# *UNDERSTANDING MARINE ELECTRIC PROPULSION SYSTEM BATTERY PERFORMANCE*

Boat owners choosing to convert to or purchase a vessel with an electric propulsion system often struggle with questions about batteries – what type, how long will they last, what motoring range will they deliver, how to charge them, etc. Often, they look to what they have learned over the years from dealing with their 12- or 24-volt house batteries for answers. Unfortunately, important differences between marine electric house and propulsion loads result in a need for a fresh look at the question of what batteries work best for propulsion applications. We have found that our customers can arrive at satisfactory results for a wide variety of boating profiles once they set aside what they know about their house batteries and accept that there is more to a battery than its capacity.

We have also found that by starting the "battery conversation" with an unexpected analogy – water tanks – we can convey a key idea quickly. Imagine a full 500 gallon water tank with a garden hose attached. If you open the spigot so that 1 gallon per minute flows out through the hose, the tank will be empty in 500 minutes. Now imagine replacing the garden hose with a fire hose that can handle 10 gallons per minute, refilling the tank and opening the spigot again. The larger hose will obviously cause the tank to empty faster, but has the amount of water in the tank initially changed? "No," you say, "500 gallons is 500 gallons no matter how big the hose is." And this is correct. To understand batteries, however, imagine that just by connecting the larger hose, the 500-gallon tank suddenly only had 380 gallons of water in it. In other words, a battery's capacity varies with how quickly energy flows out and is put it back in. As a result, a conversation about what battery type fits what application has to include two different parameters – the capacity in amp-hours or kWh and the "C" rating.

The C rating is a parameter adopted by the industry to describe the discharge and recharge capability of the batteries. C ratings are like golf scores – the lower the number, the better. For house loads on boats, Lifeline AGM batteries have emerged as a popular choice, so we will use them to illustrate how C ratings work. The first thing to understand about AGM batteries is that the term refers to a wide variety of battery types that share the common feature of using glass fiber matting between the plates to hold the electrolyte solution. Think of AGM as a "clan" made up of "families" with different characteristics for different applications. The Lifeline batteries, like most AGM's, carry a C rating of C20. This means that you divide the amp-hour rating by 20 to get the discharge current the amp-hour rating applies to. The 250 Amp-hour Lifeline, for instance, is a 250 amp-hour battery only so long as you discharge it at 250 / 20 = 12.5 amps or less. This is fine for house loads on most cruising sailboats. But electric propulsion installations involve discharge currents of 60, 80 or even 100 amps or more. Conventional AGMs like the Lifelines lose significant amounts of their capacity at these higher discharge currents. For example, take a look on Page 30 of the attached Lifeline manual and note the "4 hour" curve which ends at just above 80%. This corresponds to C4, or 250 / 4 = 62.5 amps. At this rate, the 250 amp-hour battery is really only good for 80% of its nominal capacity, or = 200 amp-hours. At higher currents, the capacity loss accelerates.

For applications involving sustained high discharge currents, battery engineers developed a new design concept known as the Thin Plate Pure Lead (TPPL) battery. TPPL batteries are a special type of AGM with a higher number of thinner plates in the same size package as well as thicker collector busses. They therefore present incoming and outgoing current with less resistance, and they support faster charging and discharging. Think of TPPL as an elite family within the AGM clan. NorthStar Energy1's, for example, are conservatively rated C3, so that their 210 amp-hour battery can handle 210 / 3 = 70 amps with no loss of capacity. In other words, at typical electric propulsion currents, the NorthStar Energy1 210 amp-hour battery, at 128 pounds, actually stores more usable energy than the Lifeline 250 at 162 pounds. In addition, the NorthStar will last 500+ cycles even if they are routinely discharged to 20% whereas the Lifelines lose life if discharged below 50%.

Boat owners looking at electric propulsion have other options besides TPPL batteries for providing energy storage along with high discharge and recharge capability. Flooded “wet cell” golf cart batteries, for example, also offer low “C” ratings, but they require frequent refilling of their electrolyte solution and they must be well-vented. We recommend them only for live-aboards who are meticulous in their maintenance practices. Meanwhile, Lithium Iron Phosphate (LiPO4Fe) batteries have also gained acceptance in marine applications over the past few years. While costly, they have also come down in price to the point at which, with their very long life spans, they are cheaper on a per-cycle basis than TPPL. As a result, they are economical for frequent-use applications like water taxis in which the savings can be realized within a few years. LiPO4Fe batteries also weigh less and take up less space than TPPL’s do, and this can be a deciding factor in highly weight-sensitive applications such as racing sailboats. Most of CeMA’s customers have opted for the TPPL’s as they find that the payback from the longer life of the LiPO4Fe’s would take too long to be realized, and, after having removed a large diesel engine or two, they don’t need the weight and space savings offered by LiPO4Fe’s.

CeMA’s installed fleet of TPPL’s has proven itself well both in day sailing and cruising electric propulsion applications.

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