THE DELTA D2
– AUSTRALIA'S DIESEL HELICOPTER

In an industry increasingly challenged to deal with fuel and climatic concerns, three enterprising Australians are taking a radically innovative approach. **Dennis Raubenheimer** investigates.

"WHAT THE....!"

Those would have been the words uttered by many people at the Australian International Airshow at Avalon in March, on first setting eyes on the Delta D2 helicopter. With an intriguing mixture of streamlined good looks (the front end) and distinctly van-like appearance (the rear) to anyone interested in helicopters the Delta was the biggest surprise at Avalon. New helicopters do not appear every day, and to find one in one's own national backyard, designed from the ground up by Australians, is all the more unusual. I'd have to confess to a degree of scepticism as I approached for a closer look. "Surely this can't be an all-new development?" I thought. "A modified Schweizer 300, maybe?" No, and no, I soon established. But, while tempted to think that it may be one of those hair-raising creations built and flown by someone with a scary amount of faith in their backyard mechanical skills, a closer view revealed a level of engineering that was anything but amateurish.

But if a good look-over was not evidence enough that it was a machine to be taken seriously, a little more information would have done the trick. Not only are the Delta's carbon-composite blades fabricated by the engineer responsible for the blades fitted to several Eurocopter models, but the transmission and other major components have been designed by Bill Whitney, one of Australia's most accomplished aeronautical engineers. And further investigation revealed yet another surprise: the Delta is the world's first diesel-engined helicopter.

The Delta is the brainchild of Graeme Smith, a Queensland entrepreneur known for importing and distributing the range of Rotorway kit-built helicopters. The Delta concept originated at a time when Smith's marketing of the Rotorway in Australia, New Zealand and south-east

Asia brought him into contact with people who were interested in using the machine in rural situations. One of those clients was Andrew Reid, a farmer and ex F-111 pilot who was working the Robinson R22 on vast tracts of land in northern Queensland. Reid purchased a Rotorway in the hope that it may be a more cost-effective aircraft for his farming applications. When along with its other limitations the machine proved to be underpowered, Reid and Smith discussed the possibility of replacing the Rotorway's engine with a larger unit.

"It was the most obvious issue [with the Rotorway] that we could fix," says Smith. "We went about finding another engine that we could put in and that I could offer to other customers who'd bought a Rotorway."

At that stage, due to the introduction of general sales tax and a decline in the Australian dollar, the cost of importing Rotorway kits had risen so dramatically that sales of new aircraft had almost totally dried up. Recognising that the largest market still open for helicopters in Australia was in mustering, Smith saw an opportunity to offer supplementary kits that would enable the Rotorway to be used for that purpose.

Browsing the internet in search of alternative power options for the Rotorway, Smith came across a diesel engine that was rapidly gaining attention in the fixed-wing sector overseas. A remarkably simple design, the Delta Hawk two-stroke was being offered as an alternative to the Lycoming and Continental 320 series motors in aircraft such as the Cessna 172. Smith and Reid immediately saw the benefits that a diesel would offer farmers in outlying areas.

"People out there understand diesel. They've got plenty of it. They've got huge tanks of it, and they know how to handle it," says Smith. On a subsequent business trip to the US, Reid held discussions with Delta Hawk and bought one of their engines.

Though he is a fitter and turner by trade and describes himself as "pretty good" with his hands, to convert a Rotorway to the diesel engine Smith decided that they would need the services of a qualified aeronautical engineer. A natural choice was Bill Whitney, who with 14 full aircraft designs under his belt and, fresh from having developed and certified the Boomerang trainer, also had extensive experience in certification. In addition, Whitney had worked on autogiros and had employed planetary reduction gearboxes in his design of the Vickers Vimy replica aircraft – mechanical experience that was directly relevant to helicopters.

"People out there understand diesel. They've got plenty of it. They've got huge tanks of it, and they know how to handle it." – Graeme Smith on diesel fuel in the outback.

above: **The standard of engineering in the Delta needs to be seen to be appreciated.**
right: **A helicopter with seriously useful cargo space for farmers.**

"We approached him and asked if he'd work with us and ultimately be part of the company," says Smith. "And he said, yep he'd do that – he would design the mounting of the Delta Hawk into a Rotorway frame, as well as the gearbox and all the other ancillary bits and pieces, so that we could test the engine."

The conversion of a Rotorway to diesel was completed and ground tested, but the team ultimately concluded that the Delta Hawk would not be a viable power plant for a do-it-yourself upgrade kit.

"It took all of my engineering know-how to be able to do it," says Smith. "A lot of tooling and welding and a bunch of things that I have access to – but most people don't. So the idea of selling it to somebody else as a kit was pretty much stymied from a physical point of view."

But one other aspect of the engine that made it unsuitable for the Rotorway had come as something of a surprise: the unexpectedly high power output of the diesel engine.

"We couldn't guarantee that the Rotorway drive system – or the rotor head and blades – could take it," explains Smith. "It was well and truly above the [original] engine that they had in the aircraft. We decided it wouldn't be a safe or prudent thing to do. But we were so impressed with the engine we said to Bill, 'Let's build an aircraft around the engine...'."

Funded by Andrew Reid, with Smith and Whitney contributing time on an unpaid basis, the project began with a complete reappraisal of the objectives. By then fully cognisant of the engine's capabilities, the team set about exploring the potential for a diesel helicopter to satisfy the needs of the farming and mustering market. Six years on, having been developed with the intention of initially offering it as a kit-built aircraft, the prototype approaches its first fully functional ground and hovering tests.

Looking it over, for an aircraft that has yet to undergo its first test flight, the machine appears to have progressed surprisingly far. Where one may expect an experimental helicopter to be stripped down and uncomplicated before proving its basic flight capabilities, this is not the case with this machine. Detail goes all the way down to cup holders and the most minor conveniences. And yet, it's these sorts of details that were part of the conceptual starting point for the Delta – and with weight being the primary consideration, as it is with all helicopters, it seems sensible to have worked them in from the start.

"One of the things that I wanted was to present an aircraft that was pilot friendly," says Smith. "When I was learning to fly, I got introduced to the [daily] and preflight walk-around and found that with the Robbie there are a number of places where you had to undo covers and look into things. I wondered if I couldn't make that easier. I've got inspection openings, and in places along the boom there are clear transparencies. I thought if I can make it easier for the pilot to do, he or she is more than likely going to do it. That's my simple theory."

For Smith and Whitney, that goal and philosophy must have resulted in some Eureka moments. No need to dip fuel tanks – with attendant hazards like getting dirt into the fuel – when the level can be seen within each of the machine's two semi-transparent plastic tanks through viewing slots on each side of the aircraft. And don't get fussed about where to put your water bottle on those long hot flights through the outback; there are bottle holders conveniently placed between the seats – just where you'd expect to find them.

"Where do you put your sunglasses after you jump out of the aircraft? Where do you put your phone?," poses Smith. "These are things that everybody carries nowadays, but where do you put them? They're only small, but they're the sorts of things [we thought about]."

To a farmer mending fences in the outback, perhaps the most outstanding feature of the Delta D2 will be its 1250 by 300 by 600-millimetre full-width cargo box, located almost directly under the rotor mast for minimal effect on the centre of gravity. But while utility and conveniences were seen as providing a marketing advantage in the team's target area of mustering and farming, they needed a serious engineering platform on which to base it all. It was in this area that Bill Whitney's involvement strongly influenced the project:

"Bill is adamant that even though the aircraft is initially going to be offered as an amateur build experimental aircraft, he wants to design it to [a commercial standard]. As he already has a number of certified aircraft under his belt he's very familiar with those standards. He's stressed

"You can put one end on a bit of wood and the other end on another bit of wood and stand on the middle and you can't get them to deflect. That's how strong they are. And they're as light as..." – Graeme Smith on the technology in the Delta's tail rotor blades.

the whole thing [accordingly] and the paperwork is very serious."

Whitney confirms this standpoint, speaking freely of the challenge of designing a helicopter by comparison to a fixed-wing aircraft. It's clear that the design choices that were made early in the program were not made from the point of view of making his life easy. While he has previously been involved in aspects of helicopter design and has worked on an autogiro project, the Delta is the first full helicopter design in which he has been involved.

"It's very new for me and I'm on a pretty steep learning curve," he says, before giving the reasoning behind the fundamental design and explaining that a more complicated three-bladed system was chosen for safety reasons.

"We didn't want to do a two-bladed teetering system," says Whitney. "With teetering systems you have this zero-G loss of control problem [with potential for] mast bumping or the blades swinging down to cut the back off the aircraft. Having an articulated system you can go down into negative G. Not that you would do that deliberately, but it gives you an extra margin for safety."

Transparent panels make life easier during the daily inspection.

But while a three-bladed, fully articulated rotor system may offer better safety in flight – it presents significant challenges to the designer. One of these is the propensity for ground resonance – a condition that can occur when blade spacing becomes asymmetric, causing oscillating forces to be thrown back and forth between the rotor system and the undercarriage. If unchecked, the condition can escalate rapidly to the point of self-destruction. The team awaits the first ground run with some understandable trepidation.

"We're just coming up to our first ground run now, so we've very much got our fingers crossed concerning that," says Whitney. He then provides an insight into how the issue of ground resonance is managed in the design.

"When you look at the equations for ground resonance, you've got to have damping in two locations. You've got to have damping in the rotor head and you've got to have damping in the undercarriage. And you've got to get the natural frequency of the aircraft on its undercarriage as low as you possibly can."

It's around the rotor system and blades that the Delta most clearly shows professionalism. Having made a choice fairly early on that fully composite, carbon blades were the way to go, the team first tried to find a local company that was able to produce them.

"We did a lot of research to try and find a way to build the blades in Australia, but there was just nobody in Australia that knows anything about them," says Smith. "No one has done it. There are plenty of people who think they can do it, but when you start pressing them they just don't know. So I made some contact with some people overseas that were advertising composite blades."

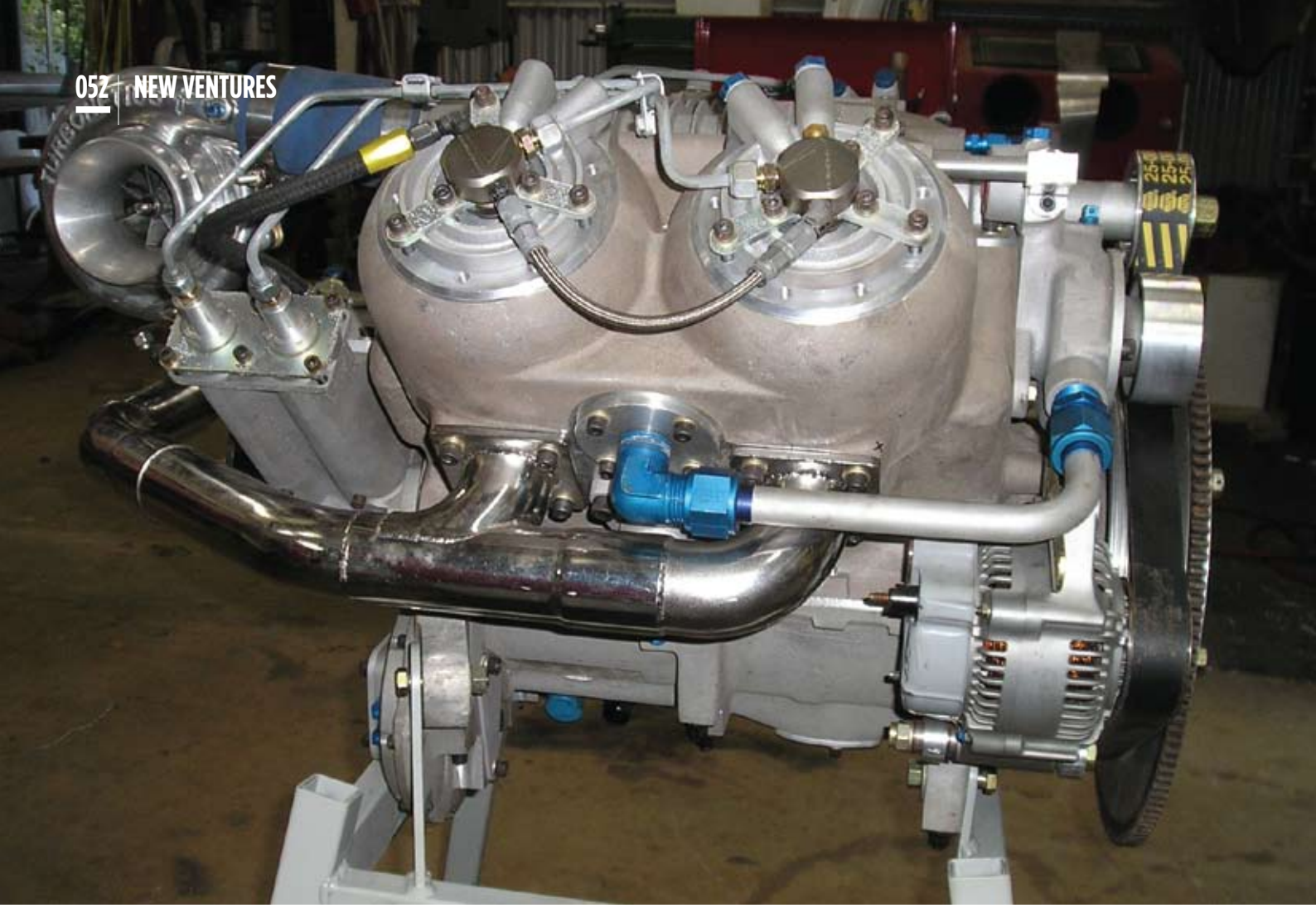
The search for a blade manufacturer ended in Paris where the team located a design engineer who had previously worked for Eurocopter. Having just come out of a post-retirement competitive restriction period the engineer was keen to become involved. By then, Bill Whitney's son Eric had also become involved in the project and had calculated the parameters for the blades, including their basic shape and performance data.

"We were able to give that information to the guy over in Paris and he tweaked it with his experience to maximise the performance," says Smith.

The move to have the blades made in France was one of considerable faith, and definitely did not come cheaply. In order for the development of tooling to be viable for the manufacturer, the team needed to order and prepay for 24 sets of blades.

"We had to pay for a lot of blades that we are still yet to receive, to allow him to fund the building of the mould," says Smith.

It may be a kit-built aircraft, but the Delta's blades use cutting edge technology. Designed for an unlimited



above: **The Delta Hawk diesel engine lies at the heart of the D2 project.**

life (or replacement depending on condition) the blades are internally lead-weighted and employ a variable chord with progressive twist – features normally found only in far more expensive or military helicopters.

"We expect to see a far more efficient blade than the common helicopter," says Smith. "Though that technology is not new it's not usually used in [this class of] helicopter."

The Delta's tail rotor blades take a similarly high-technology approach and will also be provided by the French manufacturer.

"They are all carbon fibre," says Smith. "You can put one end on a bit of wood and the other end on another bit of wood and stand on the middle and you can't get them to deflect. That's how strong they are. And they're as light as. There is incredible skill in knowing how to build them."

Working our way from the rotor system down to the engine, there are more surprises. Unlike the R22, R44 and Schweizer 300, which each use a horizontally mounted engine connected via a multi-v-belt/clutch arrangement, the Delta uses a vertically mounted engine driving a planetary gearbox through a centrifugal clutch. This gives its transmission more in common with a Bell 47 than most popular light helicopters in its class. While heavier and more complex, in the Delta Whitney has aimed for better economy through mechanical efficiency.

"The power loss through a planetary system with straight cut teeth is very small, probably less than one percent," says Whitney. "Whereas if you use, say, spiral bevel gears or something like that you're probably going to lose 2.5 to three percent of your power. That can be as much as six horsepower going to heating oil in the gearbox."

In making these choices of weight versus efficiency, the team has placed considerable faith in the power output of the four-cylinder, two-stroke, water-cooled, turbocharged diesel engine. At the heart of this unique aircraft, the engine is central to the value they foresee in the project.

"Using a two-stroke allowed them to build a [monoblock] engine where there are no separate barrels; they're all part of the one block," explains Smith. "There's no separate head and the two-stroke allowed them to get the power at a weight that is comparable to what's out there now. It's not cheaper to buy the engine, but over 2000 hours you'll save the cost of your engine in fuel and maintenance. No spark plugs to change, no magnetos to overhaul. No high tension leads, no valves and no head gaskets. There are very few parts that you need to look at from a maintenance point of view."

Putting out a new aircraft while proving an unusually large number of unique features would appear to be risky from a financial point of view, but Smith is unrepentant.

"If we are going to be successful in this we had to be better than what's out there currently, otherwise why would people change?," he asks. "Price is one thing, but there have got to be other things. We went about in our design to address all of the issues that the R22 has, and be better. We've got a cargo box; we're running on diesel, which is available anywhere. We don't have any belts in the system, we're going to be faster, we're going to be cheaper to buy and cheaper to maintain. And we're going to use less fuel."

Whitney supports this view and outlines the way he sees the development progressing to the next stage.

This is very much a developmental prototype," he says. "We're going to learn a lot of lessons and we will undoubtedly make changes in our production aircraft. The first aircraft is a bit on the heavy side. They always

"We're just coming up to our first ground run now, so we've very much got our fingers crossed concerning that."
– Bill Whitney on the challenge of designing to avoid ground resonance

are. We're looking at making the undercarriage arches out of composites and changing the base structure, and we'll probably make the main planet carrier for the transmission out of titanium rather than steel. We'd like to lose about 60 kilograms if we can. That could be a fairly big ask, but that's what we'd like to do."

As this article goes to press the Delta team will be putting the D2 through the first phases of flight-testing. Who the test pilot will be they are not saying at this stage, but do confirm that the person who will first fly the Delta will be a trained test pilot with a military background. The flight test regime will follow a textbook method for helicopters.

"We'll progressively go through the flight test procedures establishing as we go what's normal and then start to push the envelope once we're comfortable with the recovery techniques in the various situations," says Smith.

"It's not a risk free project by any means," says Whitney. "[But our funding partner] wants to experiment and see how it goes. In life you never know until you try, do you?" **HN.**