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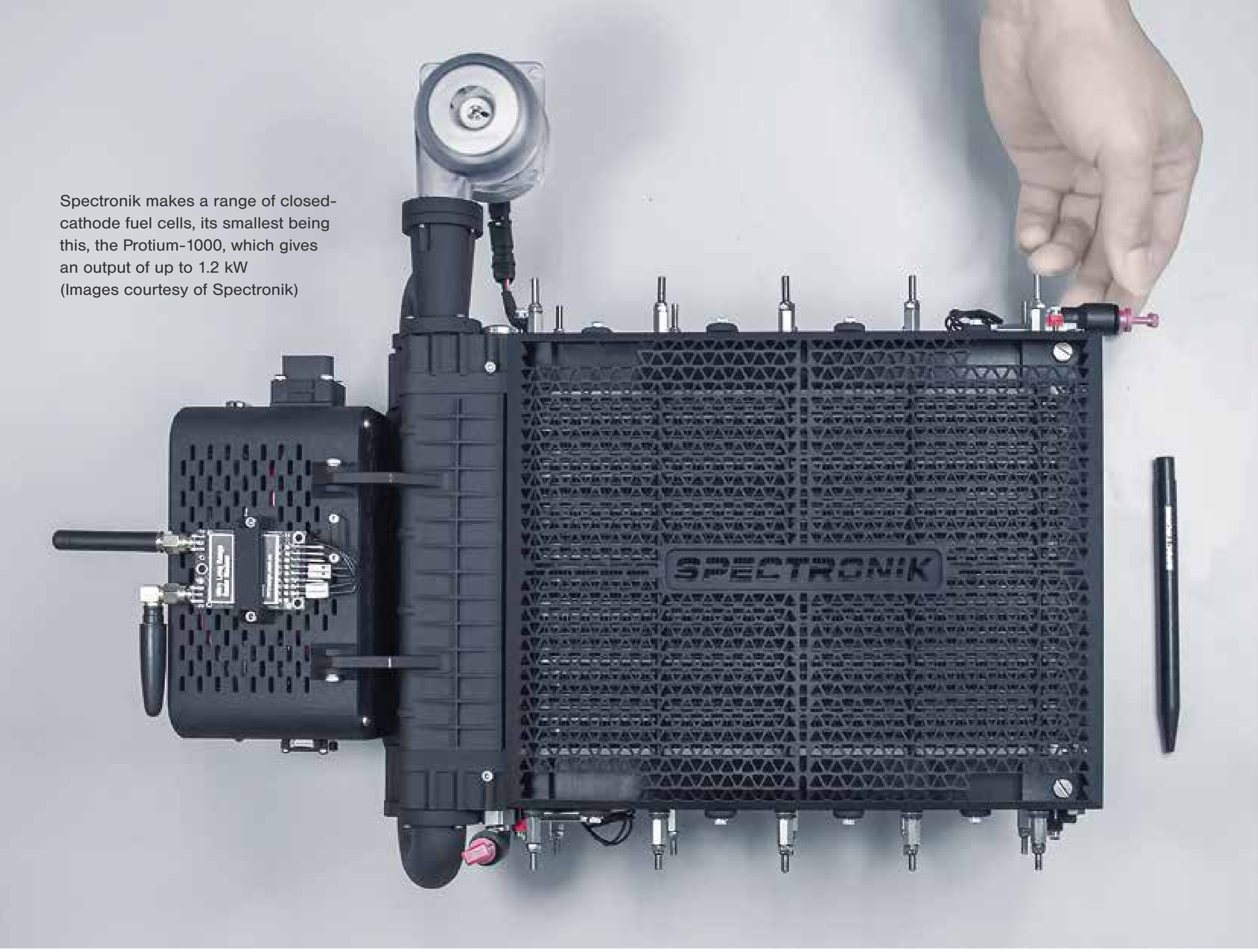

Spectronik makes a range of closed-cathode fuel cells, its smallest being this, the Protium-1000, which gives an output of up to 1.2 kW (Images courtesy of Spectronik)

Closed circuit

Rory Jackson investigates this range of closed-cathode fuel cells, which offer better performance than open-cathode systems

Hydrogen is rapidly being adopted across unmanned systems as an energy carrier and power source, and new designs and technologies for hydrogen fuel cells are accordingly being commercialised for UAV manufacturers and operators in civil, industrial and defence markets.

One of the most widely discussed of these is the closed-cathode proton exchange membrane (PEM) fuel cell. Unlike open-cathode PEM fuel cells, which use the same airstream for reaction and cooling, closed-cathode systems are designed with separate cooling and oxidant channels. As thermal management and oxidant supply are two different systems with very different efficiency considerations, running them separately by way of a closed-cathode architecture can greatly enhance the performance and safety of PEM cells.

While some closed-cathode fuel cells have been made principally for space and UUV applications (such as Teledyne's EDR fuel cell, featured in *UST* 35, December 2020/January 2021), Singapore-based Spectronik has developed its cell architecture for high-end UAVs and new automotive systems.

Although the company also offers open-cathode cells (see sidebar on page 63) it has devoted several years of r&d to optimising its Protium series of closed-cathode cells for greater operational safety, stability of performance, longevity and other critical parameters compared with conventional open-cathode types.

It currently offers four closed-cathode products. The smallest is the

Protium-1000, which measures 322 x 290 x 154 mm, weighs 3.03 kg, incorporates 30 cells in total for current generation, and can output up to 1.2 kW, or a continuous 1000 W (hence its name), consuming hydrogen gas at a rate of 12.5 litres/minute (1.12 g/minute).

The three larger variants are also named for their continuous rated power outputs. The Protium-1500 weighs 4.22 kg and can produce up to 1.8 kW, the Protium-2000 peaks at 2.4 kW and weighs 5.27 kg, and the Protium-2500 can output up to 3 kW from a system weight of 5.84 kg (with 75 cells in the largest system's stack).

All four systems are air-cooled, producing a rated current output of 55.5 A over an operating temperature range of -10 to +45 C, with a rated operating altitude of 1.5 km above ground level, although they have been tested successfully at higher altitudes. Also, they all have a mean lifetime of 1000 hours – after that, power outputs can start to drop below their rated levels, but the cells can be refurbished by changing the membrane electrode assemblies (MEAs).

The cells consist of the MEAs with polymer electrolyte membranes sandwiched by catalyst and gas diffusion layers, and extra layers for sealing and cooling. Each cell stack comes with an external airbox-like manifold, axial cooling fans, radial intake blowers and an electronics module containing control systems, power converters and a radio modem for live performance monitoring at the vehicle operator's GCS.

PEM fuel cells

Proton exchange membrane or polymer electrolyte membrane (PEM) fuel cells generate electrical energy via an electrochemical reaction of hydrogen and oxygen taking place inside the membrane electrode assembly (MEA) at the core of each cell structure.

The MEA consists of a PEM layer sandwiched between an anode and a cathode that serve to diffuse the reactant gases (and each also embeds a catalyst layer, typically platinum).

Hydrogen flows into the PEM's anode, while oxygen flows into the cathode, each gas typically being distributed via a flow field installed into the two plates that enclose each cell.

The catalyst layer splits the hydrogen gas molecules at the anode into protons and electrons. While protons pass through the central, semi-permeable membrane, reacting with the oxygen molecules to form water and leave the cell via the exhaust, the electrons flow along a circuit as an electric current.

A number of ancillary sensors and other systems ensure there is the right balance of heat, humidity and reactants inside the stack of cells, with additional control systems managing the power output and hence the rate at which reactants are consumed. Collectively these systems are referred to as the balance of plant.

Airflow management

Since open-cathode cells use the same airstream for cooling and the reaction of oxygen and hydrogen to produce electric current, that implies a simpler and less expensive architecture than if separate airstreams are used. Most often, that is manifested by their developers forgoing an extra plate that would otherwise normally be installed to seal the cathode's air supply.

However, this reliance on a single stream of air for thermal management and oxidant supply produces a number of inefficiencies relative to having two dedicated and separate streams.

The Protium cells are designed to avoid these inefficiencies – and indeed improve considerably over existing cell architectures – by having a dedicated radial blower installed at the corner of each cell stack. This draws in and compresses air for delivery to the cells' cathodes through channels running the length of the powerplant, while axial fans pull coolant air through channels that run along its width.

Separating the oxidant and cooling channels enables the fuel cell to function safely (with a stable and controlled internal level of humidity) across a wider ambient temperature range. For example, if the stack's internal and surrounding environments are cold, running the cooling fans is unnecessary. At such times, only the oxidant blower needs to work, and the system can save on parasitic losses from the cooling fans.

"In an open-cathode cell, the fans would still need to run to provide reactant airflow, further cooling an already cold fuel cell," Spectronik's CEO Jogjaman Jap explains. "As a result, the performance would drop because optimum cell temperature couldn't be reached. That excess cooling also risks flooding the cells, which would lead to fuel starvation, cell degradation and damage to the cell materials."

Also, in a hot environment, having separate oxidant and cooling channels means the cooling fans can turn at a high speed while the oxidant blower can spin at a far lower speed and power to maintain stoichiometry for the electrochemical reaction. That allows an appropriate level of humidity in the cell to be maintained so that the stack can continue outputting the required power.

In an open-cathode cell, running the fans at maximum to intensify air-cooling in hot environments would also remove much of the internal water content, severely risking dehydration of the polymer electrode membrane and

The company's latest UAV customer is the Phoenix hexacopter from Thunder Tiger Robotix

hence causing considerable drops in performance.

"Our internal testing has found that open-cathode cell power derates by 98% more than equivalent closed-cathode systems in 55 C environments," Jap explains. "The closed-cathode architecture can therefore function safely in mission conditions that are not possible with open-cathode cells.

"Our closed-cathode cells are rated to operate smoothly from -10 C to +45 C, and have been successfully tested to run from -15 C to +57 C. By comparison, most conventional open-cathode cells rarely operate well outside the 0-35 C range, and can suffer performance losses near the upper and lower ends of their temperature range."

Jap notes that having an additional blower in open-cathode architectures can sometimes mean a slightly higher balance-of-plant load (and therefore slightly higher power consumption), such as when running at around half maximum continuous power at room temperatures. However, net energy savings can be achieved when operating in environments below 5 C, and for UAVs carrying out deliveries or surveys over inhabited areas, the major gains in power stability and therefore safety are of far greater benefit than marginal changes in fuel consumption.

> Our internal testing has found that open-cathode cell power derates by 98% more than equivalent closed-cathode systems in 55 C conditions

"Also, the number of fans and blowers depends on the stack model," he adds. "For example, the Protium-1000 has two fans and one blower, while the Protium-2000 has four fans and two blowers."

The specific power output of the closed-cathode stack is further improved by using a different filtering configuration than on open-cathode designs.

When a single airstream is used for both cooling and supplying cathode oxidant, the entire face of the cell stack must be filtered to protect the cathode channels against contamination from dust and other particles. In the case of the Protium-1000, this is a surface measuring around 228 x 142 mm.

By contrast, filtering the oxidant intake blower needs only a circular filter of about 32 cm in diameter – 1/40th the area of the cooling face on Spectronik's Protium-1000, and a greater difference still on the larger systems, thus saving on weight and material costs.

"Moreover, if you have to draw


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Extensive research and testing of both open- and closed-cathode fuel cells and ancillary systems has informed Spectronik's engineers on a variety of engineering choices


The fuel cells' blowers and cathode manifolds are carefully designed to optimise airflow and efficiency across the stack

cooling air through a filter to protect the cathodes, the filter interferes with the air pressure, so about 10-15% more fan power is required for the same amount of cooling," Jap adds. "So our filtering approach helps avoid fan-related losses, particularly in warmer weather."

Cathode airbox

For distributing oxygen into cathodes and hydrogen into anodes, some fuel cell designs have used bipolar plates designed with corner 'windows', which when stacked on top of each of other create longitudinal tunnel-like internal manifolds for air and hydrogen gas to flow through.

Spectronik uses an alternative, patent-pending configuration for its cell and stack, which retains the hydrogen windows and manifold (respectively), but forgoes the oxygen windows for an external, airbox-like manifold.

This manifold is bolted onto the side of the stack. Made from ABS plastic, internally it features a number of channels and valves for dynamically directing and proportioning airflow during operations, with the oxidant blower mounted on top to feed air into it. Meanwhile, the cathode separator plates are designed with an open side facing the external manifold's output region to receive air directly into their flow fields.

"We've come up with this approach for a couple of key reasons," Jap says. "If you use an internal manifold consisting of fixed windows, there must be a limit to how many cells you can modularly stack – at a certain point, the window will be too small volumetrically to deliver enough air at the stoichiometric pressure needed for the load.

"That means the cells at the farther end of the stack will produce less power than those nearer the air inlet. If a stack isn't using all its cells equally, it isn't optimising its efficiency."

The external manifold uses one large window to deliver air to all the cells at once, meaning there is no drop-off in power at the cell extremities, even in the 2.5 kW Protium-2500 or any larger ones customers may request.

Spectronik's COO Maung Maung Zarli adds, "The reason we don't use this same airbox-type system for the hydrogen feed is that hydrogen gas is generally always stored at much higher pressure than air. Even with a blower you get only maybe 0.2 bar of air compared with upwards of 300 bar for hydrogen, so it isn't easy for large PEM cells to get the right air pressure all the way through the stack. We don't want our end-users to have to use a larger air compressor, as that would add more volume, weight and cost than our external manifold."

Another key advantage of the external manifold comes from its internal structure and valves, which on top of the manifold outlet's uniform spread of air can enable controlled, non-uniform distribution of it.

For instance, as performance levels can vary between different cells in a stack or different regions of cells, a fuel cell controller (FCC) can detect which cells are producing less power, and widen or close valves in the manifold. This will increase the delivery of air to the underperforming cells to ramp up their electricity generation, and optimise the performance and efficiency across the stack.

Company history

Spectronik was founded in 2011 by CEO Jogjaman Jap and COO Maung Maung Zarli, who had already been working on commercial fuel cell technology for a few years.

"While there's a lot of discussion these days about the green benefits of hydrogen mobility, the reason we started Spectronik was because we saw a specific niche for hydrogen power in aerospace, particularly in UAVs," Jap says. "Our first customer was Boeing, who saw great maturity in many UAV components such as carbon fibre, propellers, cameras and flight control software, but the problem was achieving longer endurances in small packages."

Boeing's UAV engineers had been trialling small gasoline engines at the time, which they judged as problematic in terms of reliability, MTBFs, vibration, heat signatures and emissions. Switching to all-electric powertrains would remove many of these issues, but lithium batteries had proven too heavy and not worth the minimal amount of flight time they gave.

In 2014 therefore, Boeing invited Spectronik to develop hydrogen fuel cells for its Type 2 (up to 25 kg MTOW) fixed-wing UAV test platform, so over the following two years Spectronik produced an open-cathode, air-cooled fuel cell to Boeing's specifications in form factor and temperature.

Towards the completion of the research project, in 2016, Boeing gave Spectronik's 250 W cell its highest ratings on size, weight, performance, energy storage, firmware stability and quality of workmanship. Around the same time, Jap and Zarli felt that considerable improvements in performance, precision and reliability could be achieved by developing a closed-cathode architecture, so they formulated and produced one over the following two years.

By 2018, Spectronik had supplied both open- and closed-cathode cells to a number of UAV manufacturers (both fixed-wing and multi-rotor) in defence and commercial markets across Southeast Asia and Australia.

Most recently this has included a UAV from Thunder Tiger Robotix called the H2-X6 Phoenix. This is a carbon fibre hexacopter that can fly for up to 90 minutes while carrying a 2 kg payload (or 120 minutes with no payload), as well as a 9 litre tank for hydrogen stored at 40 MPa working pressure. That powers a Protium-2000 cell, equipped with a 5000 mAh 9S lithium-polymer hybrid battery for high transients.

Overall, the H2-X6 Phoenix has a 21 kg MTOW and is designed principally for infrastructure inspections and similar commercial applications, with its hydrogen powertrain enabling a 30 km flight range as well as a wi-fi comms range of 2 km (over 2.4 GHz) and a 20 km, 433 MHz link.

"Projects such as these have given us valuable experience in the precision engineering of fuel cells and how to integrate them on different shapes and sizes of UAS, in terms of packaging, centre of gravity, power distribution and comms," Jap adds.

Cell materials and structure

As a result of the humidity stability in the Protium cells, each cell generates around 0.8-1 A/cm^2, compared with 0.6-0.7 A/cm^2 for equivalent open-cathode systems, according to Spectronik's tests. This higher current density effectively translates into a higher power-to-cost ratio, as the MEA is often the most expensive part of the fuel cell system.

"The membrane is an expanded polytetrafluoroethylene-reinforced ionomer, and is about 15 microns thick," Jap adds, noting that the company cannot disclose the type and amount of catalyst material used for the electrochemical reaction.

The structural layers making up each cell in the Protium stack contain a few innovations. First, the anode separator plate is made from a 0.29 mm flexible graphite foil, which features no flow field for directing the hydrogen; instead, the flow field is stamped directly onto the anode gas diffusion layer (GDL).

Spectronik has opted for a graphite foil and anode GDL flow-field configuration, as it is lighter than CNC-machined graphite plate and therefore more suitable for aerospace applications. It is also sufficiently corrosion-resistant compared with metallic plates.

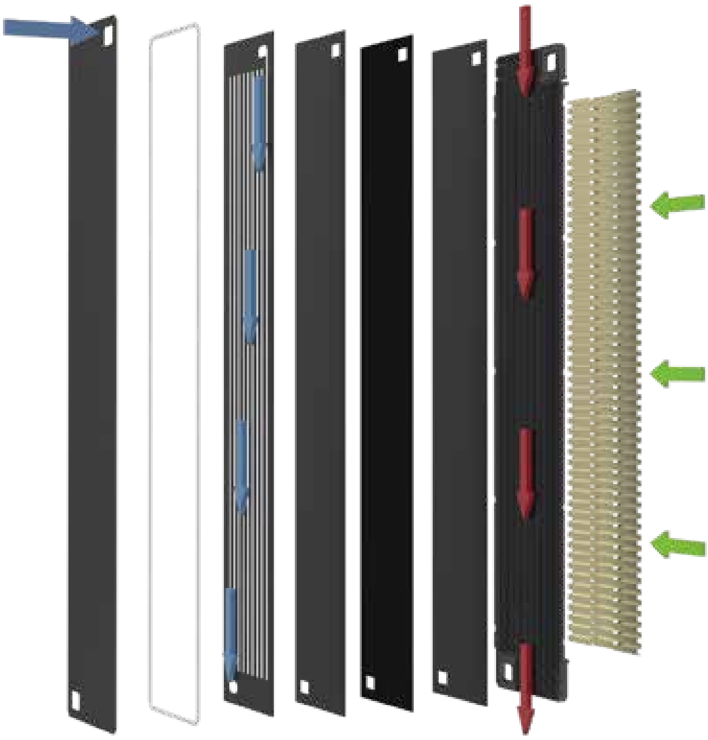
"Graphite is very stable chemically, so unlike some metal plates it doesn't need electroplating or any other coatings," Jap adds. "It's also very cost-effective, which helps us to be flexible with our design, as r&d might find better flow-field arrangements for using hydrogen in different integrations and environments.

"Also, CNC-machining the hydrogen flow field onto a graphite plate takes more than 100 times longer than stamping it. Stamping is less costly than CNC as well, and we can switch to automated stamping if we get a bulk order.

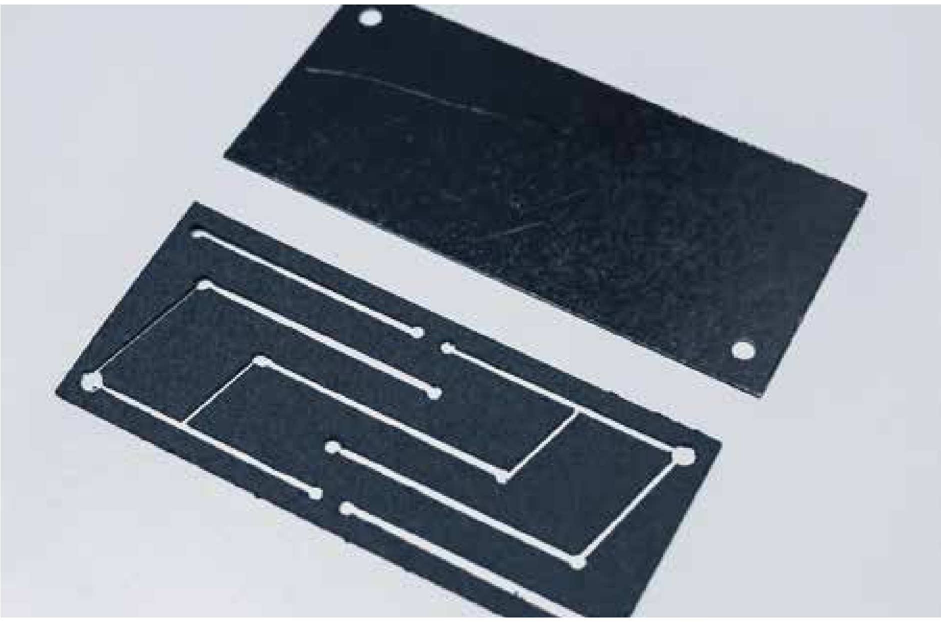
"Additionally, while stamped metal could actually be a lighter and thinner alternative, its chemical stability would be worse than graphite's."

The GDLs themselves are provided by SGL Carbon Sigracet, although the exact products are undisclosed.

The cathode separator plate meanwhile is currently made from CNC-machined graphite plate, to accommodate the necessary height of the oxidant channels' cross-sectional areas (they are much higher than those of the anodes). For volume production, Spectronik plans



A breakdown of the layers in each closed-cathode cell, with hydrogen flow indicated in blue, oxidant in red and cooling airflow in green



The anode separator plate (upper) is 0.29 mm thick and made of graphite foil, while the anode flow field is stamped directly into the gas diffusion layer (lower)

to switch to compression moulding, to save time and costs.

On the opposite side of each cell assembly from the anode separator plate is a cooling fin made from corrugated 0.05 mm stainless steel. They incorporate an offset fin design, which compared with standard straight fins helps induce greater turbulence in the incoming airflow (meaning an increase in the overall cooling effect), as well as providing higher structural strength to avoid deformations from the cells having to be tightly sealed and pressurised. They are then coated in gold for corrosion resistance and conductivity.

"The offset design and ultra-conductive gold plating together achieve very good in-plane electrical conductivity," Zarli adds. "There's less need for through-plane electrical conductivity, as the current will flow along the gold plating."

Jap notes, "Like the anode GDL design, the cooling fin design is quite mature. We're confident that we've fully optimised it, which is why we've invested in die-sets for stamping them. In a typical open-cathode cell stack, electroplatings such as gold with a nickel underlay can corrode and poison the cell, leading to premature drops in performance and stack failure.

"However, as the metallic cooling fin is never in direct contact with the cathode in this fuel cell – only the graphite separator plates – such a situation is avoided. Also, no by-product water is ever in contact with the cooling fin, further reducing the possibility of corrosion. As a result, overall stack lifetime is increased."

Lastly, each cell is sealed using a self-curing adhesive gasket, which is installed using an automated dispensing mechanism.

In a typical open-cathode cell stack, electroplating with gold with a nickel underlay can poison and corrode the cell, leading to stack failure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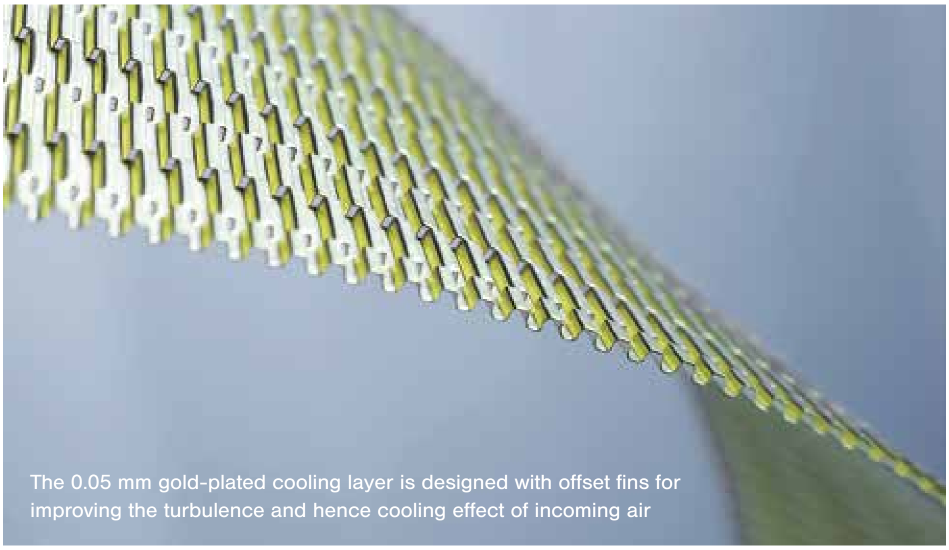
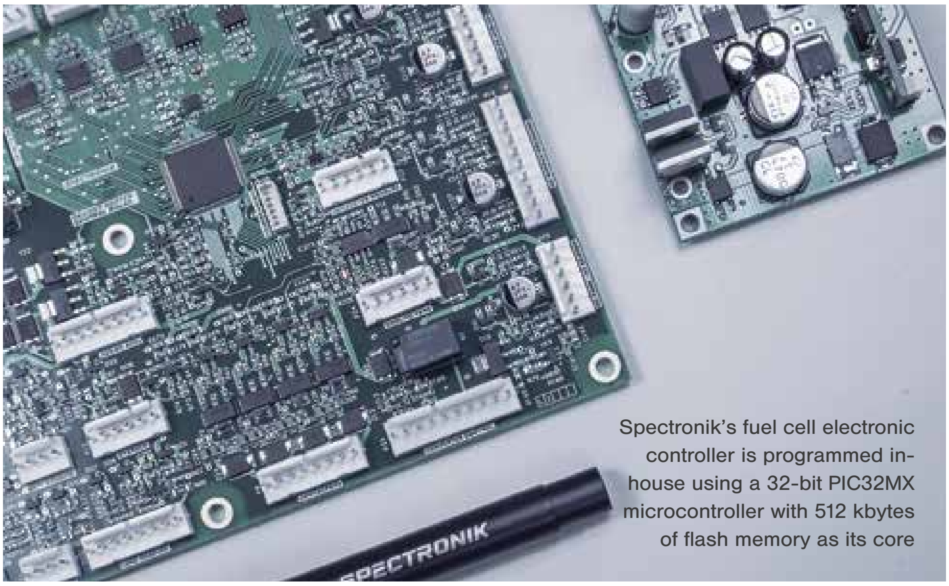


The 0.05 mm gold-plated cooling layer is designed with offset fins for improving the turbulence and hence cooling effect of incoming air



Spectronik's fuel cell electronic controller is programmed in-house using a 32-bit PIC32MX microcontroller with 512 kbytes of flash memory as its core

System operation

Such is the difficulty of achieving stable humidity and hence a stable linear power output with open-cathode cells that it is common for them to incorporate current pulsing for their continuous operation.

Current pulsing is a form of intermittent short-circuiting of the stack using MOSFETs in the FCC, to drop the stack's voltage sharply, spike its current and so forcibly rehydrate the cells and boost power output back to its rated levels.

For safe current pulsing, the power source and load must be intermittently disconnected. To avoid sudden drops in propulsion during these brief moments, a hybrid battery or supercapacitor large enough to maintain constant power delivery to the vehicle's motors must be integrated. It could be argued that coupling large batteries – the heaviest energy storage solution – with hydrogen gas tanks, the lightest form of energy storage, is inherently counter-intuitive for aerospace applications.

As a consequence of having far more stable humidity over their operating time, the Protium cells can use far smaller batteries or supercapacitors relative to open-cathode cells, reducing overall powertrain mass and bringing the weight benefits of hydrogen gas energy storage to the fore.

"Current pulsing can also have detrimental effects on the lifetime of a stack; by not relying on it, we help UAV manufacturers keep their replacement costs low," Jap adds. "Theoretically, end-users could run our fuel cells on their UAVs with no hybrid battery as a secondary power supply at all, although our FCC is programmed with some key functions relating to how batteries are used that make it potentially useful to install at least a small one on board."

As a final point here, Spectronik has tested its closed-cathode architecture at -15 C, as per customer requests, and developed a cold-start capability for operating the system and powering UAVs at such low temperatures without the need for any external heaters or power sources.

"It's a proprietary technique at the moment, based on the use of hydrogen gas and some internal control systems for creating heat inside the fuel cell to achieve the necessary thermal conditions for the electrochemical reaction," Jap notes.

Control and safety electronics

Along with the other electronics, the FCC is housed in an enclosure next to the airbox, where it monitors key health and performance parameters including the stack's internal temperature, pressure, voltage, current and gas tank pressure (to calculate the fuel level).

It also controls the balance of plant, including the blower, cooling fans, manifold internal valves, the hydrogen valves on top of the stack's upper end plate and the purge solenoid valve.

The system used is a PIC32MX microcontroller from Microchip Technologies. It is a 32-bit controller with a 120 MHz DSP-enhanced core, 512 kbytes of flash memory, 128 kbytes of SRAM, a fail-safe clock monitor and advanced memory protection, which supports multiple comms and control interfaces including six UARTs, two I2Cs, and USB 2.0 and CAN 2.0B ports.

"We've also programmed a few smart features into this controller," Jap says. "For example, the purge valve is controlled intelligently via our energy accumulator function.

"Smaller fuel cells typically use a dead-ended, non-circulating fuel stream that produces stagnant fuel zones in the anode reaction area. By-product water can also cross over to the anode channels, impeding the reactions. Purging allows that water to be flushed out of the anode streams and restores the rich hydrogen concentration in the anode.

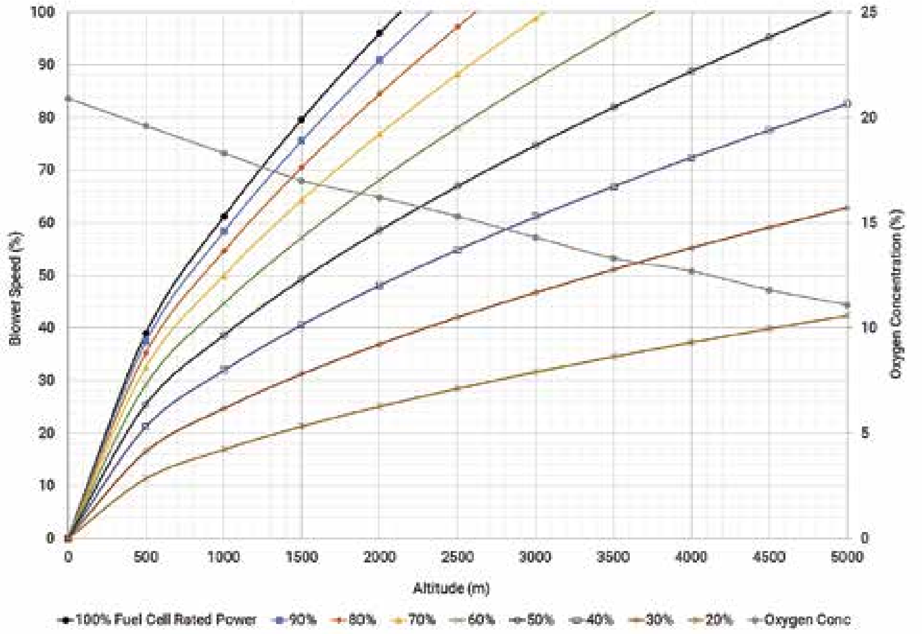
"Our FCC monitors and calculates the accumulated energy output between each purge, and accelerates or decelerates purging when a certain threshold for energy output in kWh has been reached."

This function enables more frequent purging during heavy loads to maintain an optimal fuel cell power output, as well as reduced rates of purging during low loads to prevent unnecessary hydrogen fuel losses, as some hydrogen molecules will inevitably be lost along with the by-product water if the valve is opened more often than needed.

"Some fuel cells will still keep purging at a fixed rate – say every 20 seconds – even when they're on standby; a lot of fuel can be wasted that way," Jap observes. "Or some users will run them at the top of their rated output for a long time, then start to lose power and accrue damage, and they don't realise it's because the purging system isn't being operated intelligently. Our smart accumulator constantly checks for the optimal purge frequency, and controls the valve accordingly."

The FCC is also programmed with an early leak detection function. This works by monitoring the pressure at the stack's inlets and outlets, calculating the differential between them, and tracking when it deviates from expected values. During such deviations it can immediately alert the user that stack sealing might have been compromised.

Other cell designs can take longer to detect leaks, for example by using hydrogen sensors outside the stack to detect gases only when build-ups have already happened. Or, in some instances, the cell supplier merely recommends that the end-user integrates such sensors for leak detection inside their vehicle hull themselves, which some users inevitably ignore.



A map of the blower's output curves at different altitudes, oxygen densities and power outputs

> We've noticed that more and more users want to engage in heavy transient loading such as hard braking. That kills the lifetime of cells

By contrast, Spectronik's use of software and integrated pressure sensors can detect leaks and notify the end-user as quickly as within a second of them occurring, enabling a UAV's safe and early landing or a return to base, theoretically preventing emergency landings in cities or over water.

An altitude sensor is also integrated so that the FCC can continuously determine and track changes in air density, as that directly affects the fuel cell's oxidant supply and hence performance.

"We've pre-programmed and embedded a blower curve algorithm into the FCC, so that at higher altitudes (and lower air densities) than the standard 1500 m, it can compensate by running the blower faster to force more air into the stack," Jap says.

"Also, as our customers will always deliver us a typical load profile of the vehicle they want to run using our cells, we've noticed that more and more of them want to engage in heavy transient loading – hard accelerations and braking, for example. That kills the lifetime of fuel cells; specifically, the heavy shifts in output voltage will damage the catalyst layer and material.

"So we've introduced a power regulator board with modular DC-DC converters and an additional dedicated controller to regulate the fuel cell output during transients, by progressively ramping current up or down in a stepwise manner. That prevents the cell voltage from toggling up or down too aggressively.

"A small hybrid battery or even a supercapacitor is more than enough for providing those instantaneous jumps in power while the cell stack's power output catches up or for absorbing the excess power during deceleration. We've had good results with Maxwell supercapacitors, which we can supply as standard with our closed-cathode products."

Jap further notes that end-users could also benefit from this arrangement by using the hybrid supercapacitor or battery for energy regeneration (from wheels or rotors during braking).

"In many UAV fuel cell arrangements, the hybrid battery needs to be large and heavy enough to store sufficient energy for sustained, stable propulsion as well as provide power to the control systems amid periodic current pulsing, and also because it often provides the power boost needed for take-off while the fuel cell is initialising.

"As we don't use current pulsing, our cell's electrical supply is self-sustaining, so the cell itself never needs to take any power from the hybrid battery – users can therefore right-size this aspect for their application. For instance, a supercapacitor could instead be used for handling the higher transient loads much better than a battery, and without losing lifespan or having any of the other safety issues that lithium batteries can come with."

To ensure that such alerts and performance telemetry are available to the end-user independently of (or redundantly alongside) their own UAV's data links, the standard Protium cell also comes with an integrated radio modem.

The model used is an RFD 868x Modem BARE from RFDesign, which has a 10 km range and a data link bandwidth of 500 kbit/s (up to a maximum of 750 kbit/s if the user increases the output power above standard limits). It transmits over the 868-869 MHz band with a typical output of 1 W (+30 dBm) and AED hardware-accelerated encryption for users' data security, along with electroshock-discharge protection and filtering on all I/Os.

Specifications

Protium Aerospace fuel cells
PEM fuel cells
Hydrogen gas, dry, 99.999% purity
Closed cathode
Air-cooled
TBO: 1000 hours

Protium-1000
Dimensions: 322 x 290 x 154 mm
Weight: 3.03 kg
Operating voltage: 18-27 V DC
Operating current: 55.5 A
Maximum current: 66.6 A
Operating power output: 1 kW
Maximum power output: 1.2 kW

Protium-1500
Dimensions: 434 x 290 x 154 mm
Weight: 4.22 kg
Operating voltage: 27-41 V DC
Operating current: 55.5 A
Maximum current: 66.6 A
Operating power output: 1.5 kW
Maximum power output: 1.8 kW

Protium-2000
Dimensions: 492 x 290 x 154 mm
Weight: 5.27 kg
Operating voltage: 36-54 V DC
Operating current: 55.5 A
Maximum current: 66.6 A
Operating power output: 2 kW
Maximum power output: 2.4 kW

Protium-2500
Dimensions: 548 x 290 x 154 mm
Weight: 5.84 kg
Operating voltage: 45-68 V DC
Operating current: 55.5 A
Maximum current: 66.6 A
Operating power output: 2.5 kW
Maximum power output: 3 kW

Some key suppliers

Membrane electrode assemblies: Gore
Gas diffusion layer: SGL Carbon Sigracet
Electro-valves: The Lee Company
Oxidant blower: Micronel
Cooling fan: Delta Electronics
Gas ports: Swagelok
Metal cooling fin: Robinson Fin Machines
Cell voltage monitoring module: Infineon
DC-DC converter: Synqor
Supercapacitors: Maxwell
Fuel cell controller: Microchip Technologies
Radio modem: RFDesign
UAV development partner: Thunder Tiger Robotix

"That means users can accurately track and record voltage, power, temperature, remaining fuel and so on to carry out smart analytics on these at their control station if they wish," Jap adds.

Conclusion

The company has been supplying open-cathode cells to the industry for a few years now, and plans to continue offering them as well as its closed-cathode types for long-endurance electric UAVs, in applications including offshore asset inspections, persistent urban survey and search & rescue operations.

These plans include integrating its cells into a new version of the Phoenix UAV from Thunder Tiger Robotix, which will be capable of 180 minutes of flight with a 2 kg payload, and which is anticipated for release next year.

Continued r&d into ways of further enhancing the manufacturability of its systems is also anticipated, to ensure mass production can be achieved as commercial and civil UAV operations become part of daily life in cities worldwide.