed. The new lead cable connector is able accommodate the efficient positioning two sets of cables on top of the battery. Even the intercell connector covers were considered. By simply slotting the covers to vent heat off the top of the connector, heat built up under the cover can be reduced. Finally, 4/0 cables are used on fast charge batteries to minimize current resistance and reduce heat.

Traditionally, battery engineers designed motive power battery components to meet a range of application requirements. Cold storage facilities, hot ambient temperatures, three shift operations, among others forced designers to size components to meet these extreme conditions, while the majority of applications did not approach the demands of these conditions. Fast charging requires batteries to be used exclusively in applications that push the limits of a battery and its components every day, including pushing charge currents to the upper limit, rarely providing a cooling or resting time, and relying on lift truck operators to "plug in" at every break and finding time to adequately maintain the battery. Doing more with less is the mantra in most operations today, and fast charging can provide significant operational savings if the system is managed correctly and correct charger and battery are utilized.

EnerSys is the largest industrial battery manufacturer in the world, operating 21 manufacturing and assembly facilities worldwide for customers in over 100 countries. Worldwide and Americas headquarters are located in Reading, Pennsylvania, USA with regional headquarters in Europe and Asia.

EnerSys is uniquely positioned to provide expertise in designing, building, installing and maintaining a comprehensive stored energy solution for industrial applications throughout the world. The company's products and services are focused on two primary markets: Motive Power (North & South America) or (Europe) and Reserve Power (Worldwide), (Aerospace & Defense) or (Speciality Batteries).

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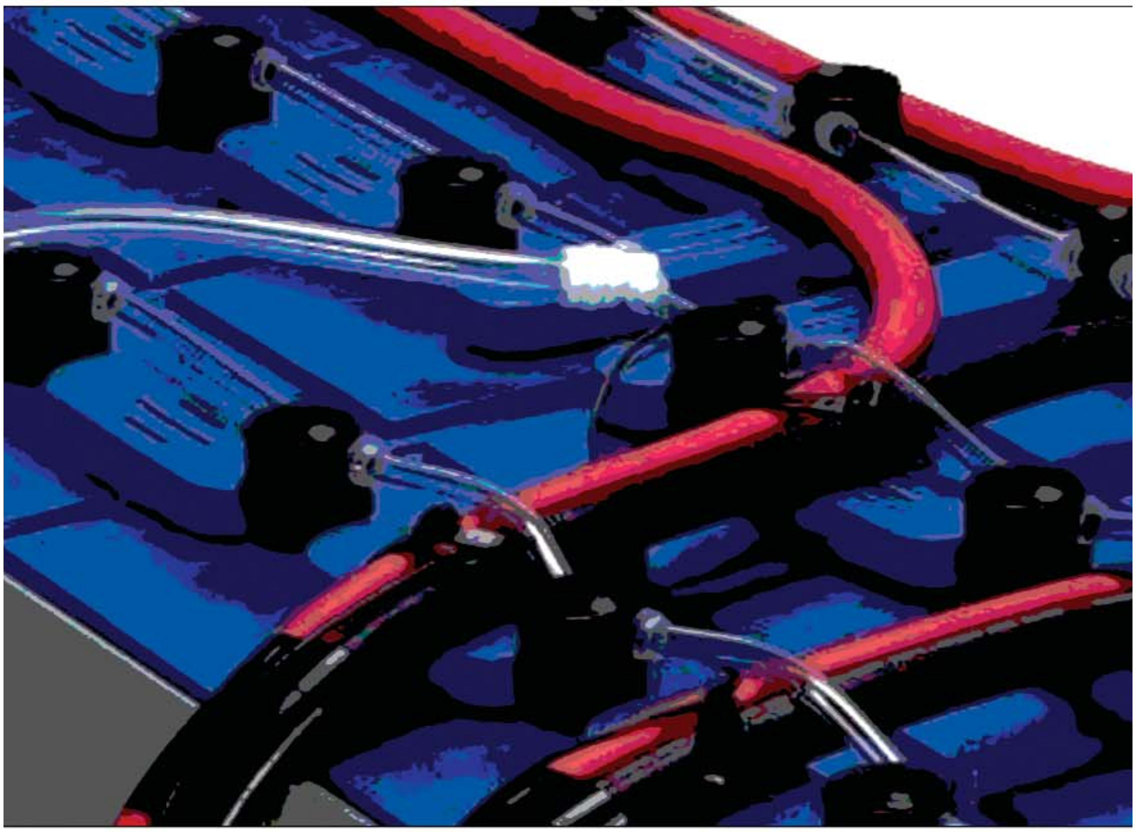

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