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① ALL ELECTRIC: PROS & CONS

The Swedish-built Arcona 435Z—with its lithium-ion batteries, Solbian solar panels and new Oceanvolt ServoProp drive leg—is the first all-electric cruising boat we’ve ever reviewed. Here are some of the promises and pitfalls.

SYSTEMS

This past October, I saw one of the most interesting exhibits in more than 500 new cruising sailboats I’ve reviewed over two decades. It was the Arcona 435Z, built in Sweden and introduced by Graham Balch of Green Yachts in San Francisco. Balch describes his business as “a new brokerage dedicated to the electric revolution on the water,” and it was the “Z” in the boat’s name, which stands for “zero emissions,” that made this boat so interesting. This was the first electric propulsion system—not hybrid but *all-electric*—I’d ever seen on a cruising sailboat.

Electric propulsion isn’t new. Since 1879, electric motors have propelled boats; a fleet of some four-dozen electric launches transported visitors around the 1893 Colombian Exposition in Chicago. But cruising sailboats are not launches, and the open sea is not a protected canal. When we’re using cruising boats as they’re



meant to be used, they seldom end their day plugged into a shore-power outlet. Cruising boats comprise many devices—stove, refrigerator, freezer, windlass, winches, autopilot,

radar, lights—whose power typically comes from a tank of fossil fuel. And today’s cruising sailors are accustomed to using diesel auxiliary power to motor through lulls or punch

Imported into the US market by Green Marine, the Swedish-built Arcona 435Z is a rarity: an all-electric cruising sailboat.

into headwinds and seas.

Starting about 15 years ago, we saw a wave of diesel-electric and hybrid propulsion systems on production and custom cruising boats (see “Perpetuated Motion,” March 2005). Both of those systems ultimately start with an onboard internal-combustion engine. A diesel-electric propulsion system relies on a running genset to directly power the electric motor that turns the propeller. A hybrid system relies on batteries to power the electric motor, plus an internal-combustion genset to recharge the batteries.

fossil-fuel engine at all. Instead, it has a bank of lithium batteries, several solar panels, and a proprietary propulsion leg that looks like a saildrive. “This boat,” Balch said, “has the very first production unit in the world of Oceanvolt’s newest electric propulsion system, called the ServoProp.”

For our sea trial, Balch was joined by Derek Rupe, CEO of Oceanvolt USA. “If you can sail the boat and you have some solar, you can go anywhere in the world, and you can make all your power underway while you go,” Rupe said. When we spoke

ServoProp is a leg with a feathering propeller that can be set for optimal pitch in three modes: forward, reverse and regeneration.

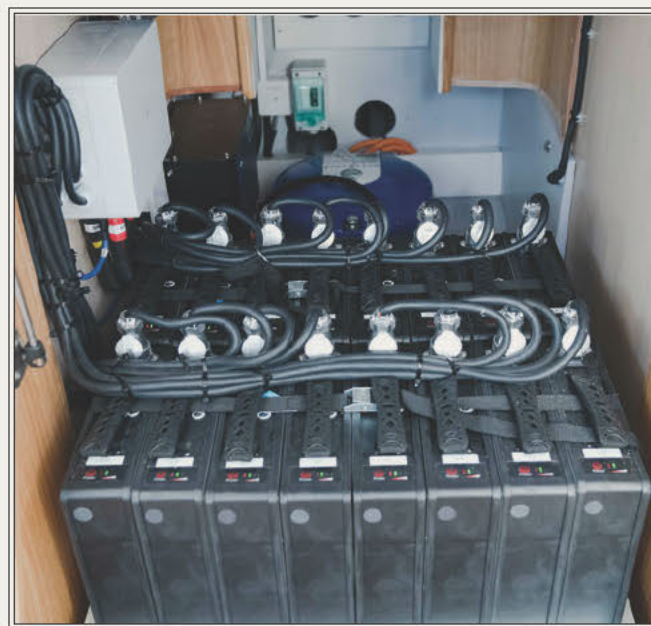
“You don’t need fuel,” Rupe said. “You don’t need to dock; you can go anywhere you want to go and always have the power for living and propulsion.”

That’s the promise. But are there also pitfalls?

INNOVATION AND RISK

Marine electric propulsion is an emerging technology. Compared with the mature and settled technology of diesel engines and lead-acid batteries,

the first-wave discoveries of a new technology; if they’re clear-eyed about supporting an ongoing experiment, they see themselves as partners with the developers, accepting failures as opportunities for learning. Sailors motivated primarily by changing the trajectory of climate change might be especially willing to modify their behavior to limit their own output of greenhouse gases. Investing in any emerging technology asks you to start with a clear assessment of your own risk tolerance. We’ll return to this theme with one or two real-life examples.



On the Arcona 435Z, the space where you’d normally expect to find a diesel auxiliary is occupied by a bank of lithium-ion batteries (left). Lithium batteries have far greater power density than lead-acid batteries, meaning they’re lighter for a given capacity. The Oceanvolt system allows you to monitor batteries at both the module level and cell level (right).

One of the promises of a hybrid system is the ability to regenerate electrical power. Regeneration means using boatspeed under sail to turn the propeller, whose spinning shaft sends electrons from the electric motor back through an electronic controller to recharge the batteries. In such a system, the boat’s propeller is both an electrical load (when running under power) and a charging source (when sailing in regeneration mode).

The Arcona 435Z was different from both of these systems: It incorporates no onboard

in October 2020, he touted three high-profile sailors who were using the Oceanvolt electric propulsion system: Alex Thomson, for his *Hugo Boss Open 60* Vendée Globe program; Jimmy Cornell, for his Elcano 500 expedition; and Riley Whitelam and Elayna Carausu, who had been teasing their new boat for months on their popular Sailing La Vagabonde YouTube channel.

The efficiency of Oceanvolt’s ServoProp and the regeneration from it is the promised game-changer in each of these boats. The

electric-propulsion systems—with their electronic controllers and lithium batteries—are in a stage of development best described as adolescent. Every sailor has his or her own tolerance for technical innovation. For the promise of fewer seconds per mile, grand-prix-racing sailors willingly trade a high risk of expensive damage to the sails, rig or the boat’s structure itself; cruising sailors, by contrast, tend to favor yearslong reliability in their equipment as they seek miles per day.

Folks who identify as early adopters take special joy in

The American Boat and Yacht Council, founded in 1954, sets recommended standards for systems installed on recreational boats. For decades, ABYC has published standards related to installations of diesel and gasoline engines, as well as electrical systems based around lead-acid batteries. By contrast, it was only three years ago that ABYC came out with its first electric-propulsion standard (revised July 2021). And only last year it published its first technical-information report on lithium batteries (a technical-information report

is an early step toward a future standard). The takeaway is that if you need help servicing your diesel engine or electrical system built around lead-acid batteries, you can pull into any reasonable-size port and find competent technicians to help you. With electric propulsion and lithium batteries, that pool of skilled talent is significantly scarcer.

To say that a technology is mature simply means that we’ve learned to live with it, warts and all, but that it holds few remaining surprises. Certainly, diesel-propulsion and lead-acid-battery technologies each leave plenty of room for improvement.

means you can use far more of the bank’s capacity, not merely the first half. And they accept a charge much more quickly; compare that to several hours a day running an engine to keep the beers iced down.

But the pitfalls? Let’s start with ABYC TE-13, *Lithium Ion Batteries*. Some of its language is bracing. “Lithium ion batteries are unlike lead-acid batteries in two important respects,” the report says. “1) The electrolyte within most lithium ion batteries is flammable. 2) Under certain fault conditions, lithium ion batteries can enter a condition known as thermal runaway, which results in rapid internal

a mechanic opened the aft electronic equipment bay of the Boeing 787-8 to find smoke and flames billowing from the auxiliary-power unit. The fire extinguisher he used didn’t put out the flames. Eventually Boston firefighters put out the fire with Halotron, but when removing the still-hissing batteries from the plane, one of the firefighters was burned through his professional protective gear.

Samsung Galaxy cellphones, MacBook Pro laptops, powered skateboards—in the past decade, these and other devices have been recalled after their lithium batteries burned up. In that period, several

installed to prevent damage to the battery and provide for battery shutoff if potentially dangerous conditions exist.” It defines a bank’s “safe operating envelope” according to such parameters as high- and low-voltage limits, charging and discharging temperature limits, and charging and discharging current limits.

Graham Balch takes these safety recommendations a step further: “To our knowledge, the BMS has to monitor at the cell level. With most batteries, the BMS monitors at the module level.” The difference? “Let’s say you have 24 cells inside the battery module, and three of them stop working.



This fall, Green Marine introduced a new all-electric yacht to American sailors: the Salona 46 with two Oceanvolt ServoProps, and the ability to hydrogenerate twice as fast. The Salona features twin control panels and throttles (left), a pair of dedicated Oceanvolt motor controllers (center), and a Victron Energy Quattro charger/inverter (right).

When a charge of fuel ignites in the combustion chamber of a diesel engine, some three-quarters of the energy is lost in heat and the mechanical inefficiencies of converting reciprocating motion to rotation. Lead-acid batteries become damaged if we routinely discharge more than half of their capacity. During charging, they’re slow to take the electrons we could deliver.

Lithium batteries are comparatively full of promise. Their power density is far greater than that of lead-acid batteries, meaning they’re much lighter for a given capacity. They’re capable of being deeply discharged, which

heating. Once initiated, it is a self-perpetuating and exothermic reaction that can be difficult to halt.”

Thermal runaway? Difficult to halt? *Self-perpetuating?*

“Typically, the best approach is to remove heat as fast as possible, which is most effectively done by flooding the battery with water,” TE-13 continues, “although this may have serious consequences for the boat’s electrical systems, machinery, buoyancy, etc.”

If you were following the news in January 2013, you might remember the story of Japan Airlines Flight 008. Shortly after landing at Boston’s Logan Airport,

high-end custom boats were declared a total loss following failures from lithium batteries. In March 2021, a 78-foot Norwegian hybrid-powered tour boat, built in 2019 with a 790 kW capacity battery bank, experienced thermal runaway that kept firefighters on watch for several days after the crew safely abandoned the ship.

Yes, experts are learning a lot about how to mitigate the risks around lithium batteries. But we’re still on the learning curve.

ABYC’s TE-13 “System Design” section starts, “All lithium-ion battery systems should have a battery management system (BMS)

Well, the other 21 have to work harder to compensate for those three. And that’s where thermal events occur.”

Balch followed the story of the Norwegian tour boat this past spring. He believes that the battery installation in that case didn’t meet waterproofing standards: “The hypothesis is that due to water intrusion, there was reverse polarity in one or more of the cells, which is worse than cells simply not working. It means that they’re actively working against the other cells. But if the BMS is monitoring only at the module level, you wouldn’t know it.”

On the Green Yachts website, Graham lists five battery

manufacturers whose BMS regimes monitor at the cell level. “If I were sailing on an electric boat, whether it be commercial or recreational, I would feel comfortable with having batteries from these five companies and no other,” he said.

The broader takeaway for today’s sailors is that lithium batteries bring their own sets of problems and solutions, which are different from those of conventional propulsion and power-supply technologies. A reasonably skilled sailor could be expected to change fuel filters or bleed a diesel engine if it shuts down in rough conditions. With lithium-ion batteries aboard, an operator needs to understand the causes and remedies of thermal runaway, and be ready to respond if the BMS shuts down the boat’s power.

REAL-WORLD ELECTRIC CRUISING BOATS

When we met Oceanvolt’s Derek Rupe a year ago, he and his wife had taken their all-electric boat to the Bahamas and back the previous season. Before that, he’d been installing electric-propulsion packages for six years on new Alerion 41s and other refit projects. “My real passion is on the technical side of things—installations, really getting that right. That’s half the picture. The technology is there, but it needs to be installed correctly.”

When talking to Rupe, I immediately encountered my first learning curve. I posed questions about the Oceanvolt system in amps and amp-hours; he responded in watts and kilowatt-hours. This was yet another example of the different mindset sailors of electric boats need to hold. Why? Because most cruising boats have just one or two electrical systems: DC and AC. The AC system might operate at 110 or 220 volts; the DC side might operate at 12 or 24 volts. On your own boat, that voltage is a given. From there we tend to think in terms of amps needed to power a load, and amp-hours of capacity in our

battery banks. Going back to basics, the power formula tells us that power (watts) equals electrical potential (volts) times current (amps). If your boat’s electrical system is 12 volts and you know that your windlass is rated at 400 watts, it follows that the windlass is rated to draw 33 amps.

But an all-electric boat might comprise several systems at different voltages. A single battery bank might supply cabin lights at 12 volts DC; winches and windlasses at 24 volts DC; the propulsion motor at 48 volts DC; and an induction stove, microwave and television at 110



The Oceanvolt ServoProp has a feathering propeller that can be set for optimal pitch in three modes.

volts AC. A DC-to-DC power converter steps the voltage up or down, and an inverter changes DC to AC. Instead of translating through all those systems, the Oceanvolt monitor (and Derek Rupe) simply reports in watts coming in or going out of the bank.

“We keep all our thoughts in watts,” Rupe said. “Watts count in the AC induction. They count in the DC-to-DC converter. They count the solar in. They count the hydrogeneration in. And the power-management systems tracks it that way for shore-power in.

“On a boat like this, maybe

I have 500 watts coming in the solar panels,” he continued. “So then I can think: ‘Well, my fridge is using 90 watts. My boat has an electric stove. When I cook a big meal, I can see that for every hour we cook, we lose about 10 to 12 minutes of our cruising range.’”

During his Bahamas cruising season, Rupe observed that on days that they were sailing, the combination of solar panels and hydroregeneration supplied all the power he and his wife needed. “When we weren’t sailing,” he said, “we found that we were losing 8 percent each day, in the difference from what the sun gave us to what we were using for the fridge, lights, charging our laptops, and all that stuff.”

Rupe’s solution? “Twice in Eleuthera and once outside Major’s, we went out and sailed laps for a couple of hours because the batteries were below 30 percent of capacity. It was good sailing, and the wind was coming over the shore, so we didn’t have any sea state. We did a couple of hot laps on nice beam reaches, and generated about 700 watts an hour.”

Of the three sailors Rupe touted in October 2020—Alex Thomson, Jimmy Cornell and the Sailing La Vagabonde couple—only Cornell can report back on his all-electric experiences with Oceanvolt. Alex Thomson ended his circumnavigation abruptly last November, just 20 days after the Vendée Globe start, when *Hugo Boss* collided with an object in the South Atlantic. And at press time in early fall 2021, Riley and Elayna had just recently announced the build of their new Rapido trimaran; keep an eye on their YouTube channel for more about their experiences with the Oceanvolt propulsion system.

As for Cornell—circumnavigator, *World Cruising Routes* author, creator of the transoceanic rally, and veteran of some 200,000 ocean miles—he suspended his planned Elcano 500 round-the-world expedition solely because of the Oceanvolt system in his new Outremer catamaran. His

Aventura Zero Logs on the Cornell Sailing website, particularly the *Electric Shock* article posted on December 2, 2020, are essential reading for any sailor interested in sailing an electric boat. “Sailing around the world on an electric boat with zero emissions along the route of the first circumnavigation was such a tempting opportunity to do something meaningful and in tune with our concern for protecting the environment that my family agreed I should do it,” Cornell wrote. “What this passage has shown was that in spite of all our efforts to save energy, we were unable to regenerate sufficient electricity to cover consumption and top up the batteries.”

Cornell’s experience in that article is raw, and his tone in that moment bitterly disappointed. We recommend it as essential reading—not as a final rejection of the electric-boat concept or of Oceanvolt’s system, or even as an endorsement of Cornell’s own decision that the system didn’t work. I suspect that I may have arrived at the same conclusion. Yet given the same boat in the same conditions, one imagines that a new breed of sailor—a Graham Balch or a Derek Rupe—may have responded differently to the constraints imposed by an all-electric boat, as nearly every cruising sailor today habitually responds to the inconvenient constraints of diesel engines and lead-acid batteries.

“If you bring electric winches, electric heads and an induction stove, and then sail into a high-pressure system, you’ll set yourself up for failure,” Balch said. “You have to balance your power inputs and your power outputs.

“Sailing an electric boat is a return to the tradition of sailing that the crutch of a diesel engine has gotten us away from,” he added. “Magellan’s fleet got all the way around the world, and they didn’t have a diesel engine.”