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# Somewhere under the Rainbow



Beneath the sleek teak decks of the newest J-Class yacht is a hybrid engine and power system that's taken the team at WhisperPower and Holland Jachtbouw years to develop – then they had to fit it into a yacht that wasn't designed for engines. **Don Hoyt Gorman** goes below deck with some of the leading minds in marine hybrid power and comes up charged.

Holland Jachtbouw's *Rainbow* is a technological marvel, designed and built to the highest standards, intended to compete in the J-Class races and win.

Just outside Amsterdam, on the north side of the North Sea Canal, Holland Jachtbouw has been putting the finishing touches to *Rainbow*, the brand-new J-Class yacht based on the original 1934 William Starling Burgess design launched from Herreshoff yard in Bristol, Rhode Island.

*Rainbow* is expected to be at the upcoming J-Class races in Falmouth, England, this summer, followed by races in the Solent and around the Isle of Wight in the Hundred Guinea Cup. It will be the first time in over three generations that a whole fleet of Js will race together, and the spectacle will be nothing short of breathtaking. For a certain kind of sailor and admirer – this writer included – Js represent the high watermark of sailing design. Subsequent advancements enabled evolved rigs and hull-forms after WWII which, sadly, rarely achieved the sublime visual impact of a pair of Js under full sail, canted hard over, thundering away to victory.

Like the original, Holland Jachtbouw's *Rainbow* is a technological marvel, designed and built to the highest standards, intended to compete in the J-Class races and win. The original

was built and launched in 100 days and had no engines whatsoever. The current iteration required two years to build and features race-optimised naval architecture by Dykstra and Partners, Southern Spars' high-modulus carbon mast, boom and spinnaker pole, continuous carbon fibre rigging, 3Di racing sails and Lewmar high-speed hydraulic winches. Below decks, she's packing arguably the most advanced marine hybrid power and propulsion system afloat in a sailing yacht today.

In 2007, Holland Jachtbouw kicked off an internal project to consider hybrid power and propulsion. The project's youthful leader, Arjen Zijlmans, is a career marine engineer and technical director at the yard. On his travels around the world, he started to pick up bits and pieces – batteries, DC busses, generators – and tinkered with them after-hours with a small team at the yard to see what they could figure out. "Only 15 per cent of the total installed power was being used over the course of the year on some of the yachts we examined," he said. "That's incredibly inefficient. I just wanted to find a more clever way of providing energy."

RAINBOW'S CREW GATHER THE JIB AFTER THE YACHT'S HYBRID POWER SYSTEM HAS HOISTED THE SPINNAKER.



With the emergence of new lithium-ion batteries that are smaller, lighter and don't produce explosive gases when charging or discharging, the option to store excess energy and draw on it in a more effective way had become accessible. Zijlmans also wanted to build a generator that was independent of frequency, enabling the engine to run on the optimum speed to provide power to the yacht.

Various companies around the world had spotted the opportunity that new battery systems and variable RPM generators could offer terrestrial clients and were working on a plethora of hybrid engineering solutions, including some of the biggest names in propulsion and engineering – Siemens and BAE Systems. While they developed and rolled out hybrid city bus fleets worldwide – not to mention Toyota's successful Prius line – the yacht world considered its options and tinkered with ideas that would work for individual owner projects.

A year into his testing and calculations, Zijlmans met with one of the leading Dutch minds in marine power, Roel J. ter Heide. Ter Heide, the entrepreneur and engineer who had started power-engineering firm Mastervolt, had recently spun out its generator arm as WhisperPower and, crucially, was looking at building a hybrid marine system for yachts.

"Holland Jachtbouw had developed a concept system for the (un-built) Hollander project," ter Heide explained, "which we discussed with the owner who wanted to build *Rainbow*." The owner, who has a significant real estate concern, was integrating 'green' thinking into his businesses, and understood the prestige of owning a forward-thinking hybrid system yacht. "He really wanted to ensure that his yacht would have redundancies built in for power and services," Zijlmans explained. "On most sail racing yachts, there's just the one engine, and if it fails, it's no fun."

"We spent a year trying to find commercial or military components to meet the *Rainbow* spec," ter Heide explained, "but there were issues with Lloyd's classification and simple

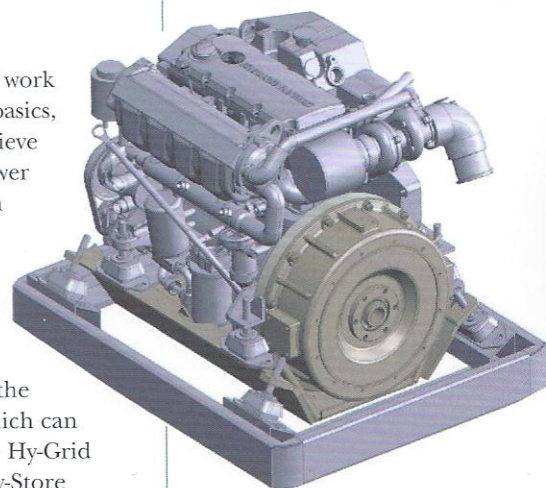
technical things that didn't work for us. So we went back to basics, built a business plan to achieve the targets and WhisperPower Hybrid Systems was born in 2009."

## WHISPERPOWER HYBRID

Over a year and a half, WhisperPower developed the Hy-Gen system models, which can generate up to 200kW, the Hy-Grid distribution system, the Hy-Store storage system and the Hy-Control interface to monitor and run the system. "We spent almost eight months on trial-and-error testing of military supplies and drew the conclusion that the only thing that was commercially available was industrial electronic inverters or converters. Water-cooled, bi-directional power conversion is available by the kilogram, but you have to programme it for your application."

The rest of the components WhisperPower either designed and had manufactured or bought (batteries and engines for instance) and built into their very specific systems and specifications. Their key sub-contractors and suppliers were Combimac, Vacon and ADK. Their objective was simple: deliver a system that could provide silent, electric propulsion for an hour or more; could manage the hydraulic system for sailing entirely off the batteries so that no generators are running while under sail; and one that could charge the batteries while under sail (10kW max). It was also key to have silence at night, so a major investment was made in a substantial battery pack to cover this specification.

The owner ultimately settled on a parallel hybrid mechanism that maintains the mechanical connection between the engine and propeller shaft. It has the dual benefit of delivering either direct physical power to the prop shaft from the engine or fuel-efficient and silent propulsion in electrical mode.



THE 50KW HY-GEN FROM WHISPERPOWER, SHOWING THE PERMANENT-MAGNET (PM) IN GREY. IT WILL RUN AT 1,200-1,500RPM FOR SILENT RUNNING TO KEEP BATTERIES CHARGED OR UP TO 3,200RPM IN HIGH-POWER MODE.

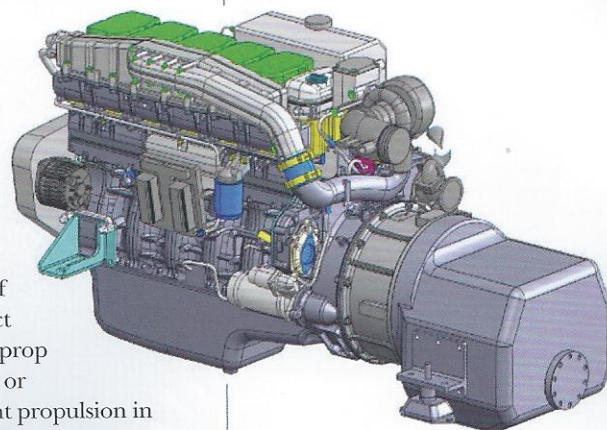
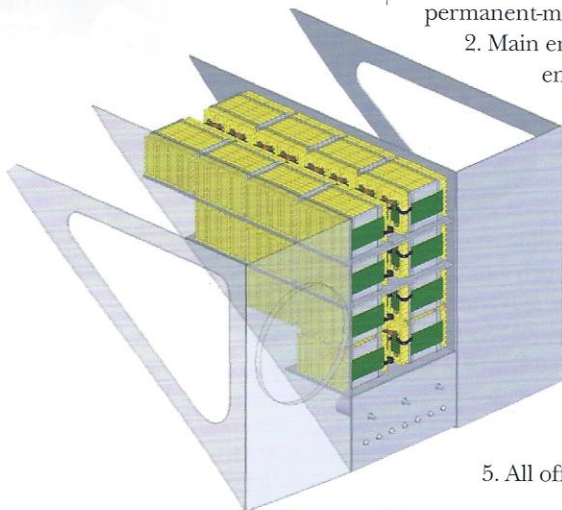


DIAGRAM OF *RAINBOW*'S 300KW SIX-CYLINDER SCANIA MAIN ENGINE, FITTED WITH THE PM GENERATOR/MOTOR WITH OVERRUNNING CLUTCH AND A ZF GEARBOX COUPLED TO A WEST MEKAN CONTROLLABLE PITCH PROPELLER.

RAINBOW'S TWO 40KWH LFP BATTERY BANKS HAVE 10 BATTERIES WITH 16 3.2V CELLS, PASSIVELY BALANCED (THEY GIVE OFF HEAT TO MAINTAIN AN EVEN STATE OF CHARGE).



The drive train has five modes:

1. Propulsion from the Scania main engine, with energy pulled from the permanent-magnet (PM) generator.
2. Main engine propulsion without energy pulled from the PM generator – reserved for high-speed cruising or if the PM motor isn't working.
3. 50kW of electric propulsion using only the PM motor, which provides seven to eight knots of speed.
4. Main engine running only to turn the PM as a back-up generator.
5. All off.

There's also the regeneration power mode that uses the prop shaft to turn the PM generator while under sail, thus producing a small amount of energy for the grid at a cost of about 1.5 knots of sailing speed. *Rainbow's* system doesn't augment the powerful main engine with an electric motor boost, although Zijlmans commented that more efficient and powerful battery packs might make that an option for motoryachts in the future.

The range of manufactured and packaged solutions that WhisperPower has developed for this project is now commercially available and actively

being marketed to superyachts. The next J-Class from Holland Jachtbouw – not the J-8 *Yankee*, but another newly arrived at the yard after the client was impressed by the performance of *Rainbow's* installation – will also use this system, while other Dutch yards are considering the technology as well.

### ON BOARD RAINBOW

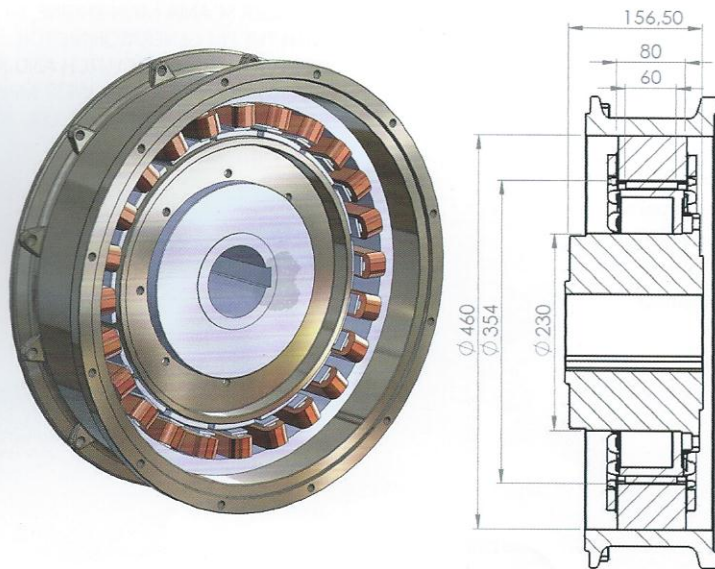
While the system itself is ingenious in concept – especially after playing with it on the workbenches at WhisperPower's R&D lab in Drachten, North Holland – walking on board *Rainbow* in Zaandam, it becomes quite clear how the installation presented a real problem, considering the classic J layout the yard had to work with. There will come a day, when, to fix one component, they'll need to pull five others out to reach it.

"You can't alter the lines of the boat – it was challenging!" Zijlmans says. "Maintenance-wise, there are definitely lessons we've learned with the installation on *Rainbow*. We're relying on equipment that doesn't require much maintenance." The enabling technology – the high-end LiFePo4 (LFP) batteries robotically manufactured by European Batteries in Finland – is basically invisible. They are fitted port and starboard in water- and air-tight compartments between the fresh-water tanks and the fuel oil tanks, with each side offering 40kWh of available energy – enough to allow eight hours of silent operation overnight. Each individual battery cell is connected to a battery monitoring system (BMS) that senses charge and internal temperature. The BMS feeds into the helm-level monitoring and control system.

The whole engine room installation is built under Lloyd's survey with an unmanned machinery space (UMS) notation. It's manageable, but hardly a comfy workspace for an average-sized man. WhisperPower's 50kW Hy-Gen box sits aft and to port of the centreline. It's a white and green sound-isolating box containing the four-cylinder Steyr engine driving the PM generator bolted to one end.

Below the aluminium floor plates, there's another PM affixed to the six-cylinder 300kW Scania main

DIAGRAM OF WHISPERPOWER'S PERMANENT MAGNET GENERATOR WITH INTEGRATED OVERRUNNING CLUTCH, WHICH, WHEN ATTACHED TO THE PROPELLER SHAFT, CAN ALSO FUNCTION AS A MOTOR. IT IS LIQUID-COOLED AND WEIGHS 140KG.





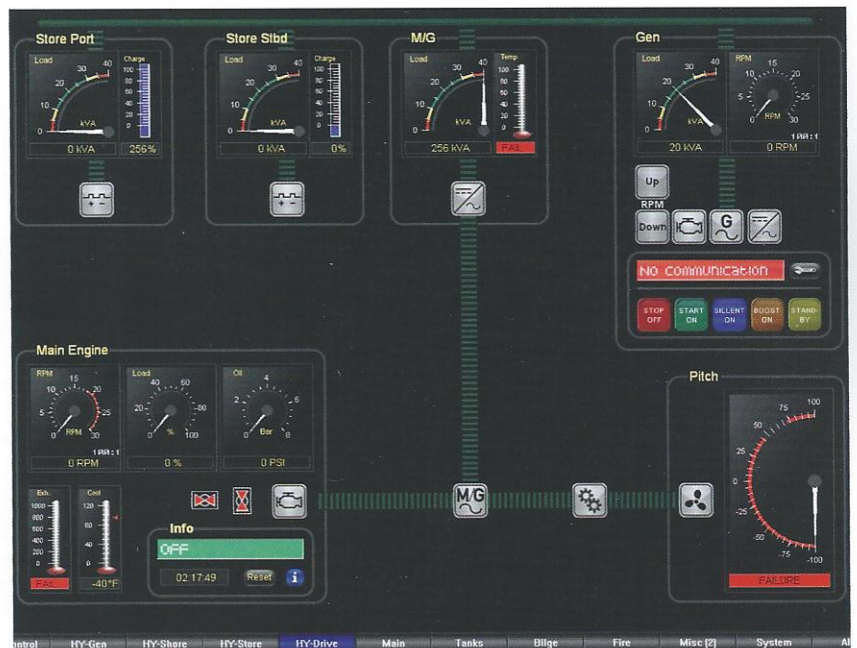
engine, between the motor and the ZF gearbox. The West Mekan controllable pitch propeller, if left in gear while the main engine is off, can turn the main engine PM and generate energy from the flow of water under the hull. The resistance of the prop when turning the PM costs about a knot and a half of speed, according to Zijlmans; and, of course, the Hy-Gen, battery pack or both can power the prop for quiet running at low speeds.

The backbone of the system is the DC bus, which connects all components, aptly named the Hy-Grid. It connects the two battery banks and the two PM generators to the rest of the yacht's energy grid, including winch hydraulics for sail handling, air conditioning and bilge pumps, as well as shore power. The system is fed energy by both generators as needed, while the battery banks either accept energy for charging, or provide energy for boosts or silent running. The way the system is designed, there are no artefacts of big power changes coming on – so no lights flickering when running the main winches, for instance. The system has two modes: shore power and "Isle" operation. All AC-required power is directed through two AC converters, one forward, one aft, with the aft one also handling the engine room.

Given the limitations of shore power, the batteries provide power during peak loads (dinnertime, AC running throughout, lights, music, hairdryers and the like all on at once). If the batteries are low, the Hy-Gen generator kicks in (and the main engine could as well if the load was big enough).

## OPERATION

Part of the elegance of the system is its user interface design. Arjen's wife, Mirjam, is actually a graphic designer and helped to develop the icons that WhisperPower use for the system – another nice cooperative example of how the teams came together. The interface is a touchscreen with elegantly simple icons and graphics that display operational status and controls for the generators, shore power, battery banks, as well as the usual main engine controls, tanks, bilges, fire systems and alarms.

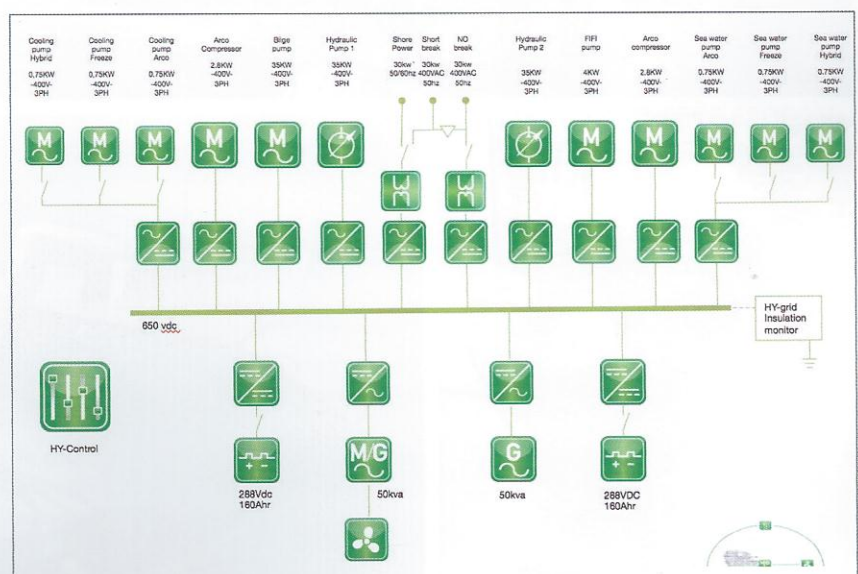


Starting from 'dead ship', the DC bus is pre-charged from shore power, batteries or gensets. The bus kicks in within seconds, as it senses 500 volts of DC current. When the batteries are down to 20 per cent charge, the system turns the genset on (if the main engine generator isn't already providing power to the grid) and speeds up to full power to charge the batteries as quickly as possible. The system always senses the yacht's electricity needs, and will adjust the speed of the generator to provide just the energy that's demanded.

In situations where the electricity demand is actually higher than the grid is able to supply, the system shuts off power from the grid to low-priority systems in three groups. The first group is the galley, the second group is washing and drying, and the third

ABOVE: WHISPERPOWER'S HY-CONTROL USER INTERFACE PROVIDES A CLEAR OVERVIEW OF THE STATUS OF THE COMPLETE HYBRID POWER AND PROPULSION SYSTEM.

OVERVIEW OF THE ENTIRE HYBRID SYSTEM SHOWING THE HY-GRID DC BUS AS THE GREEN LINE AT CENTRE, CONNECTING THE BATTERIES, GENERATORS, SHORE POWER, PUMPS AND AC CONVERTERS.



“We were really excited to see whether the system was quick and stable enough to deal with these load steps generated by a team of 25 pros on deck pushing winch buttons! Happily, it did!”

TOP LEFT: ROEL J TER HEIDE, PRESIDENT, & MARTIJN FAVOT, CHIEF TECHNOLOGY OFFICER, OF WHISPERPOWER, AT THE BENCH-TESTING FACILITY IN DRACHTEN, NORTH HOLLAND, WHERE RAINBOW'S SYSTEM WAS SET UP AND TRIALLED PRIOR TO INSTALLATION AT THE HOLLAND JACHTBOUW SHIPYARD IN ZANDAAM. TOP RIGHT: ARJEN ZIJLMANS, TECHNICAL DIRECTOR OF HOLLAND JACHTBOUW. BOTTOM ROW: WHISPERPOWER'S PRODUCT RANGE INCLUDES COMPONENTS FOR MARINE, MOBILE AND LAND-BASED POWER REQUIREMENTS.

group is the water maker and sewage treatment. The system is constantly sensing the load and ensuring there is sufficient energy supply to keep the yacht powered up and operating safely – and as quietly as possible.

With racing mode enabled, the quiet-running Hy-Gen system will offer 50kW of boost power to the Lewmar high-speed winches when needed – otherwise, racing is completely silent running off the batteries. “Racing mode is a very important consideration for a J-Class. Energy-wise, it’s also the most interesting, with space, sound and performance all in conflict.”

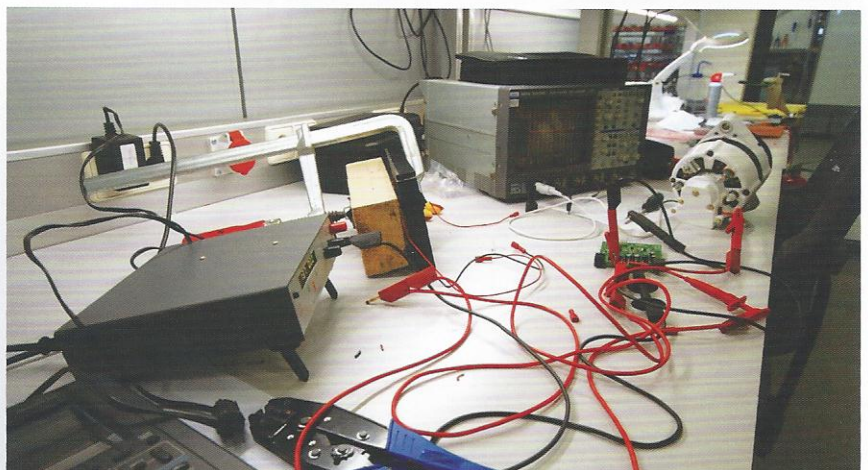
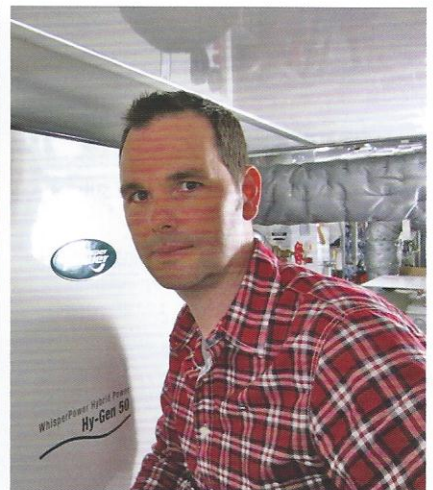
It can't be understated how complex the engineering here is. “You have to programme all the parameters according to the specifications that you develop with the owner, crew and yard,” ter Heide explained. “Once the physical components are installed aboard, the programmers spend weeks and weeks programming and testing the system. It's a big part of the installation cost.”

“This really is a decentralised system which allows a better use of space; it's reduced the volume and weight of the total installation by 35 per cent when compared to a similar requirement AC installation. It's robust, and manages small variations within the power supply.”

Both Lloyd's Register and Cayman Islands flag state were key in advising on ensuring *Rainbow's* system is ready for future upgrades without compromising safety or operating issues.

### SEA TRIALS

After our visit, *Rainbow* proceeded with sea trials. “We've been fine-tuning the battery system, adjusting how it changes from supplying power to drawing power (discharging and charging),” Zijlmans said. “The most interesting thing was watching the peak loads on board during gybe manoeuvres. All of the hydraulics are powered through two huge 35kW electric motors. We've had to make adjustments on the winches – there will never be enough hydraulic power





when all the race crew are pushing all buttons at the same time!”

Martijn Favot, chief technology officer for WhisperPower, commented that the hydraulics worked smoothly on the Hy-Store Li ion battery pack. “The genverter power sources, 50kW integrated with the main engine and the stand-alone variable speed 50kW genverter, are delivering the promised power silently and in a redundant way,” he said. “Power sharing between these power sources and the Hy-Gen battery via the high DC bus is functioning amazingly well.” During sea trials, Luc Toepoel of WhisperPower stayed on board to oversee the system and worked with *Rainbow*’s engineer, Terence Pretorius, who’s learned quickly: the system turns out to be very simple to handle.

“There are still some small cooling issues we have to solve,” Zijlmans pointed out. “These are basically driven by Class requirements on redundancy and easy maintenance as all equipment is built in very tight within the available space.”

Captain Nick Haley, who previously skippered two Holland Jachtbouw yachts, *Windrose of Amsterdam* and *Athos*, is keen on the instant access to power that they should have for sailing hydraulics, winches, etc. “Modern sailing yachts with hydraulically powered deck winches and thrusters have always created a challenge when it comes to matching power availability with the expected loads,” Haley said. “For 95 per cent of a race, two

generators and a main engine (if it has a power take-off) will be working on a very low load.”

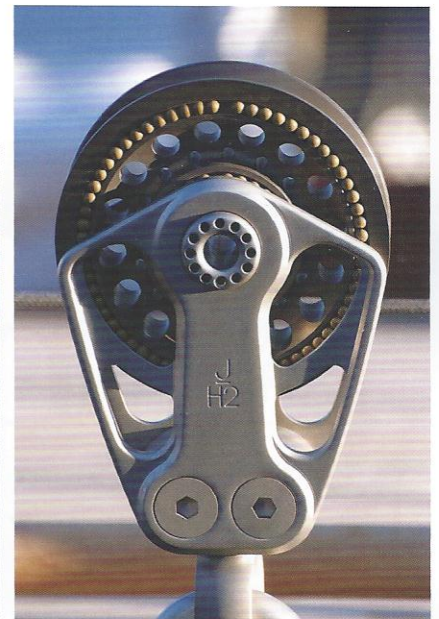
On *Rainbow*, the crew should be able to match power availability to demand much more efficiently. “The Hy-Gen can be run to charge the batteries while powering essentials,” Haley pointed out. “During high winch usage, when the electrical load peaks above what the generator can supply, the batteries switch instantaneously to discharge mode and fill the gap in the power demand. The initial trials have been promising and we hope to prove the system during the course of this summer.”

## CONCLUSION

If *Rainbow* makes her scheduled appointment in the Solent races this summer (*Hanuman* sadly pulled out of the races in late April), she’ll be up against *Endeavour*, *Velsheda*, *Ranger* and *Lionheart*. She will be the only J able to race silently – something her owner and crew alike will surely enjoy. It’s taken almost 80 years to bring *Rainbow* back, and aficionados and bystanders alike will appreciate the effort. Such is the beauty of the Js, but it is what powers her insides that has truly complemented her traditional lines – innovation, ingenuity and hard-won results. ■

**Images:** Don Hoyt Gorman, Marloes van der Haag & Holland Jachtbouw

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LEFT: *RAINBOW* BACK FROM HER SECOND DAY OF SEA TRIALS.  
ABOVE: A DECK BLOCK ON *RAINBOW* WITH A CERAMIC SHEAVE & STAINLESS-STEEL CHEEKS AND SHACKLE BEAT BLASTED TO ACHIEVE A TITANIUM LOOK.

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*If Rainbow makes her scheduled appointment in the Solent races this summer, she’ll be up against Endeavour, Velsheda, Ranger and Lionheart. She will be the only J able to race silently...*

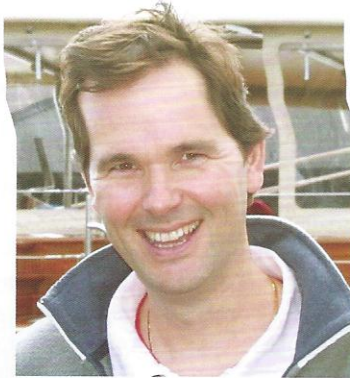
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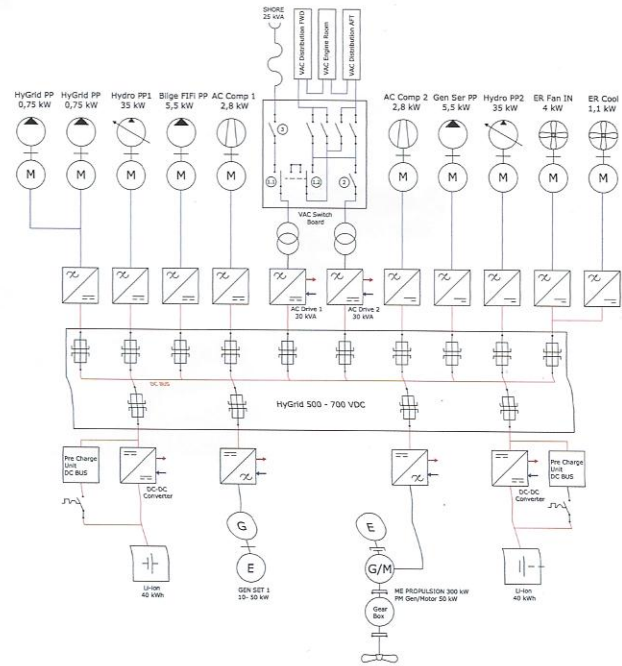
## HOLLAND JACHTBOUW

We are the first shipyard in the world to invent a hybrid propulsion system for one of our yachts. This replaces the conventional main engine and two generators configuration found on other Js, which have a larger engine room than the comparatively lighter *Rainbow* (170 tonnes). The main engine replaces the second generator, while the remaining generator is a variable-speed electric unit. The main engine generator can also act as an electric motor that can also run the propeller. This system is smaller in size and saves on fuel.

The batteries can also be charged while sailing without losing more than 1.5 knots of speed. Other key overall benefits of this propulsion solution include a dramatic reduction of the ecological footprint, a 30 per cent reduction in the fuel required to generate the hotel load, and a similar reduction in the maintenance costs for the power plant in hotel load. Redundancy is built

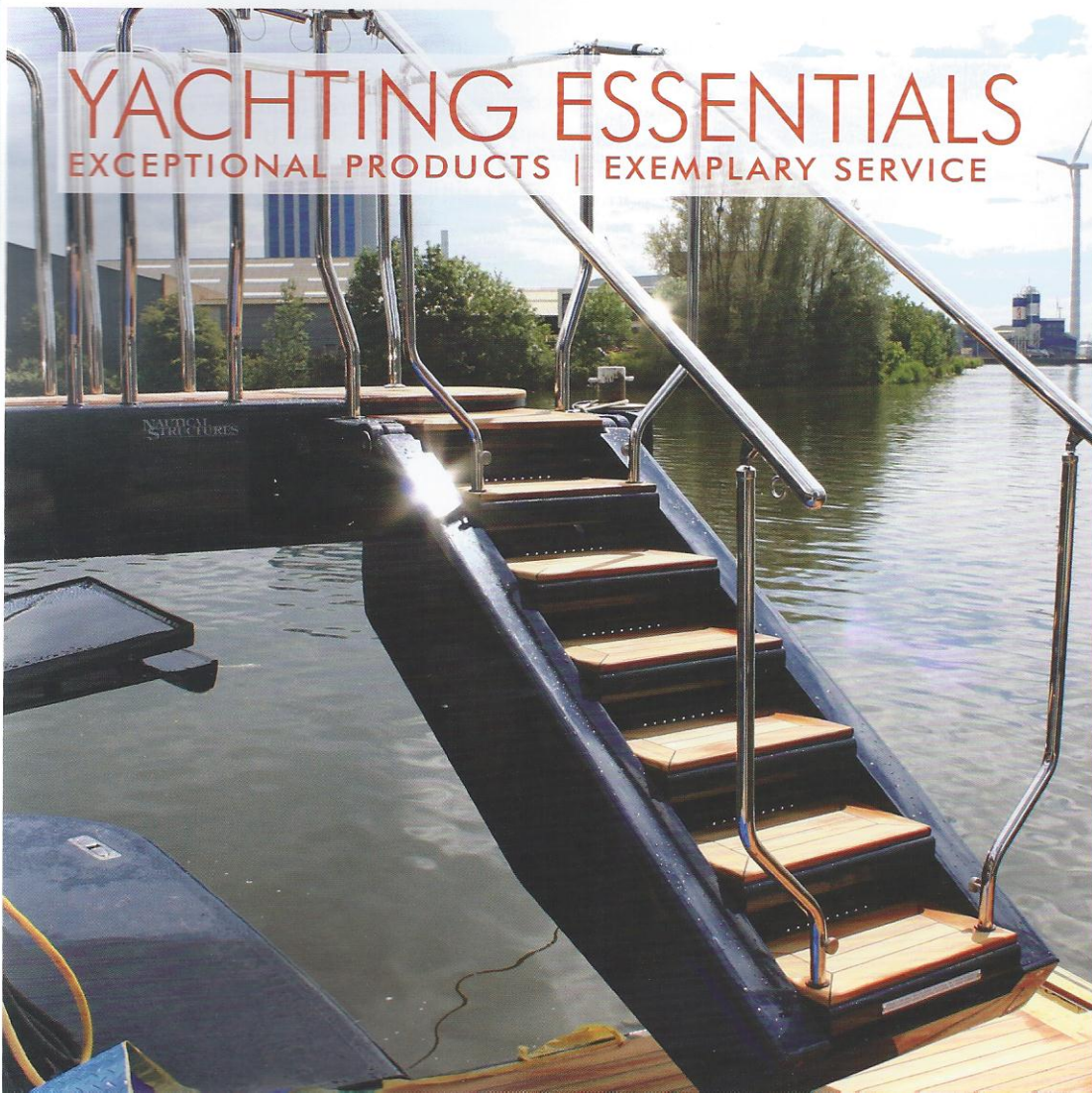


ARIËN ZIJLMANS, TECHNICAL DIRECTOR, WHO INVENTED THE HYBRID PROPULSION TECHNOLOGY USED ON *RAINBOW*. SEE OUR IN-DEPTH REPORT ON PAGE 91.



in with five power sources available: the hybrid battery, the variable speed generator, the variable-speed engine generator, the shaft generator (when sailing) and shore power (when available). There is also substantial reduction in audible noise levels both inside the yacht and out. ■

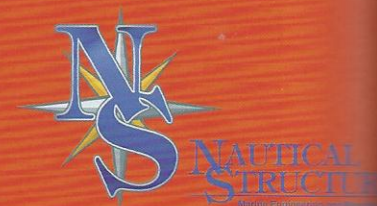
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