"Lithium-Ion Batteries: Handle With Care" by Dwight Escalera as published in Professional BoatBuilder, April/May 2012

Dramatic advances in commercially available battery technologies offer great advantages for marine applications, but the transition to these new systems poses serious risks the boating industry cannot afford to ignore.

During the past century, conventional flooded lead-acid batteries were refined into the stable devices we now take for granted. Thanks in part to the electric-vehicle industry, there has been a recent boom in the development and refinement of entirely new battery technologies, most notably lithium-ion. The advances most appealing to boatbuilders include: higher-output voltage that remains nearly constant through the operating range (no more trying to run motors or electronics on less than 12V); half the size and weight of comparable lead-acid batteries; much longer life spans with as many as 10 times the number of discharge/recharge cycles; and charging times about one-fifth those of lead-acid batteries.

Unfortunately, there are also downsides. Lithium-ion batteries are now available to anyone for installation anywhere, with no consideration of the consequences of misapplying them. The intense public interest and several boat fires caused by lithium-ion batteries prompted the American Boat & Yacht Council (ABYC) to begin drafting a technical paper addressing the hazards. What follows are some of the precautions to be included in that document.

Lithium-ion batteries must not be operated outside their safe voltage range, which differs substantially from that of conventional batteries.

A typical flooded lead-acid battery comprises six 2.1V cells in series to yield a nominal 12V. The voltage and temperature of each of these cells will vary slightly from one cell to another, but that difference is of little consequence. Exceeding the voltage during charging will boil away some electrolyte from the overcharged cell, but not create a hazard. Similarly, discharging a lead-acid battery below the recommended limits is not dangerous, although it shortens battery life span.

Lithium batteries are not so forgiving. Their chemistry allows each cell to produce about 3.4V, requiring just four cells in series for a nominal 12V (actually 13.6V, which can negatively affect some equipment connected directly to it). The slight difference of temperature or voltage between cells may cause one cell to operate outside safe limits.

If voltage exceeds the safe maximum, a cell will produce heavier-than-air gases that can catch fire and/or explode. Also, reducing the voltage below safe limits can short out the cell, again causing a fire.

The technical solution to averting these fluctuations is to monitor voltage and temperature, and to make immediate adjustments. This is done through a battery management system (BMS) mounted externally or inside the battery case. The BMS must be an integral part of an onboard lithium-ion battery system. It not only monitors the voltage and temperature of each cell, it must have the ability to adjust voltage levels between cells or to completely disconnect the battery to prevent unsafe situations. While the chemistry of lithium-ion batteries is fairly uniform between manufacturers, the design of the BMS is what distinguishes one unit from another.

When multiple lithium-ion batteries are connected in series, parallel, or series-parallel banks, a dangerous voltage imbalance can also exist between batteries. A single BMS must control all cells in the bank, or the BMS on each battery must communicate with all other BMSs in the bank. To totally disconnect the battery or bank, a normally open relay with an "off" default position – a dead man's switch – controlled by the BMS should be installed to disconnect all loads and charging sources.

Never connect other types of batteries to lithium-ion batteries. For example, emergency engine starting with a lead-acid battery in a lithium-ion bank requires redesigning the typical "paralleling" switch. It's best to install a multi-position break-before-make switch that allows use of either lithium-ion batteries or lead-acid batteries, but never both simultaneously.

As always, provide overcurrent protection at the power source. But in the case of lithium batteries, the potential currents are high enough to actually "weld" some common circuit breakers closed or damage some fuse types. Be sure they meet the required ampere interrupting capacity (AIC) to be safe.

The boating public is clamoring for the positive features of lithium-ion batteries, and they are buying these components online at discounts, often without knowing the safety risks. Unfortunately, many lithium batteries sold online do not come with a BMS, or they may be offered with a BMS that is actually a battery monitoring system, not an active management system.

In the marine industry, we need to spread the word about this problem and be vigilant to ensure that the installation of lithium-ion batteries is always done safely.