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IS THERE A DELTAHAWK ENGINE IN YOUR FUTURE?

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What would your reaction be if someone told you there could be a light aircraft engine that will never have a magneto or ignition system that fails or needs repair; an intake or exhaust valve that's stuck, broken or burned; a spark plug that's fouled or worn out; or a cylinder that needs replacement? What if there were an engine that would continue to produce 75% of its normal power with a failed fuel pump? What if such an engine had a single mechanical (non-digital) power control with no need for a pilot to control fuel/air mixture? How about an engine that runs on a non-leaded fuel already available at a reasonable price at airports throughout the world, and burns about 40 percent less fuel than the engines we're using now? What if such an engine already exists, has been extensively flight-tested, has been certified by the FAA and will be in production around mid-2024? Would you be interested?

Why We Need It

Much has been written in this magazine and other media about the future of propulsion for light aircraft and the need for new engine designs. We've covered many issues related to the Lycoming and Continental piston powerplants, mostly developed more than 70 years ago, that are currently installed in the vast majority of small planes. I recently wrote about the costs of owning an aircraft (Going All In, August 2023) and concluded that the biggest recurring costs come with operating and maintaining these engines. Even the simplest of them requires manual control of fuel/air mixture to achieve a level of efficiency that is still less than desirable; the more complex ones require careful control of power, mixture and cooling to avoid over-boosting, overheating, shock cooling, detonation and other expensive outcomes. Let's not leave out Rotax engines; according to the article cited below, they have a higher failure rate than Lycoming or Continental.

Complicating matters further, most high-compression engines require leaded fuel with its attendant concerns about internal fouling and environmental damage. Widespread availability of any unleaded 100-octane avgas replacement is still years away, and in many areas of the world leaded avgas is very expensive or unavailable.

To be fair, light aircraft engines face a variety of very difficult requirements: high power-to-weight ratio, limited size, ability to operate well across extreme ranges of altitude and temperature, the ability to produce thrust through propellers with limited RPMs, and reliability in the hands of mistake-prone pilots. In meeting these demands, some other things have been sacrificed. In short, most of the engines we've been using since the 1950s are producers of lead pollution, inefficient, complicated, high-maintenance, costly to support, not easy to operate correctly, somewhat unreliable even when operated correctly, and unsuitable for use in some areas of the world. These issues have been evident for decades. A recent on-line poll of pilots found that about 25 percent of respondents had experienced at least one engine failure in flight. In a review of accident statistics published by AvWeb, among engine failures that caused accidents, 17% were structural failures and 16% due to maintenance errors.[1] (The rest were due to fuel mismanagement, icing, or unknown causes.)

The DeltaHawk Story

There is a new design developed by DeltaHawk Engines, Inc. that could be a solution to many of these problems. This company's story is one of single-minded dedication, perseverance and survival while others fell by the wayside. The company was founded in Racine, Wisconsin in 1996 by Doug and Diane Doers and John (JP) Brooks with a vision of developing a clean-sheet light-aircraft engine. Within two years, they had a prototype engine installed on a static Velocity RG airframe. Dennis Webb, now the firm's Director of Marketing and Certification, joined in 2005. The State of Wisconsin provided some funding for manufacturing facilities and the company acquired its present facility at Batten International Airport (KRAC) in 2011. By 2014, they had a working engine prototype installed in a Cirrus SR20 and flew it to Oshkosh for AirVenture, but the road to certification was to be long and expensive.

A major cash infusion was needed to push the project forward and in 2015 it came from Al Ruud and his son Chris, a pair of lighting industry entrepreneurs who had played important roles in the worldwide transition to LED lighting. Chris became CEO of DeltaHawk and they brought in three other leaders from Ruud Lighting: John Heup as President, Wayne Guillien as Director of Operations, and Lisa Booker as Director of Human Resources. Another key slot was filled with Aaron Foege as Lead Engineer in 2017, and the present leadership team was then in place for the push to final design and certification. It took six more years of intensive testing and upgrades to technical processes, but finally on April 7, 2023, the FAA bestowed a Part 33 Airworthiness Type Certificate on the DeltaHawk DHK180 engine. More than $100 million has been spent getting to this point; the company grew from 3 to 60 employees by 2019 and is now ramping up quickly for production. The entire company has the mindset of market disrupters, as reflected in the company's tagline *Power Reimagined®*.

The DHK180

DeltaHawk was founded on the goal of producing an engine with the following attributes:

- simple
- easy to operate
- fuel-efficient
- easy to maintain, with low maintenance requirements
- great altitude performance
- improved safety and reliability
- suitable for light aircraft worldwide.

From an engineer's perspective, some of those attributes are in direct conflict. As Dennis Webb recently explained, "simple is really hard." The tendency among engineers is to solve problems by adding complexity. DeltaHawk went the opposite direction and produced an engine with approximately 40% fewer moving parts than a typical aircraft engine.

The DHK180 is a 180-horsepower V-4 compression-ignition (Diesel-cycle) two-stroke engine, direct-drive, supercharged and turbocharged, fuel-injected, piston-ported, and liquid-cooled. For the non-gearheads like me, let's delve into what these terms mean.

Compression ignition means it has no spark plugs or electric ignition system. The fuel-air mixture in the cylinders is ignited by the compression of the piston at the top of its stroke. There is a glow plug in each cylinder for cold-weather starting. Once the engine is started, it needs no electricity to continue running. The compression ratio is 20:1. (Most Lycomings are between 7.2:1 and 8.7:1.) In order to withstand that much pressure, the cylinders are inside the block rather than bolted on externally. The block is cast of an aluminum alloy with replaceable steel sleeves in the cylinders.

In a four-stroke gasoline engine, each piston must rise and fall twice for each power stroke: once for compression and ignition and again for exhaust and intake. This means each cylinder only fires once every two revolutions of the crankshaft. At 2500 RPM, a four-stroke four-cylinder engine has 5,000 power strokes per minute. A two-stroke engine like the DHK180 at 2500 RPM has 10,000 power strokes per minute. Every fall of each piston is a power stroke. Compression and ignition occur as the piston rises and begins to descend; exhaust and intake occur as the piston descends and begins to rise again. This translates to tremendous torque at low-to-medium RPM and much better fuel efficiency; no energy is wasted on the exhaust/intake stroke. Because the power pulses are double in frequency, a two-stroke also runs much more smoothly than a four-stroke at the same RPM.

The DHK180 produces 180 horsepower with a much smaller size than a four-stroke; its displacement is only 202 cubic inches, compared to the 360 of most 180-HP gas engines. The bore and stroke are 4 x 4 inches; the Lycoming IO-360's bore and stroke are 5.125 x 4.375, and putting the cylinders inside a V-4 block allows for a much more compact form factor than a flat-4 with external cylinders. This leaves a lot of room inside the cowling for accessories including a turbocharger, heat exchanger, coolant expansion tank, and oil tank.

1 "Why Engines Quit: Failures Are Avoidable," by Paul Bertorelli, AvWeb.com, September 9, 2020 https://www.avweb.com/flight-safety/accidents-ntsb/why-engines-quit-failures-are-avoidable/

Direct drive simply means there is no gearbox between the engine and propeller. Some smaller engines, notably Rotax, require over 5,000 RPM to produce rated power, but propellers can't be operated with supersonic tip speeds, so a reduction gearbox is required to bring prop speeds down within their normal range. DeltaHawk avoided that by producing an engine that makes 180 HP at normal prop speeds.

Supercharged and turbocharged. Both increase the air pressure flowing into the cylinders. The difference is that the supercharger is driven mechanically by the engine, while the turbocharger is driven by exhaust gas. Consequently, the supercharger, which in this case is a twin-screw unit attached between the cylinder heads, is very effective at low RPMs, while the turbocharger comes into play more at the high end. Together, they enable a small two-stroke Diesel to produce big power across a full range of RPMs at altitudes up to at least 17,500 feet.

In a gasoline engine, either carbureted or fuel-injected, airflow determines power; you use a throttle to control the volume of air admitted, and no matter how much fuel you could feed it, you can't exceed the fuel/air ratio that supports combustion. The DeltaHawk, on the other hand, has no throttle; it constantly forces as much air as possible into the cylinders, and fuel flow determines power.

Fuel is controlled and injected by four independent pumps, one for each cylinder, driven by a camshaft connected to the back end of the driveshaft. Each fuel pump has a helical rod inside a chamber; the rods are all rotated by a single control to determine the amount of fuel injected. If any of the pumps fail, the rest continue to work, providing partial power while you seek a place to land. There is no mixture control, just a single power lever that controls fuel flow. The entire fuel pump assembly is attached outside the block, allowing for easy maintenance, inspection, and replacement if necessary.

The cylinders are piston-ported. The ports are at the lower end of piston travel. The exhaust ports are a bit taller than the intake ports, so as the piston descends they are uncovered first, allowing the exhaust gases to exit. Then the intake ports are exposed at the bottom of the stroke. The rush of incoming air has a swirling effect that forces out any remaining exhaust and then fills the chamber for the compression stroke. This is literally a stroke of genius, in my opinion; there isn't a single moving part in the whole intake/exhaust process, other than the piston itself. In case anyone missed that point, I'll repeat it: there are no intake or exhaust valves with their complicated and failure-prone camshafts, lifters, springs, rocker arms, and rotators.

Because the cylinders are inside the block and for other reasons, the engine is liquid-cooled. The coolant pump is external and belt-driven. There is a heat exchanger in the air intake and an expansion tank just like in your car. The system holds about 6 quarts of coolant. The engine is so efficient and well-cooled that cylinder head temperatures (CHT) rarely exceed 200°F and exhaust gas temperature (EGT) is around 1200°F at maximum and 800°F at cruise power. These comparatively low temperatures should contribute to extended engine life. Liquid cooling is also more efficient because it doesn't use airflow to cool the cylinders; in an air-cooled engine, about 25% of parasite drag comes from forcing air to flow around the cylinder fins.

A typical gasoline aircraft engine wastes a significant portion of its power producing heat that is simply dumped out the exhaust pipes. Some have a turbocharger that recovers much of that energy, but they still blow a lot of heat overboard. The DeltaHawk wastes very little energy producing heat. Incidentally, most installations will include a cabin heater that takes heat from the cooling system rather than from the exhaust, which means you can warm your toes as soon as you start the engine.

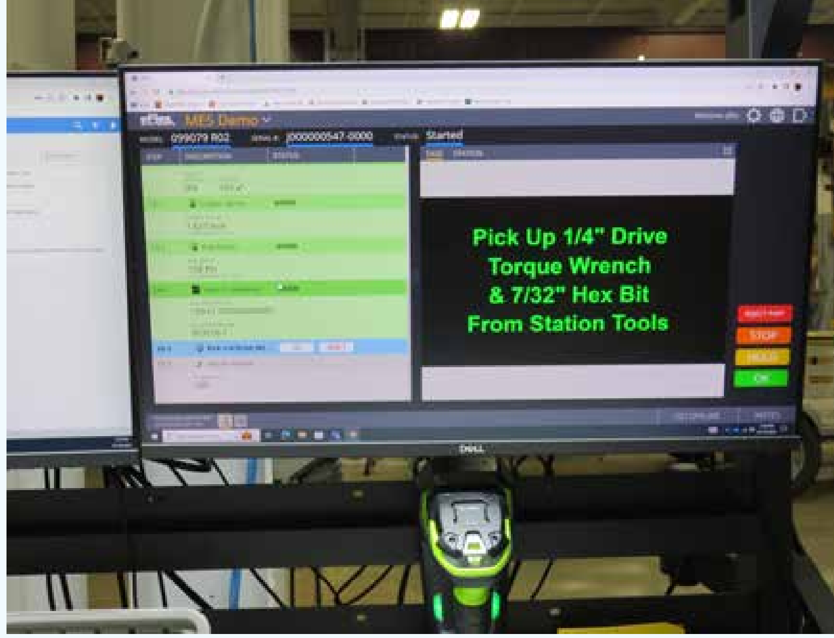
This engine is designed to burn jet fuels, primarily Jet A or JP8. It will also run on D1 and D2 road Diesel fuels, but they aren't certified for flight because they don't have the anti-icing additives of jet fuel. Jet A and its variants are much more readily available at airports worldwide than avgas, and the company sees great potential in the international market for that reason.

All of these attributes combined produced an engine that is about 40% more fuel-efficient than a typical Lycoming or Continental. Table 1 compares the DHK180 with the Lycoming IO-360-L2A currently installed in the C-172S and the Lycoming O-360-A1F6D that was originally used in the C-177B Cardinal. The DHK burns 7.3 gallons/hour at cruise power, compared to 9.67 for the 172 and 9.0 for the Cardinal. Operated for 3,000 hours at cruise power of 135 HP, this amounts to a savings of $52,199 compared to the -L2A and $39,114 less than -A1F6D for fuel alone at today's prices.

One drawback is that jet fuel weighs approximately 6.7 pounds/gallon compared to 6.02 for avgas at standard temperature and pressure. That is offset by the fuel efficiency of the engine. Jet fuel is also less widely available in the US than avgas. Of the 4,731 public-use airports in last year's FAA report, 2,282 airports sell Jet A while 3,123 sell 100LL. Jet fuel is generally a bit less expensive across the US; according to the AirNav.com Fuel Price Report as of October 15, 2023, there are 2,562 FBOs selling Jet A at a nationwide average price of $6.24, while 3,518 FBOs have 100LL at an average of $6.51.

The Plant

Dennis gave me a tour of the DeltaHawk facility in Racine and I was amazed by



Top Left: *The automated manufacturing process Jack Matthews is developing has sensed he has picked up Loctite 263, not the other Loctite on the table, hence the green status of that step.* **Right:** *Each step of an assembly process provides specific instructions and senses when the correct tools are picked up.* **Below:** *Automated part measurement validation system, accurate to .0000001 inch.*

its size, capabilities, and technological sophistication. They have a large traditional hangar where a team of A&P mechanics perform installation and testing on aircraft. They also have a test facility that is state-of-the-art, with separate test cells for fuel systems and cooling systems, a dynamometer cell, a fully-automated parts measurement system that is accurate to a one millionth of an inch, a QA center for validation of manufacturing quality, and two propeller dynamometers for full testing of engine-propeller combinations, all managed from a central control room where everything can be remote-controlled, measured and recorded. DeltaHawk does not manufacture any of the parts they will use in their engines. They have developed what Webb describes as “a phenomenal parts supply chain,” almost entirely within the US. They use their extremely high-tech QA system to assure that parts meet their exacting specifications.

Then there’s an 85,000-square-foot manufacturing building with enormous room for production. Jack Matthews gave me a demonstration of the manufacturing process control system he is developing to be used during assembly. At his workstation, a computer monitors and records every step of the process. The worker begins by scanning

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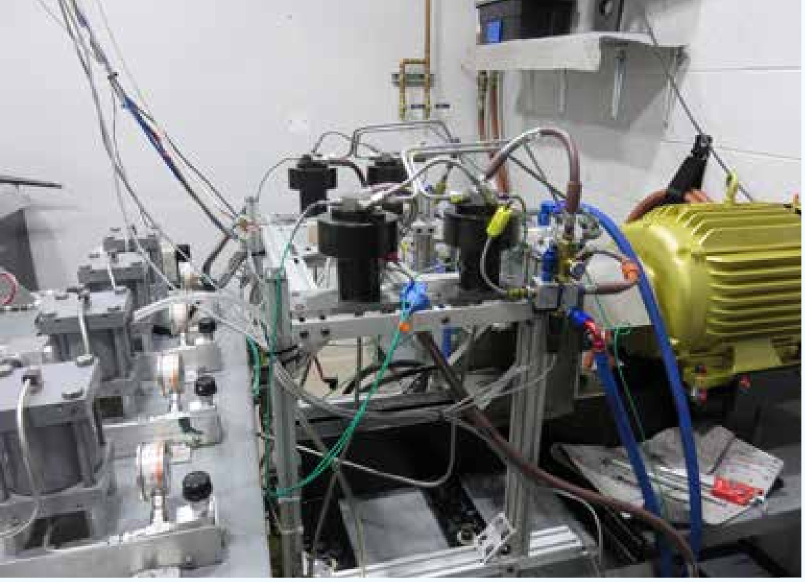
The DHK180 as installed "upside down" in a Cirrus SR20 for flight testing. The engine will run in any orientation and can be used in a pusher configuration without modification.







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***Previous page, clockwise from bottom left:** The DHK180 on a display stand, showing the red cylinder heads, green and blue coolant hoses, and turbocharger system. On the rear of the block are the four camshaft-driven fuel injector pumps, one for each cylinder. The purple-ringed duct at the top contains an air gate to provide a required secondary method of engine shutdown. **Above, 1:** A cutaway view showing the back of the supercharger on top of the block and the fuel pump assembly. **2:** Inside a cylinder with the piston at the bottom of its stroke you can see the tall exhaust ports and the short intake ports in their replaceable steel cylinder liner. **3:** From the side in this cutaway view, the camshaft that drives the fuel pumps is visible; it is spline-driven from the end of the crankshaft. **4:** The back of the DHK180 has two drive pads for accessories like a vacuum pump or prop governor. **This page, clockwise top left:** Cooling system test cell. **Right:** Fuel system test cell. **Below:** DeltaHawk has two tunnels for testing engine-propeller combinations.*

(L to R) *Chris Dzurick, Connor Naeve, Dan Meller and Araceli Beltran staff the DeltaHawk test facility.*

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an employee tag to record who made the assembly, then scanning the parts bins to confirm the correct parts are on hand. The computer refuses to allow the next step to begin until each step is completed correctly and turns green on the screen. One step, for example, was “pick up Loctite 263” and the workstation senses when that specific tube of Loctite is picked up. Every single part and material component is tagged for scanning or sensing. If a step calls for a torque wrench, there’s a specific digital torque wrench that’s preset for that step, and it won’t do anything until it gets scanned to confirm it’s set to the correct torque. Then the computer senses and records how many turns the wrench makes to confirm the bolt isn’t overtightened or cross-threaded. Jack said when FAA representatives saw this demonstration, they had never seen anything like it and were blown away, as I was too.

Dollars and Sense

In considering the economic feasibility of the DHK180, you also have to compare maintenance costs. As shown in Table 1, with a Lycoming engine you will probably spend between $6,000 and $8,000 for maintenance of magnetos and spark plugs alone in 3,000 hours of operation, plus labor for removal and installation. If you have to replace one or more cylinders before it's time for a major overhaul, the costs really start to mount up.

Speaking of overhauls, the FAA assigns time-between-overhaul recommendations, not the manufacturer, and they haven't done so yet for the DHK180. The engine is designed to last 3,000 hours, but the company doesn't have enough data to assign probability. Their ultimate goal is for owners to base overhaul decisions on condition rather than hours; the test conditions would be a cylinder leak-down pressure test and oil pressure. When an overhaul is needed, it should be far simpler and less expensive than for a comparable gas engine. There are basically only two points of wear in the engine itself: the piston rings and crankshaft bearings. The steel cylinder sleeves may also need to be replaced at some point. All of the engine accessories are external and easily serviced: fuel injector pumps, oil pump, coolant pump, and turbocharger are designed for easy access.

That leaves the cost of purchase and installation as the major economic unknowns. As shown in Table 1, DeltaHawk is shooting for a purchase price in the range of $100,000-110,000 for the DHK180. If that seems like a lot, consider that it includes a complete firewall-forward installation package: engine, mount, heat exchanger, pumps, filters, new cowling and air ducts, all necessary hardware, and usually a new propeller. It doesn't include installation. The engine also comes with a Sky-Tec 24V starter and Plane Power 70-amp alternator, with higher power options soon available.

In comparison, a new Lycoming IO-360-L2A is presently priced at $100,664 at AirPowerInc.com for the engine alone with no accessories, less a core exchange, and that's with a 14-month delivery schedule. That's for a non-turbocharged engine that decreases in power as altitude increases. If you exchange a serviceable core, it is worth $18,000-20,000 depending on the model. A new prop alone for the 172S is currently $7,841. An overhauled -L2A is $59,047 less a core exchange credit of $19,800.

The bottom line is that a new DHK180 may cost about the same as or less than a comparable new Lycoming, but we won't know until the final price is set. In a short-term analysis, it may not seem to make sense for owners of Cessnas to replace their existing powerplants with the DeltaHawk firewall-forward package when you can buy an overhauled engine and have it installed for about $45,000 including labor. Cash on hand is always a factor in these decisions.

On the other hand, consider this: if the DHK180 is good for 3,000 hours of operation before it needs an overhaul (which may be a lot cheaper than a Lycoming overhaul), you may save over $50,000 on fuel alone during that lifespan, plus about $6-8,000 on required maintenance, plus any additional maintenance on cylinders, valves, etc. You can probably sell your existing engine, prop, accessories, cowling, and other firewall-forward components for at least $20,000. Now we have a proposition that begins to make sense. If DeltaHawk numbers pan out, you get increased torque at cruise power settings, increased net thrust, reduced drag, increased reliability, simple operation, less maintenance, and

Comparison break down; DeltaHawk v. Lycoming Engines

	DeltaHawk DHK180	Lycoming IO-360-L2A (C-172R, C-172S)	Lycoming O-360-A1F6D (C-177B)
Rated power	180 HP @ 2600 RPM	180 @ 2700 RPM	180 @ 2700 RPM
Torque	363 ft-lbs	350 ft-lbs	350 ft-lbs
Displacement	202 cu in	361 cu in	361 cu in
Bore x Stroke	4 x 4 in	5.125 x 4.375	5.125 x 4.375
Dimensions (LxWxH, inches)	33 x 24 x 22	29.8 x 33.37 x 24.84	31.33 x 33.37 x 24.59
"Dry Weight DeltaHawk includes starter, alternator, turbo, exhaust. Lycoming includes starter, alternator, magnetos, spark plugs, ignition harness, intercylinder baffles."	357 lbs	278 lbs	295 lbs
Oil Capacity (Dry Sump)	~ 6 qt	8 qt	8 qt
Coolant Capacity	~ 6 qt	Air-cooled	Air-cooled
Fuel Types	Jet A & Jet A-1 Certification Fuels. Will burn JP8, D1, D2, F-24	100LL Avgas	100LL Avgas
Fuel Burn, full power, 180 HP	10.8 gph	14.0 gph	14.8 gph
Fuel Burn per hour, economy power, 135 HP	7.3 gph	9.67 gph	9.0 gph
Fuel Burn, 3000 hrs @135 HP, gallons	21900	29010	27000
US national average fuel prices per gallon (AirNav.com 10/8/23)	6.24	6.51	6.51
Fuel cost, 3000 hrs @ 135 HP	$136,656	$188,855	$175,770
Fuel cost difference, 3000 hours @ 135 HP		$52,199	$39,114
Magneto Maintenance and Repair, 6 times in 3000 hours	n/a	$6,000	$6,000
Spark plug replacement, 6 times in 3000 hours	n/a	$1,800	$1,800
Cost, new, not including installation: DeltaHawk is for complete STC package: engine and mount, heat exchanger, pumps, filters, cowling, all necessary hardware, and in most cases a propeller. Lycoming is for new engine only (without core exchange). No propeller, starter, alternator, or other accessories (AirPower, Inc., 10/8/23) (Typical core exchange credit is $18,000 - $20,000.)	Targeting $100K-110K	$100,664	$95,393

DeltaHawk's office and engine assembly facility at Racine International Airport.

less down-time. All of this remains to be seen until we know some actual numbers on Supplemental Type Certificates (STCs) for specific planes.

DeltaHawk is now working on development of STCs for application of their powerplants to aircraft models. These will be complete powerplant replacements with new engine controls, cowlings and air ducts, fuel tank inlets to accommodate jet fuel nozzles, and other changes. They currently have a Cessna 337 in their shop on which they are going to replace both engines with the DHK180 for testing. Webb promised me that we can expect STCs for the Cessna 172 and other Cessna models at some point. They are working with all of the OEM manufacturers with the goal of having DeltaHawk engines installed in new aircraft. They're also working with the major experimental kit manufacturers. They have already reached an agreement with Bearhawk Aircraft for its back-country kitplanes. According to Webb, the 4-cylinder DHK180 can be easily scaled up to six cylinders, which is in the works, and they continue to tweak the design to improve it before starting initial production.

One issue they will have to work out is the weight of the engine, when compared to non-turbocharged gas engines that produce 180 HP at sea level. The DHK180 weighs 357 pounds including starter, alternator, turbo, and exhaust. The Lycoming IO-360-L2A weighs 278 including starter, alternator, magnetos, spark plugs, ignition harness, and intercylinder baffles. On the other hand, the 200-HP turbocharged Lycoming TIO-360-A1A weighs 386 including the turbocharger, mounting bracket, exhaust manifold, controls, oil lines and baffles, so the DeltaHawk's weight compares favorably with it.

The Future

After learning many details about the engine, seeing their facility, seeing the engine run on the Velocity at their hangar, and reviewing the numbers, I'm convinced that DeltaHawk Engines has become a very serious player in the field of aircraft propulsion. They are dead serious about disrupting the current engine market, and they have the capabilities to do it. Only time will tell how this will play out, but I predict there will be many DeltaHawk engines flying at some point in the not-very-distant future.

Doug Tilghman is a retired software systems consultant who had a 1975 C-172 for thirty years until he bought a Van's RV-8 in 2020. He flies out of Lawrence, Kansas (LWC) and welcomes ideas for stories at xjayhawk72@gmail.com.