Pacific Cup Manual - Electrical Section

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Overview:

The purpose of this section is to help you review the electrical system on board your vessel and make any necessary upgrades in order to meet the challenges of an extended offshore race.

The electrical system on board your vessel is every bit as important as the main structural parts of the boat. A failure of a critical part in the vessels electrics in the middle of the Pacific Ocean could be just as life threatening as a dismasting; without power you risk losing the ability to navigate or communicate to shore and other vessels. The rigors of the race will put a huge demand on every component of the vessel, and the electrics are often overlooked until something fails. For most boats, the engine and alternator are the heart of this critical system, yet it is amazing how many high dollar race boats have poorly-maintained engines, bad wiring, or both. If the engine is rusty, crusty, oily, and poorly maintained it will surely cause problems later when you need it most.

Section I. General guidelines for all vessels:

There are specific guidelines for each different type of vessel following, but there are several key items to check for every vessel regardless of type or size:

Test your batteries! Unless the batteries are new (and not “new” like “a few years ago”, but really new) do not assume they have the proper capacity remaining. If you can’t buy or borrow a quality battery testing machine, hire a professional to check the batteries for you. Batteries are discussed in more detail in the electrical outfitting section following.

Get to know how the electrical system works and how to fix it if something breaks. At a minimum carry a good quality voltmeter so you can make basic tests if something stops working, and maybe you can get help over the radio to try to get it figured out.

Carry basic spares, at least a few feet of wire, some tape, crimp terminals, and a crimping tool. In the scheme of things this is a small weight penalty that has potential huge benefits if you need it 1000 miles from shore.

Have the wiring and all critical connections checked, and rechecked. Hire a pro if you are not sure how to do this; make sure someone looks at all of the critical battery cables, main switch, breaker panel, etc. If the power is stored in the batteries but can’t get to the GPS or radio because of poor connections it is almost as bad as having dead batteries. Fatigue, salt and corrosion constantly attack electrical connections. If you have not checked these critical items, assume they are broken or ready to fail…

Test the alternator and regulator to make sure they are set at the proper voltage for your type of batteries. With the vast array of battery types available, it is critical that the regulator be properly adjusted. Having the voltage adjustment off by just a few 10ths of a volt can drastically slow the charging process. Be sure you carry at least 2 spare belts, and don’t forget the belt that drives the sea water pump if your engine uses a separate one (ie: Yanmar engines). Alternators are discussed in more detail in the following section on electrical outfitting.

Get the engine serviced, and make sure you carry basic tools, spare parts, oil, and filters. Be sure your mechanic knows the boat is prepping for a serious offshore event. Many engines have a small secondary fuel filter that is painted over and often forgotten. Volvo and

Yanmar engines (and many others) have a small hidden fuseholder on the engine wiring harness that is often overlooked. If the hidden 50 cent fuse fails, the engine is just as dead as if the $300 starter fails. A spare starter is a great idea if the engine is more than a few years old, or if you rely heavily on the engine as your source of electricity. Every engine can be 'jump started' at the starter by bypassing the wiring harness, but you need to know how to do it. Many engines need to have +12volts supplied to the fuel solenoid, so be sure you know how and where to make the connections in an emergency. Also be sure to check the large connector plugs where the engine wiring harness connects to the engine and to the gauge panel; these connectors are notorious for causing failures. The emphasis here is to get the engine checked out well in advance, and treat it as an important part of the safety gear aboard the boat.

Corrosion / electrolysis: often misunderstood, always ignored until a catastrophic failure occurs, but bears discussion here. The most important thing to know about corrosion is that all stainless steel alloys are vulnerable to 'crevice corrosion', also known as 'stress corrosion cracking'. Any piece of stainless steel that is wet, and NOT exposed to dissolved oxygen is subject to attack. The danger with stainless steel as compared to other metal is the failure mode is almost always sudden & catastrophic failure. This means the most highly-stressed parts of the boat can fail without warning, and without many visible signs before it happens. In addition to the mast and rigging, the critical components to check are: (in order of priority)

- Keel bolts: Stainless steel and monel keelbolts are very prone to crevice corrosion, and nearly impossible to inspect. But, you can check for any signs of rusty 'bleeders' at the hull / keel joint, and carefully inspect the large nuts in the bilge to see if there is any sign of corrosion damage. If the internal keel bolts / nuts are submerged in bilge water you can almost guarantee there will be deterioration over time. A good idea is to install a small zinc or aluminum anode in the bilge, wired to the keelbolts, to reduce internal corrosion.
- Chainplates / forestay / backstay fittings: again crevice corrosion is the danger, look for any rusty stains around the chainplates where they meet the deck and / or bulkheads. If water has been leaking into the area hidden down inside the deck, it can cause the stainless to become very brittle and large cracks form even in a short period of time. If the chainplates are more than 10 years old, consider having them removed and inspected, you may be amazed at what you find.
- Mast step / mast base: usually this is easier to inspect, on aluminum masts, look for any paint bubbling or deterioration where the mast tube ends on the base casting. Be sure to clean out the small drain holes, and rinse this area with fresh water once in a while. With carbon fiber masts look for deterioration of the aluminum base casting or stainless steel mast jack pins. Carbon will attack any metal when it is allowed to sit wet for a time.
- Rudder post: as with stainless rigging and keel fittings, stainless rudder posts are vulnerable to crevice corrosion attack in the areas up inside the bearing or anywhere deprived of oxygen. Likewise if water is allowed to penetrate into the rudder layup, and the wood or foam core is saturated, corrosion can attack the stainless structure inside the rudder particularly at the welds where stiffening plates attach to the post. Look for small cracks along the leading edge of the rudder, and all around the top, especially if there are any signs of rusty stains originating from the cracks. Danger lurks within…

- Rudder bearings: Aluminum rudder bearings installed on a carbon fiber hull or carbon rudder post need to be inspected every season for any signs of galvanic corrosion on the aluminum components. Any rough feeling or grinding noises in the steering need to be investigated as this could be an indication of a problem with the bearings.
- Also rudder posts with graphite rudder bearings and stainless wear sleeves inside the bearing have suffered a lot of corrosion damage in amazingly short periods of time. Remember that graphite and carbon fiber will attack any other metal it is in contact with, as soon as the parts get wet ! Check and inspect often to avoid serious problems later.
- Saildrives: usually corrosion can be kept under control if you are diligent about maintaining your sacrificial anodes, and making sure you don't have any stray current or wiring problems on board. BUT if you are planning to add an SSB radio to your boat for this event be very careful how you install the copper foil ground plane for the radio; if you connect the engine as part of the SSB ground plane, you need to be careful about electrically connecting the vulnerable aluminum saildrive to a large lead or iron keel (and possibly a carbon fiber hull if you have one) as major corrosion damage can occur to the saildrive if this part of the system is not done properly. This is probably a good place to mention a great racer speed secret: Propeller coatings. There are several available from PropSpeed, Barnacle Buster, and others. These coatings applied to the propeller will keep it clean and free of marine growth, which reduces drag, but also has the effect of overcoating or waterproofing the propeller. This has the extra benefit of reducing the amount of galvanic corrosion between the aluminum saildrive and the bronze propeller. Highly recommended.

Section II. Outfitting the electrical system - Here we will divide the boats into 4 categories, with different electrical needs and equipment :

- **I.** **Small sport boats with no inboard engine:** Examples of this type of boat would be a Moore 24, Olson 30, Melges 32, etc. without an engine or alternator. Survival systems only, minimal power demands, and questionable sanity.
- **II.** **Basic racer / cruiser with inboard engine:** Examples would be Express 37, Sydney 38, Wylie 39, etc. Simple systems and moderate power consumption. This is the 'most bang for the buck' group.
- **III.** **Offshore race boats, with inboard power:** Examples would be Antrim Class 40, Frers 44, TP52, offshore multihulls, etc. These boats carry hi tech instrument / computer systems, and have higher power demands. This is where all the action is…
- **IV.** **Larger racer / cruisers, or boats intending to continue cruising after the race:** These boats have inboard power, plus usually an AC generator set and lots of power demand for comfort systems. Often these boats will have wind generator or solar panels. These are the boats with refrigeration, watermakers, autopilot, big stereo, etc. Good folks to party with…

The outfitting recommendations and electrical worksheets for each category are broken down in the following sections.

Small sport boats with no inboard power:

Without an inboard engine usually you have 2 options:

1. Charge up and go, using only a small solar panel as a backup, and very carefully rationing battery power and hoping to make it the whole distance without running out of power.
   OR...
2. Carry a small portable gasoline generator, and a battery charger to recharge periodically along the way. This has several advantages, if you need more than just the very basics.

Notes on using an outboard motor as a charging source:

Even though some outboards now have a small 'alternator' (usually it is actually a simple magneto) that may advertise a few amps of output, in practice this is not a feasible way to recharge batteries during the race, for several reasons.

The primary problem is drag, you are racing of course, and lowering the engine just to recharge will definitely slow you down, and NO, YOU CANNOT PUT THE ENGINE IN GEAR to "make up" for the drag caused by the engine. Been tried before, NOT legal !

Also the tiny bit of power they produce make the outboard motor the least effective 'generator per pound' of any of the possible choices.

SAMPLE SPORTBOAT ELECTRICAL LOAD WORKSHEET:			
ITEM	AMP DRAW	HRS PER DAY	DAILY A/H USED
NAV LIGHTS (LED TYPE)	0.25A	12	3.0
SSB RADIO—TRANSMIT	30A	0.5	15
SSB RADIO—RECEIVE ONLY	1.0A	2.0	2.0
CABIN LIGHTS (SMALL LED TYPE)	0.5A	2.0	1.0
NAV SYSTEM / BASIC GPS	0.5A	24	12
SAILING INSTRUMENTS	0.5A	24	12
TOTAL AMP HOURS USED PER DAY			45.0 A/HR per day

Examples:

1.0 amp x 1.0 hour = 1 amp/hour (A/hr) [example: small netbook computer for 1 hour]
1/10th amp x 10 hours = 1 A/hr [example: single LED nav light on for 10 hours]
10 amps x 10 hours = 100 A/hrs [example: 5 traditional cabin lights left on for 10 hrs]

Using this the table as an example, notice it would take 450 amp/hrs of <u>usable</u> capacity for 10 days at 45 amp/hrs a day if you do not have a way to recharge along the way. This means a fairly large battery bank, so being able to recharge could save significant weight compared to carrying enough power to make it the whole way without recharging. Note that depending on the type of battery you use, you need to carry 2x to 4x of your daily amp/hr use, in order to not over-deplete the batteries.

Note that anything you can do to save power will reduce the size of the battery bank you need to carry, so consider your system carefully to minimize the weight you need to carry. Battery-powered LED headlamps, and a small basic display for the GPS will save power compared to traditional built-in cabin lights, and a big bright GPS display.

See the following page for recommendations for a basic sportboat electrical system.

Sportboat electrical system recommendations, con't.

Portable gasoline generators - This is a viable option IF you take some time to plan the installation carefully. Particular attention must be paid to locating the unit where it won't get soaked by spray or rain, and where the exhaust will not get into the cabin or cockpit. On a small boat finding a good spot is usually a challenge. And NO, YOU CANNOT RUN THE GENERATOR INSIDE THE CABIN ! Running any fuel-burning generator inside would fill the cabin with a deadly amount of carbon monoxide and possibly put everyone on board to sleep, permanently. Usually on deck at the base of the mast is a good spot, assuming you are sailing downwind. Upwind the transom is usually best; but keep the exhaust and waterproofing in mind as your main obstacles. Remember also that all small generators are air cooled so if you make a spray cover it will need to be removed while the unit is running. Lastly you need to get the 120VAC from the generator into the 12VDC batteries. Usually the smallest AC generator you can find will suffice, but it needs to have enough output to supply the battery charger you are going to use. The Honda portable generators are usually the best, if you can find one of the discontinued 350EX models they are a great, small package.

Portable battery chargers - Get a GOOD marine charger that is at least 25 amps or so, and make sure it has a true 3 step type output. West Marine and MasterVolt have a few good versions, that are 3 step and have proper isolation between the AC and DC outputs. Beware of household or automotive chargers, as they never make as much output as they claim, plus if used in a harbor they can cause significant corrosion to your underwater metal parts. If the front of your portable charger has a switch labeled "2A / 10A / 50Amp boost" it is a fake, and they never make more than about 2 amps after they have been on for a while. Throw it away and get a real marine charger.

Batteries - usually (2) group 27 or (2) group 31 batteries for a total of 150 ~ 200 amp hours will suffice, IF you are careful with your consumption. Get the best batteries you can afford, on these small boats lithium batteries make a lot of sense as you can carry a smaller bank overall and save some significant weight.

Fuel cell - a fuel cell is also a great option for sportboats, instead of carrying a gas generator and charger. This is still an emerging technology so manufacturers are hard to define, but most importantly make sure the output can be adjusted to your battery type. See the fuel cell section for info.

Monitoring - make sure you have some type of meter or battery monitor to check the power level in your batteries, as you will surely be using almost ALL of their available power. An amp hour meter is best, as many of them offer other handy functions as well. The Xantrex Link 10 or MasterVolt BTM III are both good choices.

Solar panels - The best basic backup power system for small boats is a solar panel (or two). The solar panels need to be as far aft and as high as possible to minimize shading, see the section on solar panels for more info.

Running lights - with the advent of bright, low current draw LED running lights many smaller boats have gone back to using deck-level running lights instead of the traditional masthead tricolor, mainly to save weight in the rig. With LED running lights, there really is no good reason to leave the lights off at night. Imagine how silly you would feel if you crash into another boat running blind in the middle of the world's largest ocean, simply because you were both trying to save a little power…

Mini survivor watermaker - small watermakers can help reduce overall weight carried, for small boats consider the Survivor 35 hand-pump model, or if you have power generation, you could use the Spectra 180 or the Powersurvivor 35. Either will make enough water for a crew of 2 ~ 3 people, but will add significantly to your power consumption.

See the electrical outfitting section (following) for more info on battery types, solar panels, etc.

Basic Racer / Cruiser with inboard engine :
With an inboard engine you have the option to recharge batteries as needed.
This allows you to at least have a few cabin lights, and possibly a laptop or dedicated computer running most of the time, plus possibly a small watermaker.

If you have an inboard engine, you should consider optimizing your alternator and batteries instead of carrying a small portable gasoline generator as you will save considerable weight over carrying both. General recommendations for this class of boat would be to use efficient LED lighting, good quality batteries, and a high output alternator with a good external regulator to make recharge times as short as possible, to minimize the amount of fuel you have to carry.

SAMPLE BASIC RACER / CRUISER ELECTRICAL LOAD WORKSHEET:			
ITEM	AMP DRAW	HRS PER DAY	DAILY A/H USED
NAV LIGHTS (LED TYPE)	0.25A	12	3.0
SSB RADIO—TRANSMIT	30A	0.5	15
SSB RADIO—RECEIVE ONLY	1.0A	2.0	2.0
CABIN LIGHTS (SMALL LED TYPE)	0.5A	2.0	1.0
NAV SYSTEM / WITH LAPTOP & GPS	1.5A	24	36
SAILING INSTRUMENTS	0.5A	24	12
SPECTRA 180 WATERMAKER (typically used every 2 days for 2 hours)	15A	1	7.5
TOTAL AMP HOURS USED PER DAY			76.5 A/HR per day

Examples:
1.0 amp x 1.0 hour = 1 amp/hour (A/hr) [example: small netbook computer for 1 hour]
1/10th amp x 10 hours = 1 A/hr [example: single LED nav light on for 10 hours]
10 amps x 10 hours = 100 A/hrs [example: 5 traditional cabin lights left on for 10 hrs]

Using this table as an example, notice you need to recharge 76.5 A/hrs every day to make up for the power used, plus the battery inefficiency factor which adds another 5% ~ 10% to the recharging process. Note that this means a battery bank of 150 ~ 300 A/hrs depending on battery type used, so being able to recharge quickly could save significant weight compared to using a small alternator that would require running the engine for a long time.

Note that anything you can do to save power will reduce the size of the battery bank you need to carry, so consider your system carefully to minimize the weight you need to carry. Also adding solar panels or a fuel cell will greatly reduce the amount of fuel you need to carry.

See the electrical outfitting section (following) for more info on battery types, solar panels, etc.

Offshore Race Boats / Multihulls with inboard engine :

With a larger equipment list, and possibly a full-time navigator, the true offshore race boat has large demands for electrical power, and thus an increased need for storage and generating capability. Having all the critical data at the navigator's and tactician's fingertips equates to speed, so let them have their toys, there are ways to accommodate the power demands.

A typical offshore race boat will easily use in excess of 100 ~ 200 A/hrs per day, even more if equipped with a watermaker, hydraulics, canting keel, or water ballast pumps. Here the engine is primarily a generator, so the alternator / regulator / battery combination is critical. This requires a careful matching of components to ensure the demands will be met. Pro assistance is recommended.

General recommendations for this class of boat would be to use the largest alternator you can fit, even better is to add a 2nd alternator in addition to the stock alternator. This gives redundancy, plus allows the use of larger 150 ~ 200 amp alternators for maximum efficiency. Most engines in the 25 ~ 30Hp range are capable of driving a 200 amp alternator if properly installed.

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TYPICAL OFFSHORE RACE BOAT:			
ITEM	AMP DRAW	HRS PER DAY	DAILY A/H USED
NAV LIGHTS (LED TYPE)	0.5A	12	6.0
SSB RADIO—TRANSMIT	30A	0.5	15
SSB RADIO—RECEIVE ONLY	1.0A	2.0	2.0
CABIN LIGHTS (SMALL LED TYPE)	0.5A	8.0	4.0
NAV SYSTEM W/ 2 LAPTOPS & 2 GPS's	3.0A	24	72
SAILING INSTRUMENTS w/ multi displays	1.5A	24	36
FLEET BROADBAND SAT DOME - RCV	1.5A	12	18
FLEET BROADBAND SAT DOME - XMIT	5.0A	2	10
SPECTRA CAPE HORN WATERMAKER (typically used every 2 days for 2 hours)	25A	1	25
WATER BALLAST / HYDRAULICS	25A	1	25
TOTAL AMP HOURS USED PER DAY			213 A/HR per day

Examples:
1.0 amp x 1.0 hour = 1 amp/hour (A/hr) [example: small netbook computer for 1 hour]
1/10th amp x 10 hours = 1 A/hr [example: single LED nav light on for 10 hours]
10 amps x 10 hours = 100 A/hrs [example: 5 traditional cabin lights left on for 10 hrs]

Using this table as an example, notice you need to recharge 213 A/hrs every day to make up for the power used, plus the battery inefficiency factor which adds another 5% ~ 10% to the recharging process. Battery bank size will typically range from 300~400 A/hrs for Gel / AGM, or 200~300 A/hrs for lithium.
Note that adding solar panels or a fuel cell will reduce the size of the battery bank and reduce the amount of fuel needed, so consider your system carefully to minimize the weight you need to carry.

See the electrical outfitting section (following) for more info on alternators, battery types, solar panels, fuel cells, etc.

Larger Racer / Cruisers - including boats intending to continue cruising after the race :
With an even larger equipment list, and comfort systems such as refrigeration, watermakers, radar, and autopilots, the offshore racer / cruiser boat has the largest demands for electrical power, and thus typically an AC generator set, with large onboard battery chargers, or inverter / charger. Having all the systems for extended cruising to remote areas, increases the need to store & generate large amounts of electrical power. These boats can often make use of alternate energy systems such as wind generators and / or solar panels. A typical offshore racer / cruiser can use in excess of 200 ~ 300 A/hrs per day. As with the offshore race boats, the alternator / regulator / battery combination is critical. This requires a careful matching of components to ensure the demands will be met. Professional assistance is recommended.

It is beyond the scope of this manual to make specific recommendations for every vessel in this category, but general recommendations for these boats would be to add a 2nd alternator in addition to the stock alternator. This gives redundancy, plus allows the use of the largest 200~250 amp large case alternators for maximum efficiency. Also if you have an AC generator, make sure you have the best battery charger you can get to make sure the generator run times are as short as possible.
If you are travelling internationally, make sure your charger can accept foreign shore power.

TYPICAL RACER / CRUISER:			
ITEM	AMP DRAW	HRS PER DAY	DAILY A/H USED
NAV LIGHTS (LED TYPE)	1A	12	12
SSB RADIO—TRANSMIT	30A	0.5	15
SSB RADIO—RECEIVE ONLY	1.0A	2.0	2.0
CABIN LIGHTS (mix of LED & florescent)	5A	4.0	20
NAV SYSTEM W/ PC, RADAR & 2 GPS's	3.0A	24	72
SAILING INSTRUMENTS w/ multi displays	1.5A	24	36
STEREO / MISC ELECTRONICS	5.0A	2	10
AUTOPILOT	5.0A	12	60
400 GPD WATERMAKER (typically used every 2 days for 2 hours)	25A	1	25
REFRIGERATION (typical mid-size system)	6A	10	60
TOTAL AMP HOURS USED PER DAY			312 A/HR per day

Examples:
1.0 amp x 1.0 hour = 1 amp/hour (A/hr) [example: small netbook computer for 1 hour]
1/10th amp x 10 hours = 1 A/hr [example: single LED nav light on for 10 hours]
10 amps x 10 hours = 100 A/hrs [example: 5 traditional cabin lights left on for 10 hrs]

Using this table as an example, notice you need to recharge 312 A/hrs every day to make up for the power used, plus the battery inefficiency factor which adds another 5% ~ 10% to the recharging process. Note that this means a battery bank of 400~800 A/hrs depending on battery type used.

Note that anything you can do to generate power will reduce the size of the battery bank you need, so consider your system carefully to minimize the weight you need to carry. Also adding solar panels or a wind generator will greatly reduce the amount of fuel you need to carry.

See the electrical outfitting section (following) for more info on alternators, battery types, solar panels, battery chargers, etc.

Section III: electrical outfitting

In this section we will review each of the critical components in a typical electrical system, and make a few recommendations to consider when making equipment purchasing decisions.

Batteries:

The most important part of the electrical system; there are basically 5 types of batteries available to the racer today.

Traditional lead-acid: These have been around for a long time, better varieties are made by Rolls, Surrette, and Trojan. The key factor with lead acid is to buy the best quality battery you can afford. If you think you can cheat the electrical gods by buying batteries from Costco you will likely end up without power in the middle of the ocean. Good quality lead batteries cost about $2.00 per amp hour, (100 A/hr battery = $200) If you decide to use lead-acid batteries keep in mind they typically have a 25% useable capacity in order to survive for very long. This means you will need to carry approx 4 times the actual storage capacity you need. So although this is the lowest-cost battery option, it is also the heaviest in terms of weight. If using lead acid batteries, make sure you take into account the explosive hydrogen they vent during charging. Make sure the inverter, alternator and all other ignition sources are mounted far away to prevent a disaster. You have not lived until you have had to clean up after a battery explosion inside a boat…

Sealed Lead-Acid (including 'maintenance free' types) also known as "SLA" batteries, these are really variants of the wet lead-acid batteries, and include such brands as Delco, Optima, Johnson controls, etc. Although they benefit from reduced acid spills and explosive fumes, they perform pretty much the same as other lead-acid batteries. Some like the Optima spiral-wound versions claim fast recharge rates but most of the installations we have seen using these, and other sealed lead-acid batteries have not performed very well.

Notes on using 2 volt / 6 volt 'traction' batteries:
Traction (industrial standby) batteries have been tried in quite a few boats recently, but although they are suitable for certain applications, these batteries typically use very thick plates for long life in standby service, but they do NOT accept recharging current very quickly and are usually a poor choice for the racer building the best lightweight power system.

Gel cell: The gel cell technology has now been around for at least 15 years and is well-proven. Generally these offer the best performance-per-dollar for most boats. Expect to pay about $3.50 per amp hour (100 A/hr battery = $350) for quality Gel Cells. The top mfr for many years has been East Penn Manufacturing, sold under the labels of MK battery, Gel Tek, West Marine Sea Gel, etc. They are actually made in the USA and have some important advantages over lead-acid. The primary benefit is that they have a 50% useable capacity, while still offering a very long service life. This means you only need to carry half as much battery compared to lead-acid batteries, ie: if you use 100 amp/hrs per day, you only need a 200 amp/hr battery bank. This equates to approx. 50% weight savings over lead acid for the same useable capacity. The other primary benefit is greatly increased charging rate, they can accept nearly 100% of their amp hr rating at the beginning of the charge cycle, so recharging times are much faster than plain lead-acid batteries. Also no explosive or corrosive fumes in the battery box, and they don't spill if tipped over. The downside to Gel Cells is they need to be regulated to 14.1 volts maximum, so you need to have alternator and charger settings that are adjustable for gel settings.

AGM: (Absorbed Glass Mat) similar in many respects to Gel Cell batteries, they also typically have a 50% useable capacity and fast initial recharging rates. As with gel cell, AGM batteries do not vent explosive gasses and will not spill if tipped over. Usually about 10% ~ 20% more expensive than comparable Gel Cells, but some installers argue they warrant the premium in price. The top manufacturer of AGM batteries in the USA is Concorde Lifeline. Overall the performance and weight of AGM vs. Gel Cell is very comparable, but AGM's have one advantage in that they can operate up to 14.4 volts during recharging, so often they can be installed directly in place of lead-acid without having to replace the charging equipment. This is a big advantage for boats that are using an outboard motor, or stock alternator that is not adjustable.

Lithium : The latest technology, already in use in some high end race boats and maxi yachts, these are the best we have to offer currently, and several key players have emerged with some attractive offerings. Be advised there are always emerging technologies and newer, better technology on the horizon, but as of this writing (May 2011) there are only a few that have appeared that are ready for marine use. BEWARE of non-marine lithium batteries! While the marine Lithium Iron Phosphate batteries are intrinsically safe, the other 'off-brand' or experimental Lithium-Cobalt batteries are not safe for marine use and they can catch fire if they are discharged too low or overcharged slightly. Although they can be found online and other sources, they are not the same as Lithium Iron Phosphate and they are not worth the risk. Several high profile fires on the early adopters of this technology serve as reminders of using experimental parts on a race boat. The primary advantage of Lithium Iron Phosphate is the chemistry is safe and fires are nearly impossible. The advantages over 'regular' lead batteries are remarkable; up to 90% useable capacity, and recharging current of 3 times the A/hr rate. A 100 amp hr battery can accept 300 amps for a while, so recharging times are greatly reduced. Shorter recharging times equate to less fuel carried, so a double weight savings is gained. In addition, even a tiny 6" x 6" x 4" lithium starting battery can crank over a 30Hp diesel engine! Also, since you can use most of the power stored in the battery you can carry a lot less battery compared to other types. You will however need a pro to help you set up the system. Be very careful about over and under charging lithium batteries; even a single discharge below the critical point can damage or destroy a very expensive battery. Lithium batteries cost $20 ~ $25 per A/hr (100 A/hr battery = $2500) so these are expensive items to ruin if not properly set up. Most systems require dedicated low and high voltage cutoff devices to protect the battery, plus sophisticated controls on the charging equipment. Properly installed, lithium batteries offer the serious racer a definite advantage over other battery types.

Battery monitor meter / Amp Hour monitor:

The only true way to know how much battery power you have available is by using an accurate Amp Hour monitor meter. In addition to showing the battery Volts and Amps from all of your charge sources, these meters track the battery use over time to tell you how much power is in the batteries at any given moment. An Amp Hour meter is just like the gas gauge in your car. It tracks how many 'electric gallons' (amp hours) you have stored in the electric tank (batteries) Remember you cannot use a simple voltmeter to tell the state of the batteries; because the voltage can be low or high, depending on how much power you are using at that moment. Voltage will vary all the time as conditions change. An amp hour meter tracks the amps used, times the number of hours, to calculate Amp Hours (amps x time) The Xantrex Link 10 is a good basic meter, or the VSM from Blue Sea Systems is a good choice. The MasterVolt BTM III or MICC are excellent multipurpose meters for advanced users, that offer a host of other functions if you want more data and the ability to connect to a PC. Look for a display that is easy to read and understand, plus meters with a 2 line display makes it easy to see amp hours, plus volts and amps without having to push buttons.

Alternators:

The 2nd most important part of the electrical system (except for boats that don't have an inboard engine) is the alternator. Look for a quality name brand, some of the better units are made by Balmar, AmpTech, and MasterVolt. The main job of the alternator is to convert diesel fuel into electricity. The alternator needs to force as much power back into the batteries as fast as possible, so it needs to be very carefully integrated into the rest of the charging system. Unfortunately the alternator that comes installed from the factory on most boats is terribly undersized for the job. Even the optional (and expen$ive) 'hi output' Hitachi 80 amp unit installed on many Yanmar engines is a poor choice for most race boat applications. If you are not sure if your alternator is a good high-output version, simply open the engine box and look at the color; if it is pained the same exact color as the engine, it is a pretty safe bet that it is NOT going to do the job. Most stock alternators have 4 critical problems that make them a candidate for replacement:

1. Insufficient output—simply not enough amps to recharge the batteries quickly.
2. No adjustments for charging voltage or battery type—the system will not work well unless the alternator is carefully adjusted for the size and type of battery you are using.
3. Insufficient cooling—look at the fan, if you don't see one, it means the alternator has an internal fan and none of these (even the expensive aftermarket versions) will survive. Without a large external fan, it cannot dissipate enough heat.
4. Too small drive pulley / not enough RPM—this limits both the cooling and the charging power available to properly recharge the batteries.

Remember most alternators need to spin 6500 rotor RPM (not engine RPM) in order to reach maximum output. So if your engine has a small 4" main crankshaft drive pulley, and the alternator has a 3" pulley, your drive ratio of 4" divided by 3" = 1.33:1 means the engine would have to spin the engine at 4875 RPM (6500 div by 1.33) to get full power out of the alternator, not a viable plan.

This would suggest installing a 7" or 8" drive pulley, with the smallest alternator pulley you can get, to spin the alternator as fast as possible.

With a good custom-machined 7" drive pulley, and a small 2.7" alternator pulley, you can run the engine around 2500 RPM and get 150 or 200 amps reliably into the batteries.

Using dual belts will greatly extend the life of the belts, and reduce side loading on the front of the crankshaft. The best system of all is to leave the stock alternator in place, and add a 2nd high output alternator with 2 drive belts pulling opposite the stock alternator. This reduces the side loading on the crankshaft and does not add any additional stress to the engine water pump bearings. Remember that most engine water pumps have very small bearings that are easily damaged if you simply install a big alternator in place of the stock unit. To keep the small single belt from slipping, you have to keep it so tight that the water pump can be damaged quickly. If in doubt consult your mechanic or an electrical pro to help you spec the best parts for your system.

Also make sure you carry a spare alternator, or at least the stock alternator in a box so you can replace it if it fails. The main goal is to optimize the fuel used to recharge the batteries. Look carefully at the specs for your engine to calculate your fuel burn. Once you know the electrical load in amp hrs used per day, you will then be able to calculate the run time need to recharge your batteries. If you multiply the daily recharge time in hours, times the gallons burned per hour, you will be able to determine the fuel you need to carry to make up for the electrical power you consume during the race. Note that not all small engines are similar in their fuel burn rates, Surprisingly Lombardini and Beta brand 25 Hp engines claim very efficient fuel consumption rates of around 1/2 gallon per hour at 2500 RPM and 25% loading, Yanmar is about in the middle of the pack, while Volvo claims almost a full gallon per hour for the same loading. Get to know your engines fuel burn so you can plan accordingly. And remember efficiency counts, diesel is a lot lighter than lead batteries. If properly executed, the electrical demands are easily met, and weight is kept to a minimum. One recent system we designed used over 150 A/hrs per day, yet only carried only 13 gallons of fuel for the entire race, with a 25% fuel reserve.

External voltage regulator:

The other equally important part of the alternator system is the external voltage regulator. This is the ‘brain’ for the alternator and controls all of its functions. The regulator needs to sense the battery voltage, and control the output of the alternator to properly recharge the batteries. Note that there are very few good internally regulated alternators. In order to do the job properly, the regulator needs to be a separate, external device. Better brands are the Balmar Maxcharge 614 series, MasterVolt Alpha Pro, or the Ample Power Next Step. All of these devices have battery temperature sensors, and will get the job done in the shortest time possible. The Balmar regulators have the advantage of using an alternator temperature sensor as well, so it can help protect the critical alternator from overheating, this is a great feature. Despite the fact that most regulators have developed to the point where they are fairly reliable, always carry a spare, and make sure it is programmed and ready to go, just in case you need it. Finally, make sure you have the proper tools and connectors to replace it if needed.

A final note on installing a high output alternator: make sure you upgrade the + positive cable from the alternator output, and the ground cable as well. <u>Do not try to reuse the small stock wiring, it will surely fail !</u> The output cables need to be rated for the full maximum current the alternator can develop, so for a 100 amp alternator, this usually means at least a #2AWG cable. Also it is best to route the alternators output directly to the house bank, instead of just connecting back to the starter like the stock setup. Be sure to seal off the unused stock wires to avoid a short circuit, and label them so you can reinstall the stock alternator unit if needed.

Fuel cells:

This is the latest and most promising technology for the racer wanting to build the ultimate lightweight performance electrical system. Still an emerging technology, although they have gained a bit of popularity in Europe. Essentially a small self-contained DC generator, these devices have the ability to make clean quiet DC power from a small disposable fuel cartridge. Unfortunately because fuel cells are extremely sensitive to impurities in the fuel source, they are not available with a refillable fuel tank so it means you have to carry disposable fuel canisters with you as you travel around. The primary fuel is methanol, this makes them somewhat impractical for a cruising boat on a several year trip to 3rd world countries, but for a 2 week sprint race like the Pacific Cup, or a record breaking attempt, they offer several advantages. The prime benefit is reduced weight, and reduced complexity. They just sit in the corner making DC power, so you don't need to have a big battery bank to store reserve power. The downside is the initial cost is still quite high, between $2500 ~ $5000, and they have upper limits of temperature and humidity in which they can operate, plus in the tropics the heat and moisture in the exhaust could be a problem to dissipate. The main item to consider when looking for a fuel cell are the controls, and the output rating. Ideally the cell should be sized just slightly smaller than your average daily consumption, ie: if you use 100 A/hrs per day, try to find a 75 ~ 90A/hr per day fuel cell. This will avoid short cycling, and keeps the cell in its most efficient 'zone'. Also look for adjustable output voltage, so you can tailor the setting to your type of battery. Lastly, try to get one with automatic start / stop controls, so you don't have to manually start and stop it every charge cycle. Most cells are designed to be run for longer periods, rather than cycling on and off every few hours. Another good feature would be to be able to get replacement fuel canisters from more than 1 source, in case the mfr goes away or sells to a giant conglomerate. At least 1 mfr is advertising 'hot swap' fuel cartridges, so you can keep the unit on even while refueling.

Remember that most fuel cells only offer 'on - off' charging regulation, so you will need some other charging device like a 3 step solar panel regulator, or an engine alternator with 3 step regulator to do the final bit of charging or at least an occasional 'conditioning' charge to keep the batteries full.

Solar panels:
Solar panels are a great way for the racer / cruiser to supplement their energy system, assuming you have room to mount them and the sun is available. The #1 most important thing to consider with any solar panel installation is shading. Depending on the type of panel you have, even a small shadow covering 10% of the panel can cut output by 90%. Even a small shadow from a single shroud can significantly reduce the output of a good solar installation. This means all of those racers who simply mount a panel on the deck or on top of the main hatch almost never get any power from their panels. To be effective, solar panels need to be as far aft and outboard as possible. One of the best options is to mount a piece of stainless tubing horizontally across the transom, between the stern pulpits. Then use some rail clamps to mount your panels to this horizontal tube. Alternately, you can install a horizontal piece of tubing on each side of the cockpit from the stern pulpit, forward to the top of the aft-most stanchion, and mount panels on each side of the cockpit. With this setup you can tilt the panels to follow the sun, or stow them against the lifelines when not needed. Plus this gets the panels as far aft as possible to reduce the chance of shading.
Once you decide on a location, then you can shop around for panel(s) to fit your available space. Usually this is the determining factor, more so than anything else; try to get the biggest panel you can fit in your location. Also consider the type of panel you need:

Amorphous panels: These can be identified by their characteristic 'all one color' appearance, the front of the panel does not have separate individual cells. These panels tend to be smaller in output, usually 10 watts max, and offer lower charge voltages. This makes them more suitable for use without a regulator, as the chance of overcharging is less, but they offer little real charging power; they are better suited to keeping your car battery charged at the airport while you are out sailing…

Rigid MultiCrystalline / Polycrystalline panels: these are identified by their typical grid appearance, as they are made from many smaller cells connected in series-parallel configurations to get up to the voltage level needed to charge your batteries. Kyocera has been a long-time favorite with many installers, and they actually advertise their products as suitable for marine use. Some of the important things to look for are:

- Check the seal around the edge of the panel where the glass and frame meet. If there is any tiny path for water to get into the laminate, it will quickly attack the thin foil conductors that connect the cells together.
- Look also at the overall ‘wasted space’ in the panel, some panels are a lot bigger than they need to be simply because of the way the cells are arranged, look for a minimum of empty white space between cells.
- Check the Maximum Power Voltage (Vmpp) it needs to be at least 17.4 volts This is because all panels lose output as they get hot, and some cheaper panels barely put out 12 volts once the cells get up to temperature. You need at least 14 volts at high temperature or the panels simply do not do any work.
- Check the IP (ingress protection) rating of the electrical junction box. IP66 is Ok, IP68 is better, as this is a common failure point of many solar panel installations. Make sure your J box is sealed up tight to avoid corrosion problems.
- Bypass diodes are a great idea for multiple-panel systems, as they reduce the loss from shaded areas, but they do consume a bit of the output power, so they should only be used in systems where there is more than one panel or if you do not plan to use a regulator, as they will prevent nighttime ‘bleedback’ from the panels.

Flexible MultiCrystalline / Polycrystalline panels:
Many of the same features and output as rigid panels, but typically only offered in smaller sizes. They offer the advantage of being able to mount directly onto the deck or cabin, but keep in mind the shading issues discussed above. Otherwise they work in very similar fashion to rigid panels, but be sure to check the specs and make sure they have sufficient output for your system.

Solar regulators:
These are generally available in two types. Cheaper versions operate on the simple ‘cut-in cut-out’ principle. These are small and weigh only a few ounces, but they are not usually adjustable for different battery types. They are Ok for short term use, but they have the effect of short-cycling the batteries and can shorten the life of your expensive batteries. Several models are available from Flexcharge in the $90 ~ $150 range that have good basic features and will work for a small system.
Better solar regulators feature some type of 3 step charging output, usually by using some form of PWM (Pulse Width Modulation) to turn the panels on and off at a very high frequency to essentially control the output of the panels. These typically cost in the $150 ~ $250 range but offer the advantage of better battery charging and extended battery life. The SB2512i regulator from Blue Sky Energy is a great small package that has 3 step output, and they claim a slight advantage in output power by using MPPT technology to track the maximum voltage and current available at any given point in the solar cycle. They also offer a remote display panel that can track other battery functions besides the solar output. It is recommended to test solar panel output often as the wiring connections at the back of the panel and the deck plug are prone to damage and it is easy to overlook the fact that the panels are not working until the batteries are dead. This is where a good battery monitor is invaluable as it will clearly show the power from the solar panels.

Wind Generators:
Although not usually practical for the Pacific Cup race, wind generators are beneficial to larger boats or those wishing to do a bit of cruising after they reach Hawaii. There are essentially 3 types of wind generators for use on race boats, we will exclude the larger 2 blade versions hoisted into

the rigging, as they are simply not practical for racing use. The other types however, can be of some value.

Small 5 or 6 blade machines: these are mostly permanent-magnet generators, made in the UK. The Rutland and LVM models have been popular with long-distance racers for many years. They have small 3 ~ 5 amp outputs, but their smaller multiple blade fans make them a bit more rugged, and quieter than other alternatives, They are also a bit lighter than other options, some boats even use 2 at a time for redundancy. Note these devices all use an external shunt-type regulator to control their output, there are no 'brains' in the generator itself.

Larger 2 or 3 blade machines: These are mostly made in the USA, many are adopted from land-based applications, although the Air X Marine and the KISS are well suited to marine use. These are bigger, heavier and noisier than the smaller machines, but offer greater output, up to 15 amps under ideal conditions. The Air X Marine has a built-in regulator for its alternator, but the adjustment screw right near the spinning propeller of death is a bit awkward to adjust. In practice the Air X works well but carry spare bearings as they seem to wear out at a frightening rate. The KISS unit has a separate adjustable regulator for its alternator, which makes dialing it in a lot easier. Any of these units will help to offset your power consumption, but will be of limited value during the mostly-downwind conditions typical of the Pacific Cup.

In Conclusion:

We hope this section is helpful to you as you prepare for one of sailings greatest sporting events. The information presented here is intended to assist you with selecting equipment and planning your racing preparations. It is in no way intended as a complete guide to outfitting your vessel or rewiring your electrical system. If in doubt, always consult with a trained professional.

Other resources:

Refer to the American Boat and Yacht Council website *www.abycinc.org* for a list of ABYC certified installers in your area. These are professionals trained and certified in various marine systems and are available nationwide to check your equipment and assist with installations if necessary.

Also refer to the website *www.sfboating.com* and click on the 'services' tab for a guide to San Francisco Bay Area vendors and installers who can assist you with upgrading your systems.

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He rewired his first boat at age 11, and has been actively engaged in the marine electrical business for over 35 years. His services include electrical system design, installations, lightning protection, and corrosion consulting for all types of watercraft, as well as safety testing for harbors and yacht clubs.

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