Power Plays

THE ELEMENTS OF CHARGING SYSTEM DESIGN

Story And Photography By Steve D'Antonio

In my work as a marine systems consultant, I find myself reviewing electrical system designs and inspecting finished products from builders in both the United States and abroad. The one consistency I encounter is inconsistency. Each builder has their own approach toward battery bank and charging system design. That, in and of itself, isn't necessarily a problem; variety and uniqueness are hallmarks of the marine industry. Problems arise, however, when designs and installations fail to meet the requirements of battery manufacturers and subsequently fail to live up to the expectations of the vessels' owners.

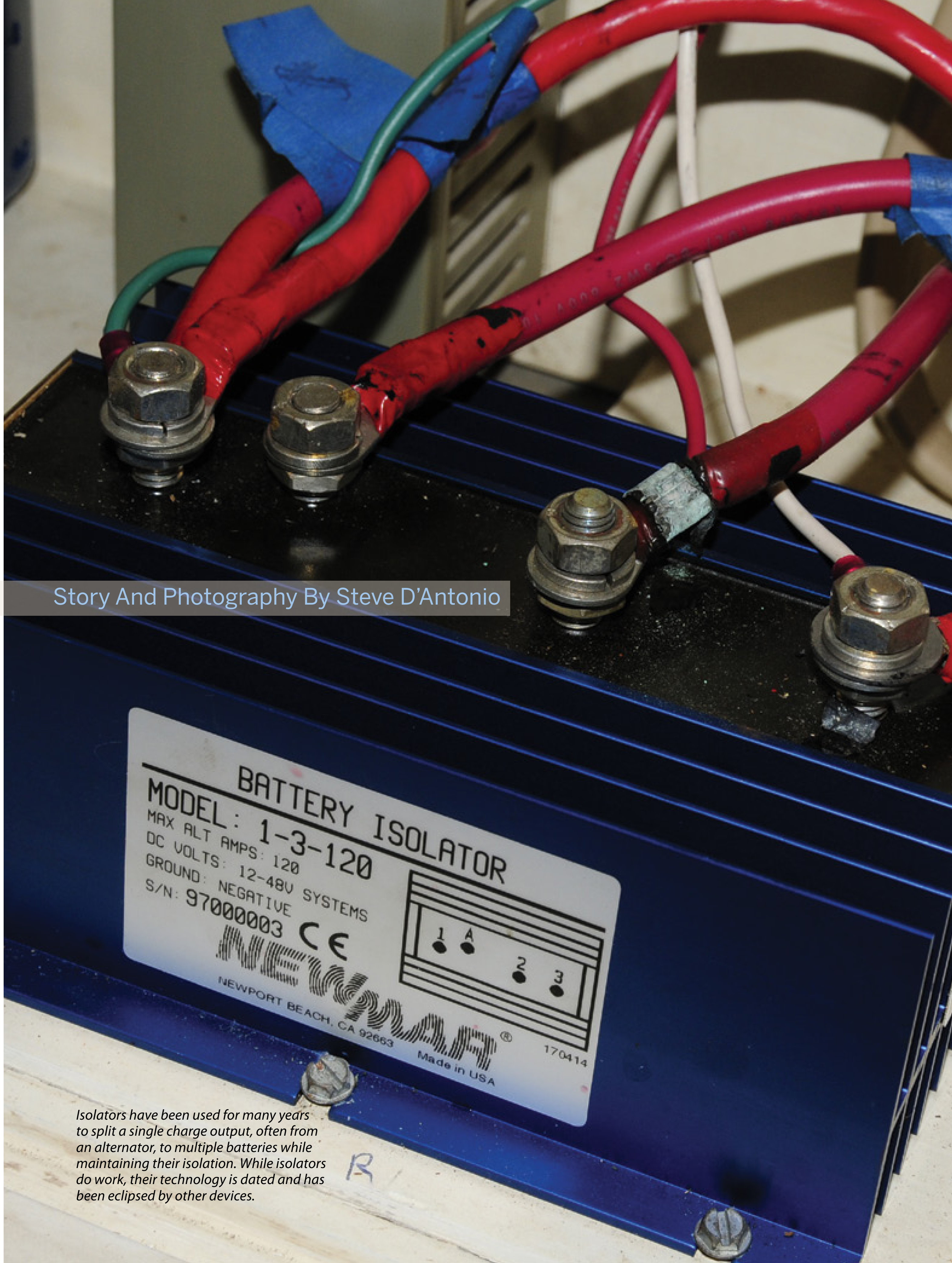
Traditionally, the builders and maintainers of vessels using more than one battery arranged them in such a way as to afford the user some degree of redundancy, and with good reason. After all, in the scheme of things marine, few features are more important than being able to start the engine.

The most common battery installation involves two equally sized battery banks that are connected to the engine via a selector switch that offers four options: "1" (battery 1 on), "2" (battery 2 on), "both" (batteries combined or paralleled) and "off" (batteries off). The switch requires users to manage the electrical current flowing from the batteries for starting and other loads, as well as the electrical current flowing to the batteries from the primary charging source, the engine-driven alternator.

For starting purposes, the skipper turns the multi-position switch to "both," which allows the engine's starter to receive the maximum amount of cranking amperage from both banks, enabling quick and easy starting. Even if the engine will start on a single bank, there's some logic to this custom of supplying additional current.

If the starter labors because a single bank is weak or inadequate–or, worse, the cabling is undersized or compromised–the drop in voltage may be excessive. This in turn will cause an increase in current flow (voltage drop and current flow are inversely proportional for loads such as starters), and this will increase the heat generated within the starter. Over time, this increased heat production and extended cranking can shorten the starter's life.

Once the engine starts, the alternator begins charging. If the selector switch remains



Isolators have been used for many years to split a single charge output, often from an alternator, to multiple batteries while maintaining their isolation. While isolators do work, their technology is dated and has been eclipsed by other devices.

in the "both" position, current from the alternator will be directed to the banks simultaneously.

This type of system has served boat owners well for many years. It's the next step where things often go awry. Once the vessel reaches its destination and drops anchor, its electrical demand, often referred to as "house load"–lights, communication and navigation electronics, fans, pumps, etc.–will draw on both battery banks equally. If the skipper forgets to turn the selector switch to "1" or "2," no batteries will remain in ready reserve to start the engine.

If the vessel is idle for long–overnight, for instance–it's all too easy to draw down both banks, at which point the crew may be forced to seek a tow.

Nowadays, however, there are other ways to ensure that a fully charged starting battery remains available at all times. More about this a little later.

BATTERY TYPES

Flooded batteries contain free electrolyte; a solution of sulfuric acid. While some are "sealed" or "maintenance free" (a suspect term), the vast majority–and particularly those designed for marine applications–are capable of being maintained by the addition of distilled water. The strength of such a design is its ability to withstand repeated or chronic overcharging. When overcharging occurs, these batteries invariably bubble or gas, sometimes vigorously, as they emit hydrogen.

Gassing for this battery type is normal; it's part of the chemical process that occurs in flooded lead-acid batteries, and it is the reason they periodically require water (hydrogen being one of the constituents of water). Under normal circumstances, flooded batteries emit hydrogen gas, even if you can't hear them doing it. Overcharging, however, should be avoided because it shortens battery life, makes frequent watering necessary and creates an explosive gas by-product.

The primary weakness of flooded batteries compared to other more modern types is that they are comparatively slow to charge and have a self-discharge rate of just under 1 percent per day at 80ºF. Because their internal resistance is relatively high, at a given moment they can accept limited charge current, typically no more than a maximum of 25 percent of their amp-hour capacity, even if the charging current is available in abundance.

Gel batteries take the sulfuric acid of a flooded battery and mix it with a material called fumed silica, essentially very pure silica dust, making a gel. The acid gel is then used to fill the battery case; it's sealed and placed under slight pressure, usually about 1.5psi. The pressure aids the recombinant process during charging, reconstituting the hydrogen gas and water vapor.

This style of battery is referred to as a sealed valve-regulated lead-acid or SVRLA battery. The cases sometimes bulge slightly as a result of the pressure under which they operate. Anything more than a slight bulge is abnormal. If overcharged, SVRLA batteries will vent, which markedly shortens their life span.

A gel battery requires no watering, and because of the manner in which the electrolyte envelops the lead plates and the pressure under which the battery operates, it recharges very quickly. Often, gel batteries recharge twice as quickly as conventional flooded batteries, provided they are connected to a properly regulated and sufficiently sized charging source.

The final battery type is an absorbed glass mat, or AGM battery. Developed and used for decades in the telecom industry, this type of battery is a newcomer to the recreational marine world. It embodies many of the attributes of the gel battery, including a sealed, maintenance-free design and quick recharge time. Its acid is held in suspension using tightly packed fine glass fabric. Both AGM and gel batteries have very low self-discharge rates. That is, if left with no load and no charge source, they tend to stay fully charged almost indefinitely. An AGM battery will accept a charge even more quickly than a gel battery–twice as fast, in most cases–provided it's connected to a charge source that is both large enough and properly regulated.

Gel and AGM batteries tend to be more expensive than the flooded type, with AGMs being the most expensive. A final thought on battery types: SVRLA batteries must be used with proprietary charge sources–that is, alternator/regulator and shorepowered chargers designated for this type of battery. Failure to do so will lead to premature failure.

CHARGE PROTOCOLS

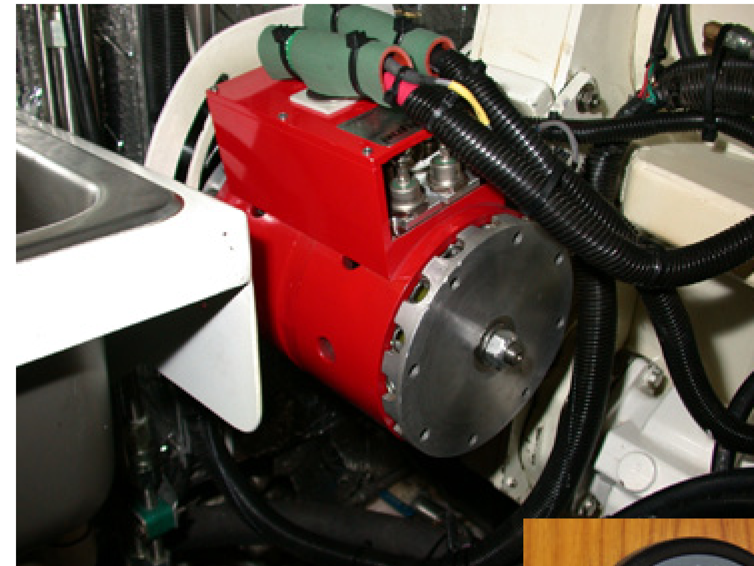
Most alternators that are supplied as standard equipment with marine engines are nearly identical to those used in automotive applications through the 1970s. There is one caveat to this comparison: Alternators, starters, ignition systems and other electrical components used aboard gasoline-powered vessels must be ignition proof. They are designed to prevent the ignition of flammable vapors that may inadvertently make their way into an engine compartment. For this reason, one should never substitute an automotive alternator or starter for the marine version; the higher price of the latter is justified. On diesel-powered vessels, this requirement does not apply.

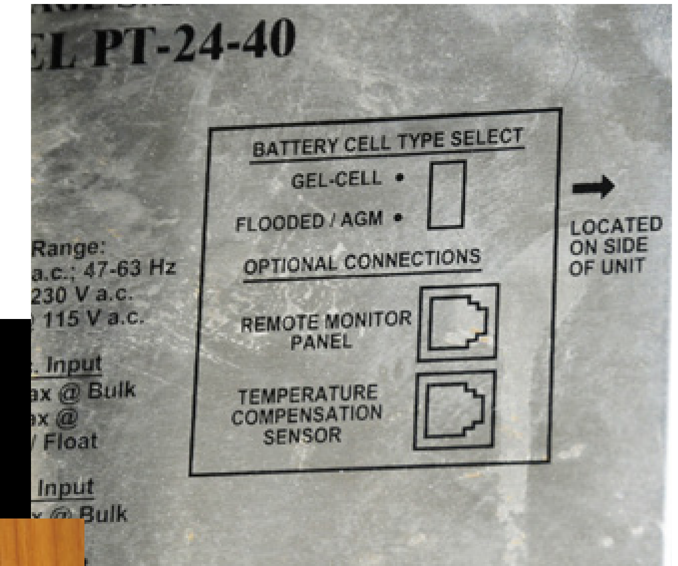
The typical marine alternator is quite simple, a blessing and a curse, and is designed primarily to replace the energy a battery supplies in the starting process. This energy is often replaced in just a few minutes of running time. After that point, the alternator's output can be used primarily for house loads. If the house loads exceed the often-modest output of stock alternators, the batteries will make up the difference, so the user must be mindful of consumption.

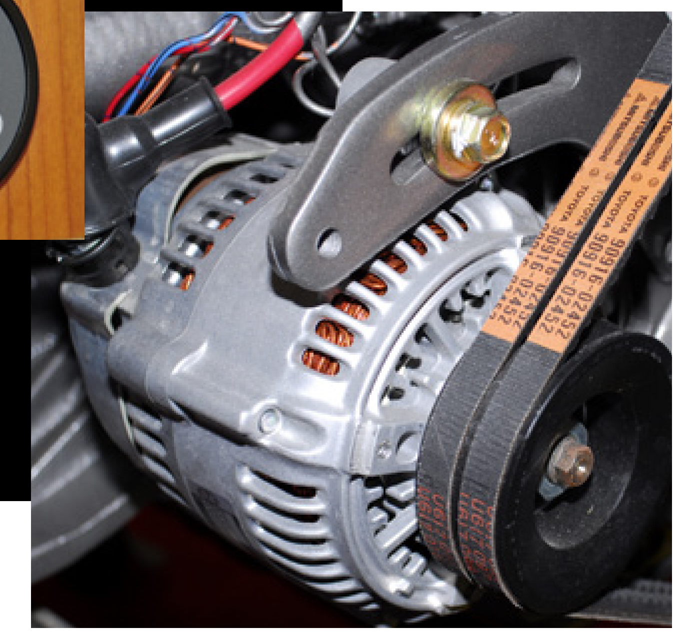
Roughly speaking, the condition of the batteries and the output of the alternator can be monitored using a voltmeter. A fully charged and "rested" battery with no loads present will measure between 12.6 and 12.8 volts. A "rested" battery is defined as one that is subject to no loads or charge sources for six hours or more. A 50 percent discharged, rested, unloaded battery will measure between 12.3 and 12.4 volts. As you can see, there is a scant few tenths of a volt difference between the two, and accurate measurement requires resting the battery, which may not be practical. No battery should be discharged beyond 50 percent of its capacity; routinely doing so diminishes the amount of energy it will provide over its life span.

From a charge point of view, the voltmeter is slightly more useful. While it's an oversimplification, any reading over approximately 13.8 volts can be considered as "charging."

Most stock alternators have a built-in regulator that monitors and controls the rate of output from the alternator. To an extent, the regulator's signals to the alternator are driven by the state of charge of the battery bank to which it's connected. When the battery is depleted or house loads are high, the regulator will command the alternator to produce more current. Standard internal regulators have two primary missions: recharge the starting battery and, in most cases, supply modest house loads. On a car, for instance, this would include running the headlights,







Purpose-made, high-output alternators differ from standard alternators in that they are typically externally regulated and are capable of sustaining high output. Most modern stand-alone chargers are capable of being programmed for different battery types and incorporate temperature compensation by using a probe affixed to the battery case. Standard internally regulated alternators, regardless of their output, are unequal to the task of quickly and efficiently charging large battery banks, particularly those of the SVRLA type. Unless house batteries can be monitored, it's difficult to know when to recharge them. The most effective means of monitoring uses an amp-hour meter—essentially a gas gauge for your battery bank.

heater fan and radio. If called on to do more than this, their performance will probably be inadequate.

WISDOM ON WIRING

Regardless of how large or small a battery bank is or what it's called upon to do, two wiring rules must be followed. First, to ensure safety, all wiring should be installed in accordance with ABYC guidelines or, where mandated, Code of Federal Regulations (CFR) guidelines. Among the most important of these is the over-current protection mandate. In short, it calls for a fuse or circuit breaker to be installed in every wire, save one, that leaves any battery's positive post.

The over-current protection, often abbreviated as OCP, must be installed within 7 inches of the battery terminal. That's right–7 inches. This distance may be increased to 72 inches if the wire is "sheathed." Sheathing can include anything from proprietary wiring loom to conduit. Wiring loom should meet ABYC guidelines for the protection it affords the wire and for fire resistance.

Therefore, if you can follow any wire from any battery's positive terminal for more than 7 inches (72 inches with sheathing) without bumping into a fuse or circuit breaker, it does not meet this guideline. Such an oversight must be corrected immediately. The reason this rule is so very important is that it may be all that stands between you and an electrical fire on your boat. Any wire between the OCP and the battery is essentially unprotected and thus a fire risk if a short circuit occurs.

The one exception is cabling used for starting circuits. Any cable that is used or can be used via paralleling switches to supply current to a starter is exempt from the OCP requirement. Because of this exemption, such cabling must be routed with extreme care to prevent any possibility of chafe or short-circuiting. Additionally, other than the terminal that is connected to the starter post, such cables must not make contact with any part of an engine or its mounts.

The second wiring rule is that battery banks, depending on the number of individual batteries included in the bank, should be wired in such a way as to draw current across the bank. For example, the positive and negative cables connected to four Group 31 batteries (similar to automotive or light-truck batteries) that are connected in parallel should attach at opposite ends of the bank to ensure that all batteries are cycled evenly. If the cables are attached to a single battery at the electrical end of the bank, that battery often bears the brunt of the discharge and is likely to become depleted before its brethren, making for an undesirable imbalance within the bank.

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A final note on wiring: Bigger is nearly always better. That's an oversimplification, of course, but where electrical current is concerned, large cables present lower resistance, which means more of the energy gets to where it's going rather than being lost as resistance-generated heat. Therefore, closely follow engine manufacturer guidelines for starter cable size and length, and rely on standard voltage-drop guidelines when making charging and starting system connections. Voltage drop should never exceed 10 percent, and 3 percent is preferable. Voltage-drop guidelines are available in a variety of books and from ABYC.

ADVANCED CHARGING

The protocol that's been detailed up to this point–relying on the alternator supplied with most engines–is inarguably one that has worked and continues to remain effective for many vessel owners and operators. However, there is a series of improvements that can be implemented that will increase the efficiency of this system while making it more user friendly.

While the use of two identical battery banks with a multi-position ("1-2-both-off") battery switch for power distribution may be familiar to many, there is room for improvement. Studies show that using a single battery bank for house loads and cycling it through approximately 50 percent discharge will yield the greatest number of amp hours over the life of the battery. Amp hours are a measure of battery capacity; 1Ah is equal to a 1-amp load operating for one hour. Think of it as the equivalent of gallons of fuel in your tank. This bank also becomes the primary recipient of charge current from any source: alternator, shorepower charger, solar panels, etc.

Large house battery banks require careful attention where wiring and over-current protection are concerned. Note the gaps between these batteries for heat dissipation purposes.

To ensure that the engine can be started under any circumstances, it should be given its own, albeit smaller, dedicated battery or battery bank. This bank remains separate from the house bank under all but emergency starting needs, so there's no danger of waking up to a dead starting battery.

Instead of the "1-2-both-off" switch, the improved arrangement uses three simpler "on-off" switches: one for each battery bank and another between the two that is used to parallel the banks manually if the engine starting battery fails.

The manner in which the parallel switch is wired is important. It should be connected in a way that allows the starting or house battery switches to remain off while still supplying paralleled voltage to that load, the starter or house. In electrician-speak, the

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connections are made to the "load" side of the switch. With such an arrangement, the user can take a defective, possibly damaged or internally shorted battery offline entirely while allowing its loads to continue to function.

For those using SVRLA batteries or those wishing to supply their flooded batteries with the quickest, healthiest possible charge, an aftermarket, high-output alternator and external regulator kit becomes a necessity. Because SVRLA batteries require a charge that's significantly different from that required by conventional flooded batteries, this must be considered as part and parcel of an upgrade to this battery style.

High-output alternator/regulator installations offer a variety of benefits for any battery type. These benefits include increased, sustained output, typically on the order of 100 or more amps; a three-step charging regimen that provides the quickest possible charge; and a temperature-compensated charge profile as warm batteries cannot be charged as quickly as cool batteries. Most aftermarket regulator kits can be programmed to charge a variety of types and brands of batteries. Consider this setup as granola and fresh vegetables for your batteries–the best charge possible.

If all the output from the alternator goes to the house bank, how, you might ask, does the starting battery get charged? One of two approaches may be used. The simplest involves the use of an isolator that splits the output of the alternator, sending it simultaneously to the house and starting banks. Because the starting bank is likely to be nearly fully charged, with a consequent higher internal resistance, it will accept less of the output, allowing the bulk to go to the house bank.

An alternative, and one I prefer, is to use one of the many proprietary starting battery charge devices that more intelligently shunt a small amount of charge to the starting battery; some even do so with temperature monitoring. These, of course, come at a higher price, but one I believe is worth the expense.

Finally, the next-generation charging system requires next-generation monitoring, something a bit more sophisticated than a voltmeter. Amp-hour meters are more useful than voltmeters because they accurately measure the amount of energy used from, or remaining in, the house battery bank. Armed with that information, you can make an informed decision regarding when it's time to recharge. As an aside, voltmeters are useful for monitoring the state of charge contained within starting batteries.

Batteries and their management are anything but a black art, as some would have you believe. Choose your batteries carefully, and ensure that they are installed properly, safely and in compliance with the appropriate guidelines. Then, make sure they are charged in a manner that suits their design, and your engine will always turn over and your cabin lights will stay on.

*Steve owns and operates Steve D'Antonio Marine Consulting (*www.stevedmarineconsulting.com*), providing consulting services to boat buyers, owners and the marine industry. He's also* PassageMaker*'s technical editor.*