Under-Promising, Over-Delivering: The AeroTwin AT972T

By Tim Kern info@TimKern.com
Photos by Tim Kern, and AeroTwin Company, Inc.

Tim Kern's beginnings in amateur-built aviation started at an early age, helping his father build Luscombes and a wood glider. Since then he's been involved with building a Preceptor Pup, a Range Rider and a Baby Lakes. From a professional background in motorcycle and auto racing, Tim's professional aviation career began at Mosler Motors in 1990, but you probably know him best from his monthly "Engine Beat" column in KITPLANES Magazine.

It's set for quantity production. A handful of units have already been delivered to beta customers, with satisfying feedback. More than that, the AeroTwin™, brainchild of New Zealand design engineer Bill White, does more than its people say it will.

The engine came into being after the investors, inventor Woody Norris (www.woodynorris.com) and Jim Barnes, looked for proper power – they needed 65 horses at 100 pounds for their AirScooter™, a single-place amphibious helicopter. They didn't like two-strokes.

Making the search even more complicated, they required a vertical-shaft engine for the micro-chopper. Of course, no suitable engine exists, as they soon found out. After brief but painful discussion, the company's founders agreed they needed to hire businessman (and brother of Jim) Dwaine Barnes to manage creation of a viable alternative.

Dwaine realized that, if they were about to be forced to create an engine, it should also have the capability of running a horizontal crankshaft to broaden its market appeal and spread development costs. Many unrelated details later, Bill White's clever design was chosen, and development for the AeroTwin engine, with an eye toward other applications, was begun.

Barnes said that the AeroTwin design is purposely so versatile, that aircraft (manned and unmanned) are just the beginning of what he hopes to have as a long customer list. The engine is small enough and powerful enough to drive watercraft, snowmobiles, custom motorcycles, garden equipment, or specialty vehicles; it is light enough to be the gasoline-powered side of hybrid vehicles. Its cooling system leads one to think of stationary equipment applications (pumps, generators, emergency air conditioning units), too.

The AeroTwin's size, output, weight, and price make it a rational replacement for the thousands of 65hp two-strokes already flying, and these same qualities, coupled with strong factory support and detailed documentation, should make it a favorite in the OEM kit and Light Sport Aircraft markets.

Since the AeroTwin can be set up to drive from either end of the crank, it would be useful in myriad other de-

The AirScooter is a single-seat, Part 103 legal ultralight, coaxial rotorcraft. It's the brainchild of Woody Norris, internationally recognized inventor and co-founder of AirScooter Corporation. Unlike many ultralights, AirScooter is not a kit; it will be offered completely assembled except for the installation of the rotor blades and will include pneumatic floats instead of traditional helicopter skids as shown in the photo above.

Built around a composite torque-box airframe, the overall height of is 11 feet with a width of 7 feet and a length of 12.5 feet, excluding the extruded aluminum rotor blades that measure 14' in diameter. Flight speeds are estimated to range from hover up to 55 knots at a gross weight of 350 pounds. With 30 pounds of fuel (five gallons) an endurance of approximately two hours is expected. Standard instrumentation includes digital readouts for fuel level, altitude and air speed, which are conveniently located between the grips of the handlebar controls. These performance specifications are engineering estimates that are corresponding well with final phase engine testing that is currently taking place.

signs; and because of the engine's four-stroke reliability, dry sump and fuel injection, the AeroTwin could find potential markets in specialized (aerobatic) training airplanes, as well.

[Author's note: Some details of the AeroTwin that appeared in my Engine Beat column for KITPLANES Magazine (September 2006 edition) have been revised since I first gathered that information. Revisions are included here, and should reflect the production configuration. Note that, even though I was indeed contracted by AeroTwin to write this article, I have done my best to give straight reportage; my opinions are, I hope, not evident. –Tim Kern]

LET'S BUILD IT

In late June, Barnes put together U.S. volume manufacturing, with dedicated assembly and test in Fort Worth (TX). In late August, as I pulled up to the 85,000+ square foot building complex (including an on-site dyno building), I couldn't help wonder just how many engines he planned to make!

It quickly turned out that the enormous facility isn't just for the Aero-Twin and AirScooter; the shop, with 3-, 4-, and 5-axis CNC machining equipment and state of the art measuring and inspection, also contracts to other major clients, including one world-class helicopter manufacturer that you've heard of. The rest of the good news is that, as the AeroTwin finds additional customers, the facility will be able to keep up.

What is now trickling out to Beta customers is a four-stroke, double overhead cam, two-valve, parallel twin of 972cc, that weighs, all–up, 118 pounds (with the turbo), and is losing weight as we speak, through running changes that include simplification of the top-end design and incorporation of magnesium cases.

HOW, WHY, AND WHAT

The Aero-Twin is an air cooled, turbocharged and fuel-injected twin, featuring single-lever control and it may be the only four-stroke gasoline engine that uses reed valves in addition to two traditional poppet valves per cylinder, for intake and exhaust.

Internal air cooling triggered the need for the sprung-flapper (reed) valves. In addition to generous finning on the one-piece cylinder/head casting, the Aero-Twin uses its natural crankcase pumping (both pistons move up simultaneously, but fire 360 degrees from each other) to cool itself.

When the pistons rise, the vacuum created in the dry-sump magnesium crankcase sucks air in through a pair of tiny air filters on the cam cases atop the engine. (Figures 1 and 2) The air travels the length of the cases and into a pair of thin-wall aluminum tubes (Figure 3), then to the crankcase through a pair of stainless steel reed valves (Figure 4), filling the case with cool air and partially relieving the vacuum. Then the pistons come down, pressurizing the crankcase and forcing nearly a liter of air out through another pair of reed valves and an air/oil separator. The oil is returned to the engine; the air proceeds out. Thus, the engine cools itself internally, using energy ordinarily wasted.

Fig. 1

Fig. 2

The photo to the right shows the upper portion of the cooling air intake system, complete with dual air filters (each side mirrors the other) and a balance tube interconnecting them.

Fresh air is drawn into the cam case through the filters and then to crankcase through aluminum tubes.

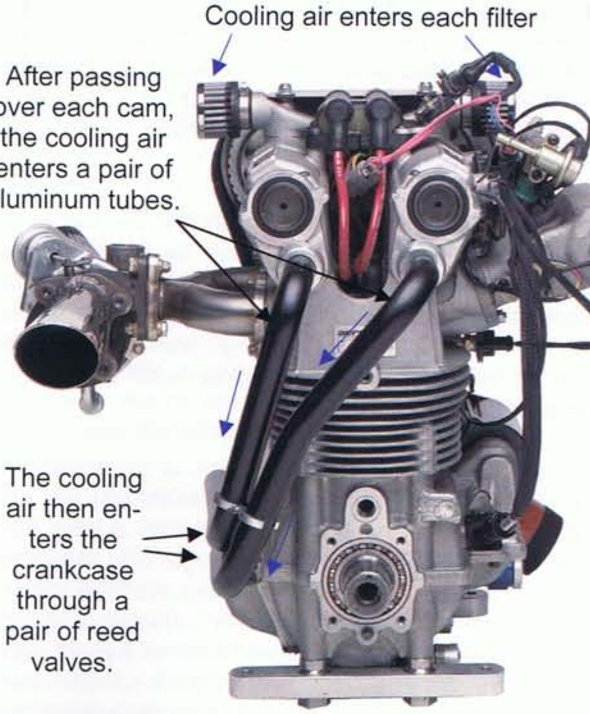
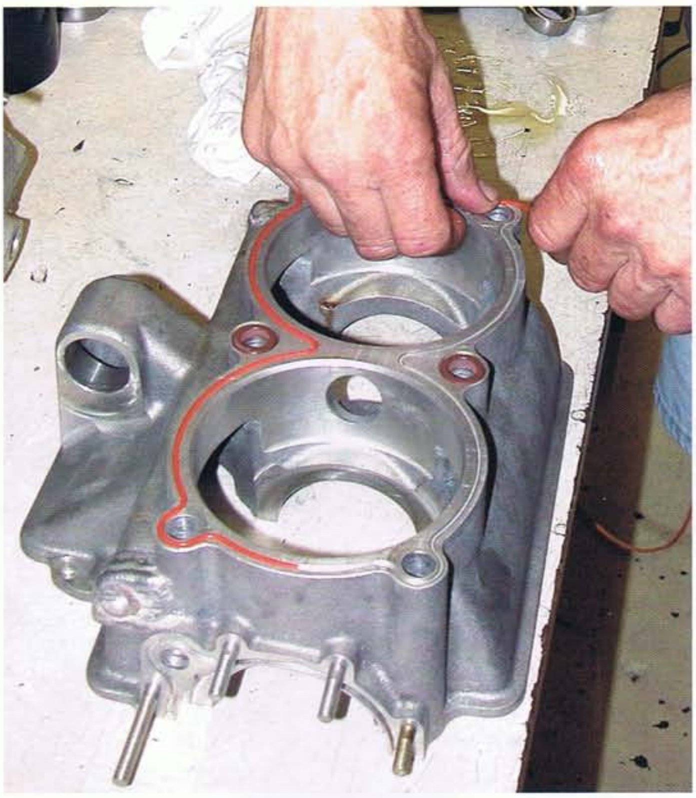


Fig. 3

Fig. 4

The dry sump arrangement is a super-scavenger, too, so there is no "oil splash" drag inside, which allows mounting the engine in that helo-required vertical position.



The engine needs no gaskets. Off-the-shelf O-rings and round-section silicone "string" are all that's needed. Shown above, the upper half of the crankcase with silicone string being used to seal the cylinder base.

Reed valve design is a notorious black art; getting the valve action just right has driven many a designer to the looney bin. I asked Bill White how much hair he pulled out, as he developed the AeroTwin's stainless steel reed valves. "Strangely enough, everything I had calculated turned out to work just perfectly, right from the start," he laughed. (He added that the reed valves may be the only components he hasn't had to revisit, during the long development process.)

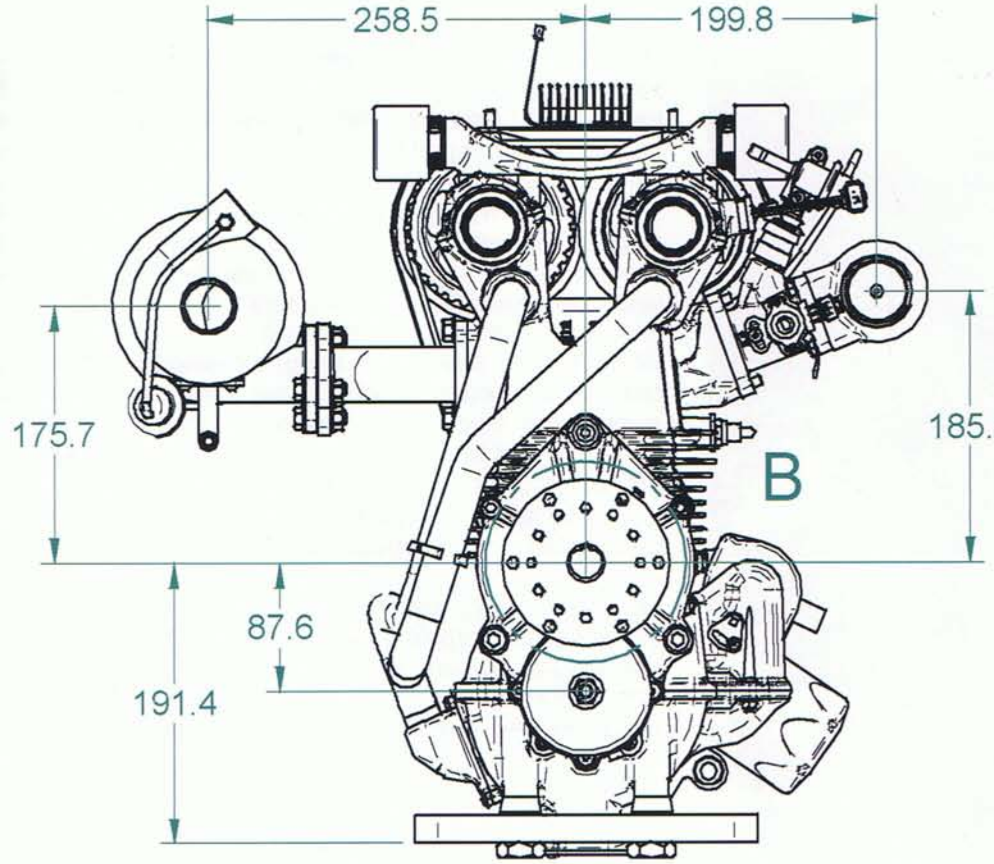
White wasn't satisfied making the engine merely rotatable; he also designed the case and cam cases to be symmetrical. Should one need to, the cylinder head can be turned end for end, the result being that the inlet and exhaust systems are swapped from side to side; if required by a future customer, the air/fuel flow could be reversed to run the opposite direction across the engine.

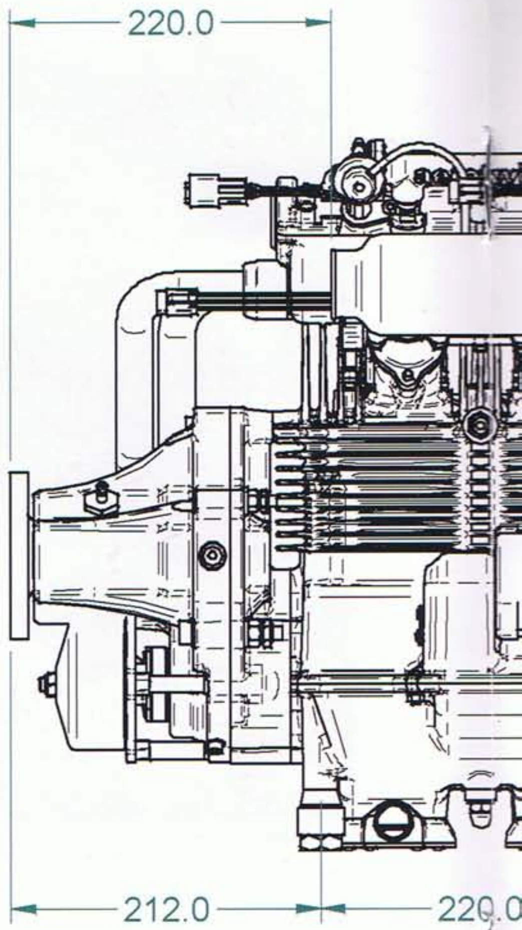
Manufacturability and maintainability were other prime concerns, and simple design was key. In addition to not needing gaskets, the whole engine case is held together with six through-bolts; the center two also serve to move the oil from the lower gallery to the cams and top end.

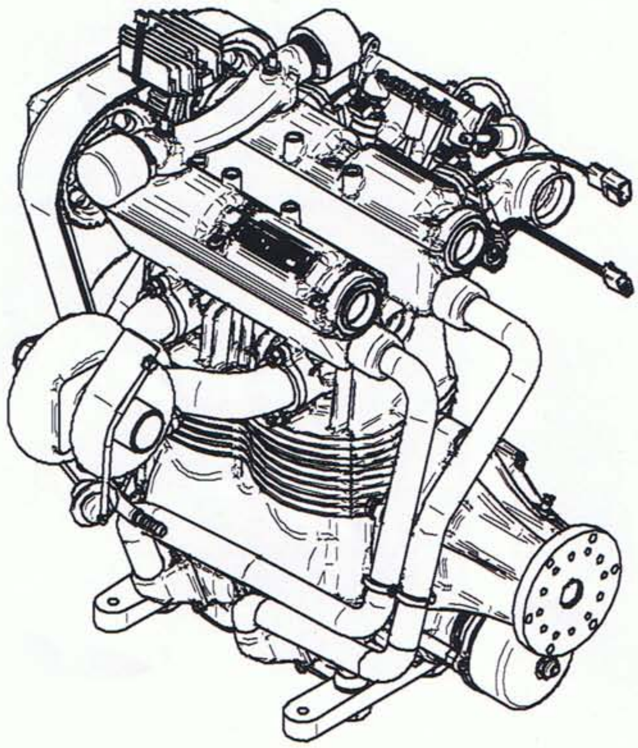
Making things light is an endless quest, resulting (so far) in a hollow cast-steel crank, hollow camshafts, and magnesium cases which saved some three pounds over their aluminum predecessors. The 132-watt (11 amps @ 12 volts), permanent-magnet alternator, now located at the

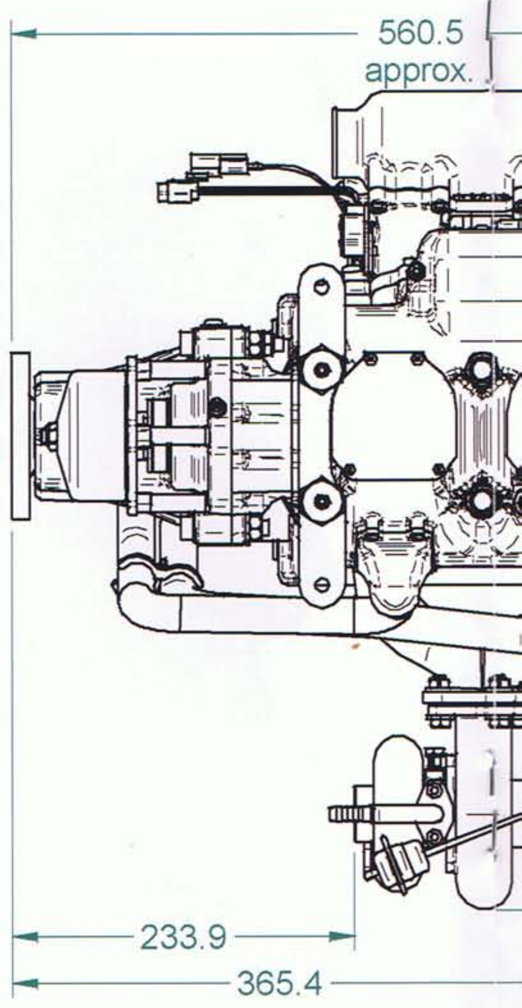
This Kitfox firewall forward installation shows the alternator mounted immediately under the PSRU and driven directly from the crankshaft. The intercooler is shown mounted under the alternator.

end of the crank opposite the power takeoff (and turning at crankshaft speed), isn't much bigger than my cell phone. The version of the engine I saw, located the alternator on the front of the gearbox, where the low-speed vibe-reducing clutch now appears.



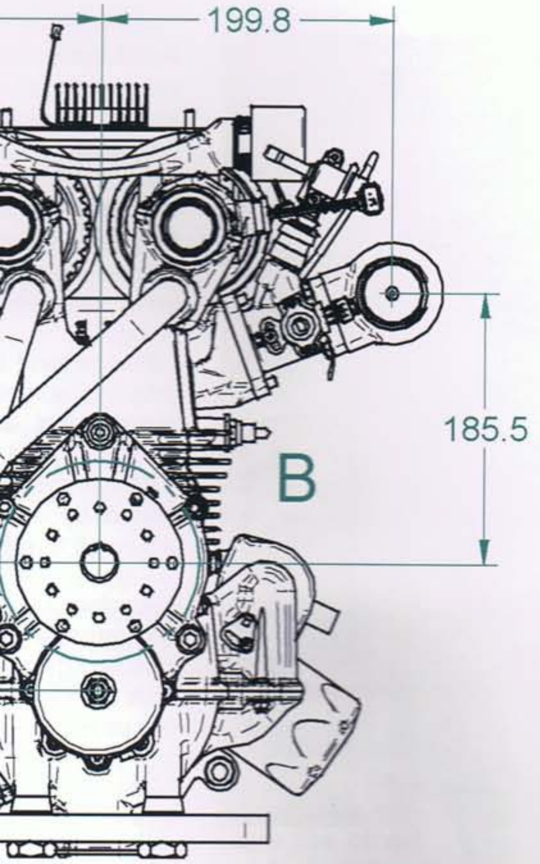


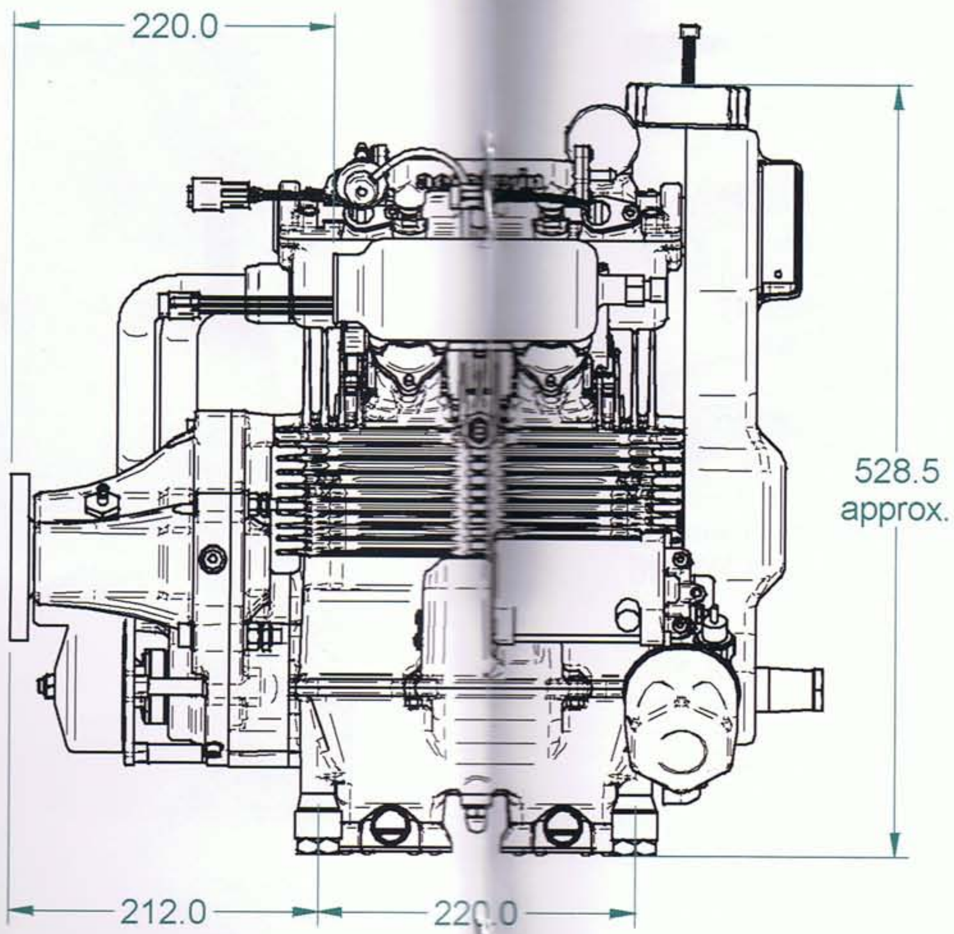


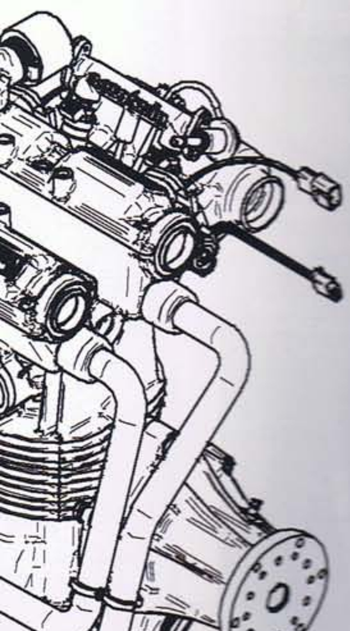


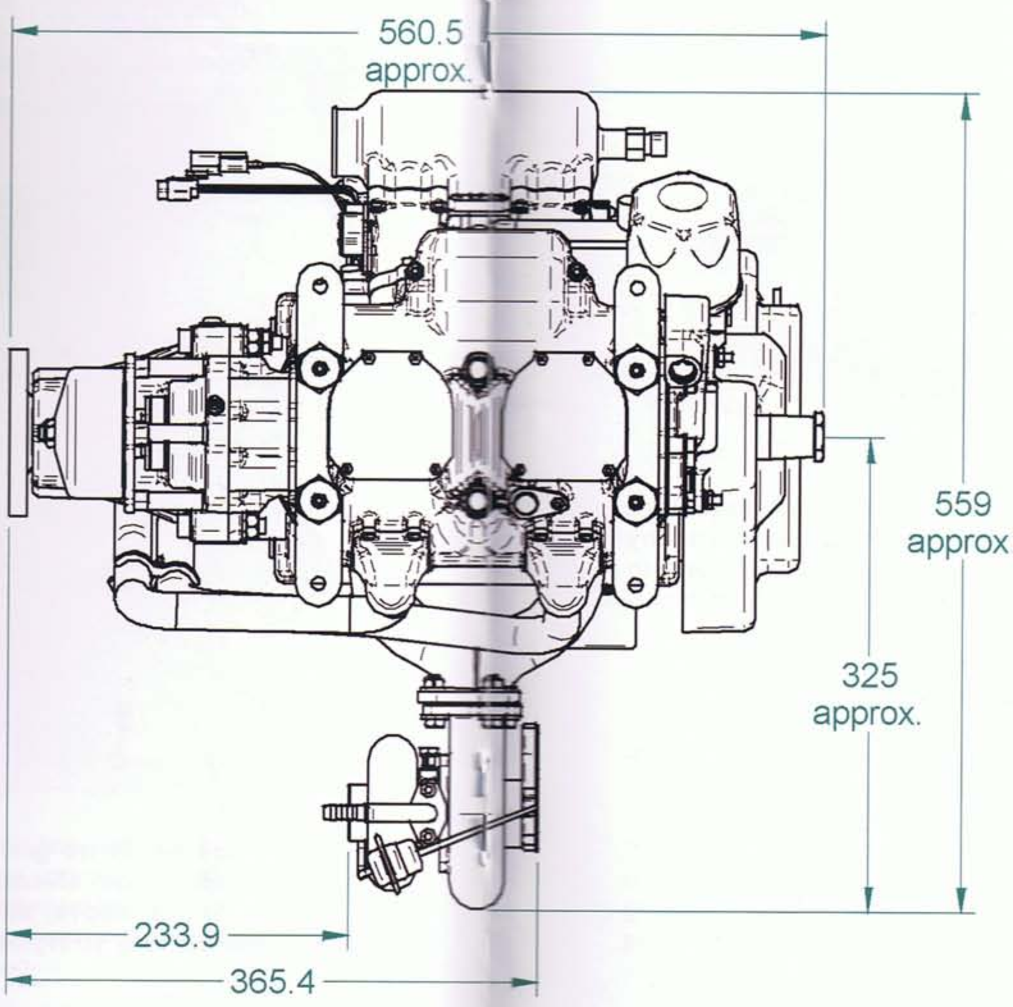
aerotwin

All dimensions referenced are metric.









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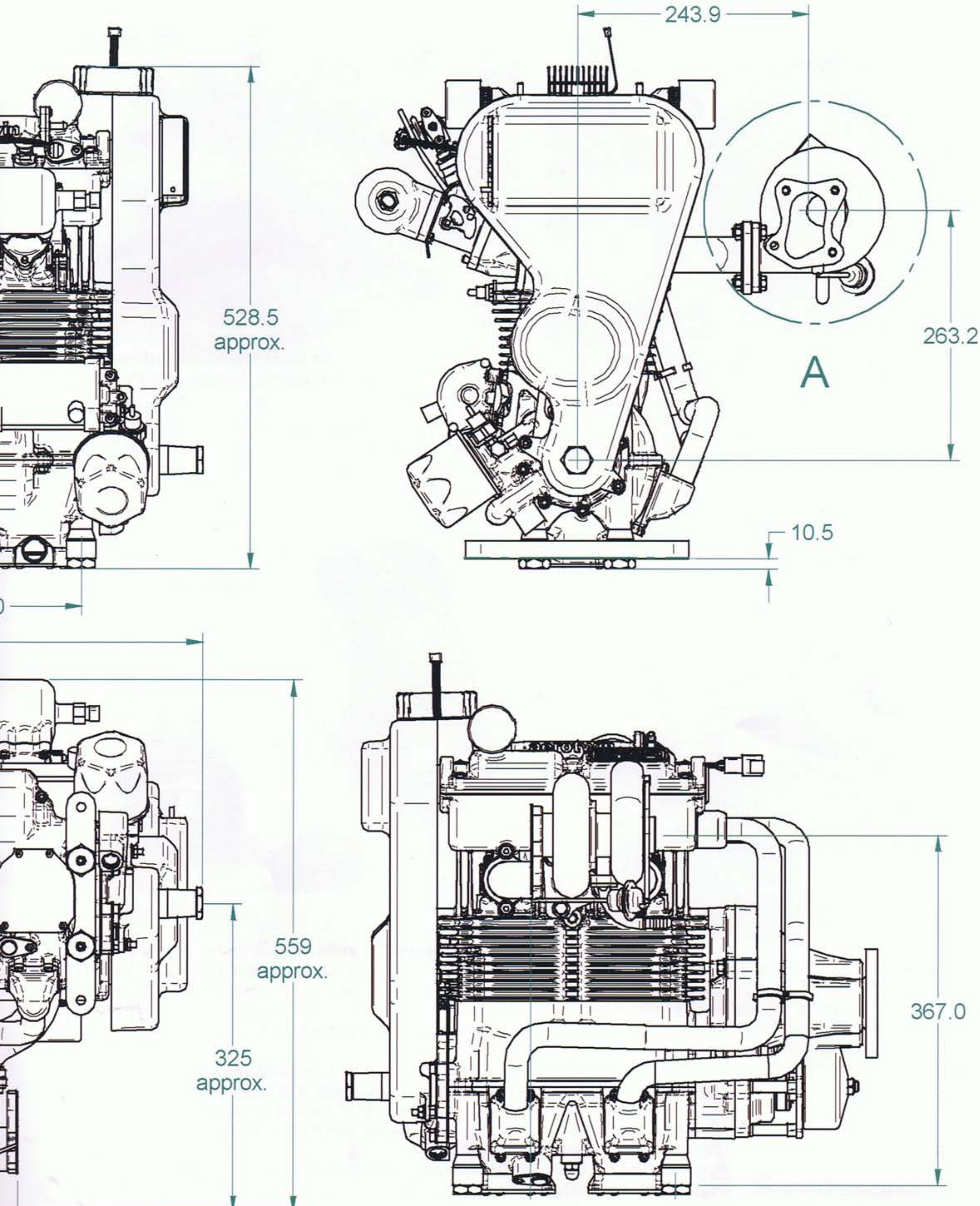
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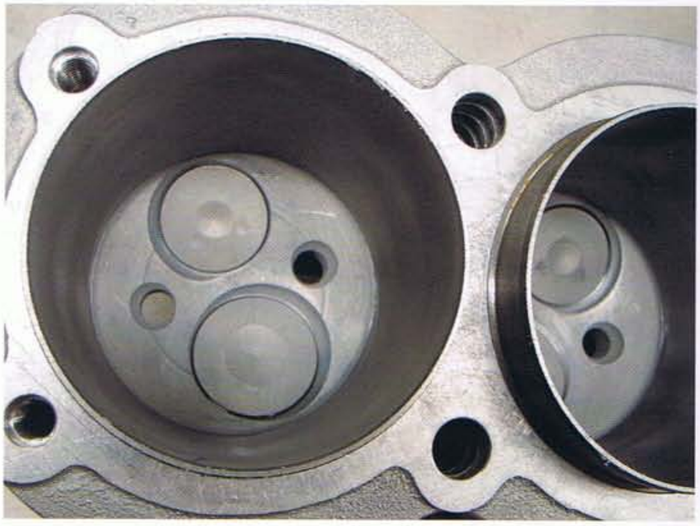
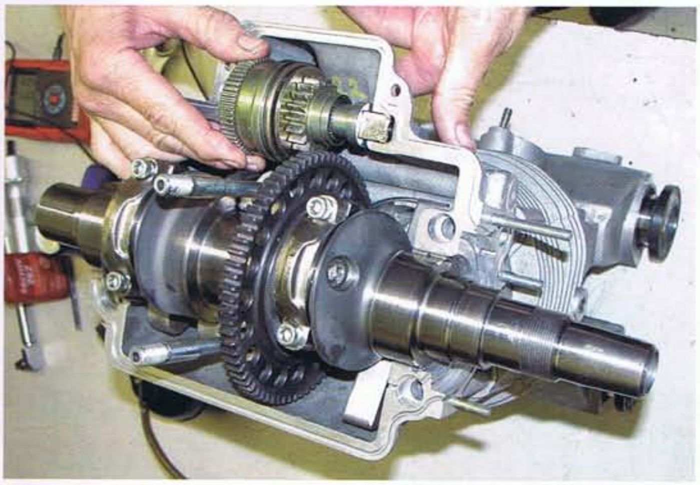


With the position of the valves within the head being mirrored from one cylinder to the other, each cylinder requires its own specific piston.

The latest version of the AeroTwin features iron bores (sleeves) in aluminum cylinder assemblies, in which the non-matching pistons slide up and down together, firing on alternate strokes.

The pistons have ceramic tops (not shown in this "photo-op" assembly), mimicking similar material on the inside of the head's portion of the combustion chamber. The pistons are unique to their relative cylinders (not interchangeable) because of the valve-clearance cutouts. See the photo at the top of this page and note the valve position.

AeroTwin has experimented with several crankshafts, squeezed between the quest for light weight and the cost of materials and processes. The original used a forged titanium crank: costs were insane. Later iterations tried a forged steel crank and a billet steel crank: heavy. Now, the engine has a cast, hollow, steel crank that incorporates cast-in counterweights.



Shown above: an earlier billet crank with bolt-on flyweights, as well as the starter bendix and flywheel mentioned below.

ACCESSORIES AND EXTERNAL SYSTEMS

In addition to the snappy alternator (permanent-magnet, remember?), the starter is a small but mighty unit, and the mounting of both is dirt-simple; bolt them on and forget them.

The off-the-shelf bendix, as well as the flywheel, lives inside the crankcase and is perpetually lubricated by engine oil, which, over time, should prove to add to its longevity. On the other hand, servicing or otherwise replacing the unit will entail splitting the case.

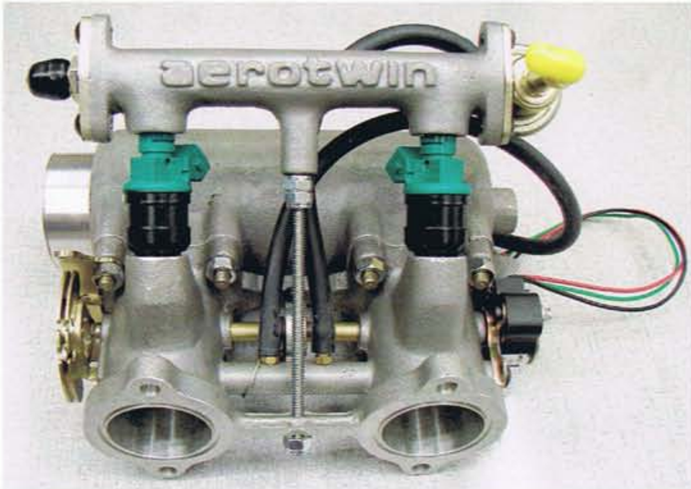
The robust gearbox is a straightforward unit with custom made, straight-cut gears and a centrifugal clutch. The clutch's drag at idle is enough to keep the propeller going; by 2800 engine rpm it's fully locked-up.

The gearbox can be mounted with the prop flange either "up" or "down," to add to the unit's versatility. Once mounted, its orientation can be changed by removing and replacing a few bolts. In the "down" position, there is an additional support bracket that bolts on.

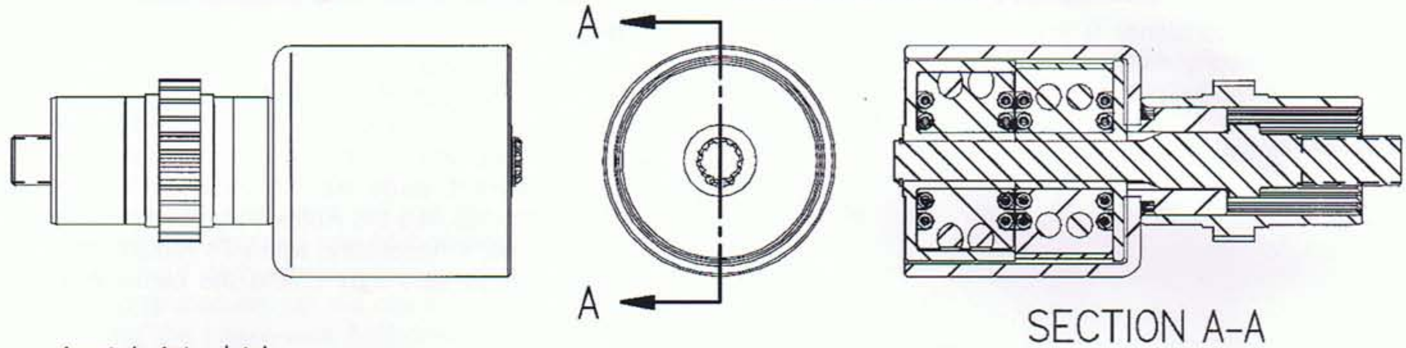
Disassembled gearbox shown without the clutch.

Three different gear ratios are available: 2.136:1; 2.000:1; and 1.875:1., accomplished by way of three individual quick-change gear sets. The gear centers remain the same for all ratios so it's just a gear pair to change from one ratio to another. All of the bearings have slip-fit mounting clearances, as does the drive shaft, so the system requires no pressing or heating to change. The casing is sealed with one perimeter o-ring, so there are no gasketing issues to contend with.

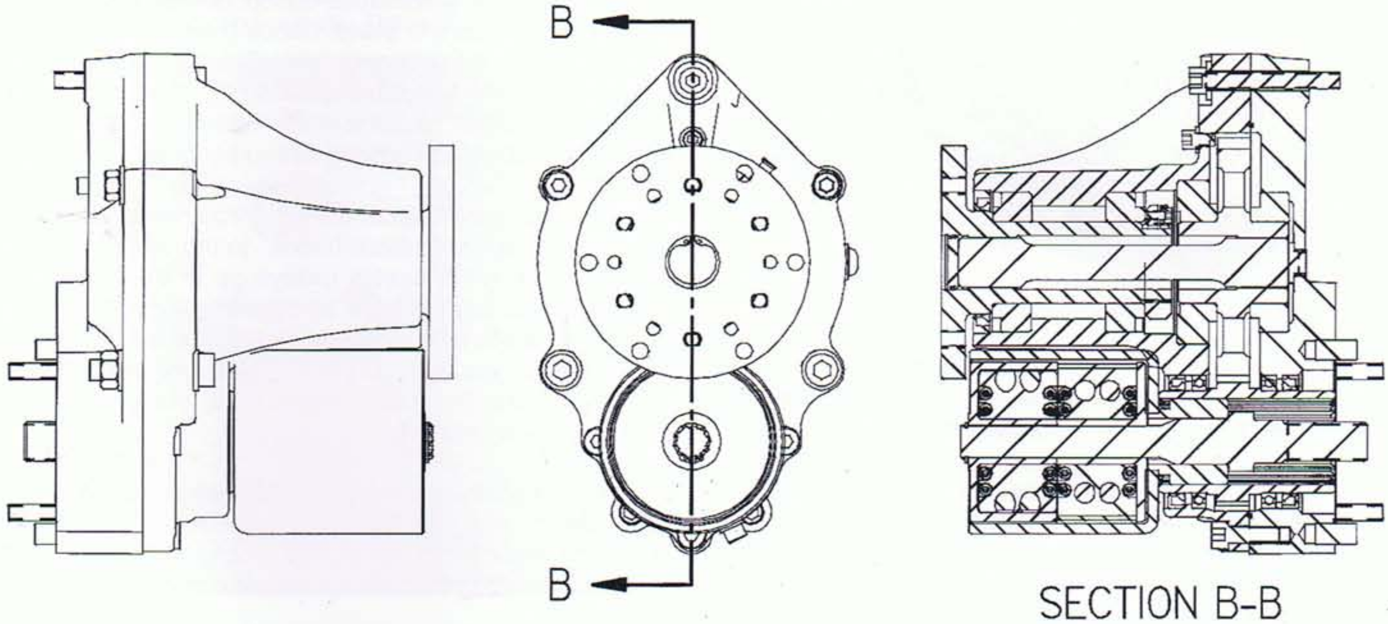
The proprietary fuel injection unit is loosely auto-based and solid-state, as is the digital engine management unit. The resulting single-lever control is great for pilots; it's particularly good for unmanned, recreational, or industrial applications.

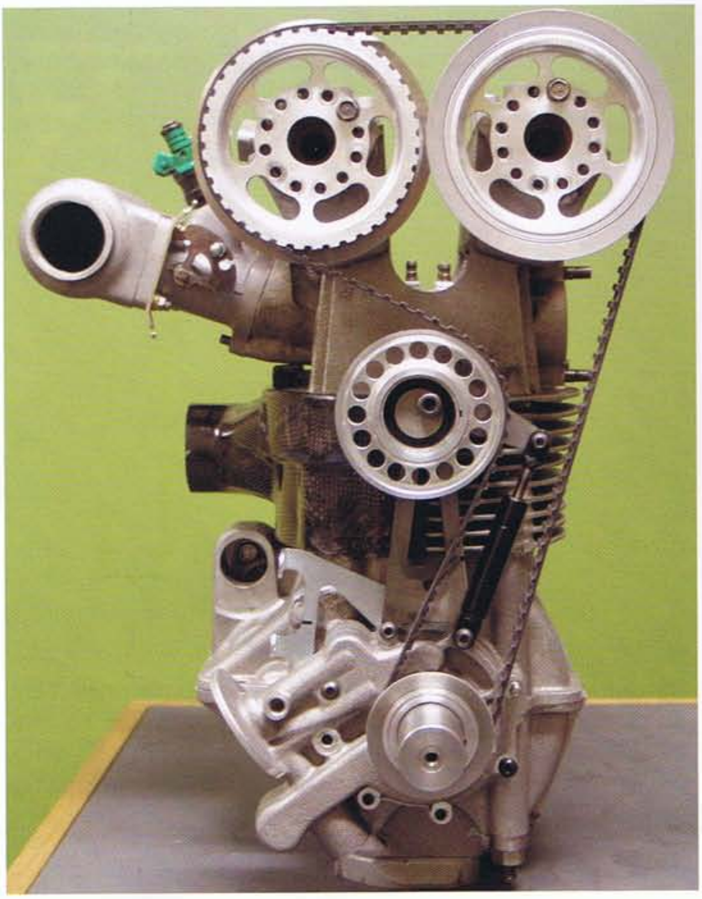


Dynamic fuel and ignition settings are determined by an air pressure transducer which indicates to the ECU the load the engine is experiencing. In conjunction with air temperature and cylinder head temperature sensors, the ECU compensates for altitude, engine load, variables in air temperature, and overall engine temperature.



Aerotwin Auto clutch





The cam belt tensioner is automatic, and simple, per White's philosophy. The gas filled damper is matched to always keep the optimal tension always on the belt.

The carbon-fiber cooling shrouds, in their latest configuration, are designed to get the most cooling from the smallest electric fan. The shrouding is not necessary in most tractor airplane configurations, but for many pushers, and for rotorcraft, stationary use, and enclosed applications, it's a must. The efficient design allows cooling air to be blown in, or sucked through; and the idea, always, is to minimize bulk, weight, and power draw.

ASSEMBLY

I watched and interfered as Jerry Maisel, the company's master mechanic, put an engine together. Starting with the top end where Jerry had already installed the valves and springs, he placed the hollow camshafts in their saddles. ***See Figure 1, page 10.*** The engine comes without shell cam bearings, like the Rotax 912, but it is designed to be line-bored, if necessary, when it's rebuilt; standard automotive shells thus may cradle the cams in rebuilt engines.

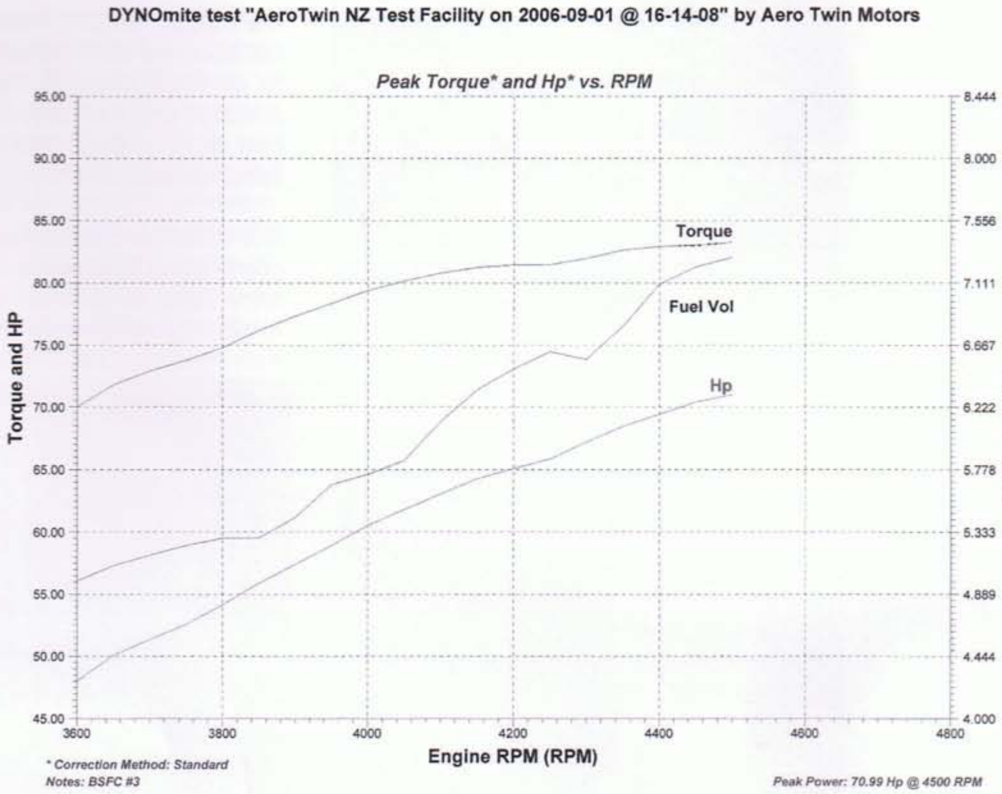
After the proper valve clearance is set (there are cupped shims under the automobile-based bucket cam followers), he set the cam in place, dabbing on assembly lube. Then he laid the silicone "string" into the machined grooves in the cylinder/head assembly, torqued on the valve covers (that hold the other half of the cam bearings), and flipped the growing assembly over.

Jerry then torqued the center two through-studs into the top-end casting. These are hollow, to transport the pressurized oil from the case's galleys up to the cam bearings. "We had a devil of a time getting the orifices just right, but we started out pretty close, and Bill [White] dialed it in," remembered Barnes. These two major tubes, along with four less-complicated outer studs, are what hold the cases together.

The top magnesium case then received its ration of silicone string, and, on hollow dowels and O-rings, slid down the two center studs, into place. With the engine standing on its head, Jerry installed the (automotiveorigin) main and thrust bearings and (having already attached the piston/rod assemblies to the crank) set the crankshaft assembly into place.

The starter clutch assembly literally drops into place, and the bottom casting, located again by hollow dowels, slides on. (The machining is so closely-matched that it took a lot of persuasion to get our photo set back apart.)

Add the four remaining through-studs and a couple of little screws near the starter's flange, torque everything, and the engine is well on its way to taking shape. Elapsed time (not counting the delays my camera work and questioning prompted): about fifteen minutes.



Smaller components such as the reed valves, starter gear adjuster, oil pump, etc. go on, using the same procedure: silicone bead; locate; lube (if necessary); then torque to spec. Nothing to it, when everything fits so well.

At the business end of the crank (notwithstanding that the design can take power from either end of the crank - we're talking about the end where the gearbox bolts on), Jerry added the proprietary cam drive cogs and tensioner. The cam belt went on and the tensioner was snugged up (the engine I saw had an earlier-design belt tensioner), and Jerry demonstrated a most-remarkable cam-timing procedure: set the crank to TDC, line up the cams using the intake-vent hold-down holes to accommodate temporary set screws that hold them, and tighten the cam-drive cogs on the front of the cams. No instruments, no hassle; one minute. Done. Forever.

Final assembly: install the fuel injection system, screw in the dual 14mm x ¾" spark plugs (a total of four), then mount and attach the ignition. Bolt on the permanent magnet alternator at one end of the assembly, turn it around and bolt on the gearbox/clutch assembly, and finally add the aluminum tubes that transfer the air from the cam boxes to the crankcase. Add the stainless steel exhaust collector, the cute little turbo (ideally sized to maintain full power to 5000 feet), and take the whole thing to the dyno room.

RUNNING THE AEROTWIN

All this cleverness is for nothing, if it doesn't work, of course. The AirScooter needs 65 horsepower and a wide power band, with good cooling, even during long periods of full-throttle operation.

I watched two dyno runs, and the AeroTwin delivered. It made a reasonable amount of noise as it warmed up (about 1000rpm), and it shook at idle. Soon, Jerry was showing off. As the rpm rose the engine smoothed out and didn't get nearly as much noisier as expected (probably because the turbo muffles the exhaust note).

As we entered the useful rpm range, the engine's best quality showed up on the console: The AeroTwin's torque curve is essentially flat, throughout the operating range. That makes the horsepower curve look like a nearly-straight line, a simple function of rpm. The AeroTwin's torque readings varied only plus or minus 2% (4% total) from 3300rpm (where the dyno started recording) to 5100+, past the aviation (not the engine's) redline, with a not-too-peaky peak at 4600. (At 5300, where the run was terminated, the engine was still cranking out over 93% of peak torque.)

Continued on page 22

AeroTwin master mechanic, Jerry Maisel, at the console of the company's in-house dynamometer.

The engine makes its rated horsepower, and then some... and then some more. If your application needs 65 horses, you won't be disappointed. (The dyno run I'm allowed to tell you about showed 69 horses. The other run, when Jerry goosed it a little longer, was considerably –lots-- higher than that.) Barnes said, "Don't mention how much power it really makes, or I'll get a hundred calls asking how many horses I can deliver. It's a 65 horsepower engine, in the aviation configuration. 65."

White told me that the gasoline he uses for his own dyno runs "...approximates worst-case. Just like some customers, I use 'aged' gas. I buy it and keep it in gas cans with loose caps for six months, before I use it." The Ft. Worth dyno, however, was running fresh gas.

Our dyno runs were limited to aviation-style speeds (in the 5,000 rpm range), but Barnes says the engine has lived well in tests above 8,000 revs. "Don't even think of asking the power at that speed," he said. "We're not yet doing the rest of the development for sustained operation up there." In order to optimize higher output, the biggest changes would be with intake tuning and capacity as well as ignition and cam timing; these would be developed for whatever application the volume customer needed.

Fuel consumption is targeted at the 4.5- 5.0 gph range at 75%,* and early tests have shown that 6.2 gph (worst-case, intermittent) is reasonable for full-load, full-throttle running. Flight tests in various aircraft are ongoing, and early results show consumption in the 5.5-6.0 gph range.

**75% of 65 HP is 48.75 HP. The "targeted" 4.5-5.0 gph translates to 28.5 pounds per hour. Divide that by the HP and you get a brake specific fuel consumption of .58 pounds per HP per hour, which is a very conservative goal. This engine should work out to be more like .45-.50 pounds per HP per hour, in my opinion. ~Pat*

AFTER YOU'VE USED IT A WHILE

The AeroTwin is designed for long life and for ease of maintenance. Bill White has wisely used proven automotive components for things that might wear out or need replacement – valve springs, keepers, caps and bucket followers; main and thrust bearings, piston rings. All

Spooled up on the dyno.

these are readily available through AeroTwin, when your projected thousand-hour TBO comes around. The total freedom from gaskets also means that you won't ever waste time searching for specialized parts.

Standard maintenance is designed to be straightforward and easy. Intervals for oil changes are 50 hours (or seasonally). The automotive spark plugs should last 50 hours or better. The K&N air filters are "permanent" items, requiring cleaning whenever they're dirty, which can be expected at 50 hours. Required fuel system checks take place every 50 hours, with fuel filter replacement recommended at 100-hour intervals. Valve checking and adjustment is expected at 100 hours. The throttle position sensor base setting is an annual inspection item. Oh – and check the transmission/engine oil level every flight, as usual.

The engine could last "forever," considering how much hobby-fliers use their airplanes (anywhere from 20 to 100 hours per year, with the average under 50, according to numerous surveys). The cylinders could, if necessary, be sleeved; it's likelier that a simple rebore will be all you'll ever need. The main bearings are available in oversizes (in the event you need to rebore the case) and undersizes (if you feel the urge to regrind the crank). Cam bearing shells are also available, if the top end should have a similar need. AeroTwin is committed to volume production, too, so plenty of parts should always be available from the factory.

SUPPORT

Factory documentation is a high priority. The engine website has numerous pages, with links to operation, parts, dimensions, and technical backup. This should make the decision to use the engine an easy one.

That is the goal of AeroTwin: to make information available, to help the designer do his own aircraft design, with accurate information. Though individuals may indeed purchase a single engine for their own aircraft, AeroTwin is set up for volume delivery. They plan to be making volume deliveries in early 2007, with the first "production" run of 200 engines early in the Spring.

WHAT SOME PEOPLE ARE SAYING

One new OEM customer performed an informal noise test, just as we were putting this article together. Here's what he wrote in an e-mail to AeroTwin:

"Our initial startup went real well. The engine performed as promised, in fact exceeded my expectations. You guys have a real winner in the light sport power category. Some good news that [we] thought you would want to know is the db level performance of the engine. Well, we took some readings and they are as follows: 2,300 [engine] rpm at [a distance of] 10 feet, pointing to the exhaust stack, 96db [and] with the engine at full throttle (around 4,300) at 10 feet, pointing at the exhaust stack [we read] 104db. I think this is exceptionally quiet considering [we ran] open stack, no muffler and we are probably reading some ambient [noise] from the prop tips as well. Anyway, this might be info someone will be interested in. "

AeroTwin MOTORS

AeroTwin™ Motors Corporation is a subsidiary of Nevada-based AirScooter Corporation. AirScooter Corporation is dedicated to innovating new flight concepts for the recreational and hobby markets, initially focusing efforts to apply a coaxial counter-rotating dual rotor system to a recreational flying vehicle.

MORE ON BILL WHITE

Bill White is THE director of engineering and has directly managed the AeroTwin development project. He is a world recognized engine expert involved in high performance and racing engines. He has worked with New Zealand Rover, Jaguar, Rolls Royce and Bentley concessionaires as well as restoring Aston Martins, Bristols and Jaguars. Recently, he was involved with Britten Motorcycle high performance engines.

CONTACT INFORMATION

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Website: www.aerotwinmotors.com

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980 American Pacific Dr., Suite 111
Henderson, NV 89014Ph: 702.566.4602
Website: www.airscooter.com

General Specifications:

- 65 HP @ 4200 RPM
- Weight: 105 lbs
- Dimensions (Height): 17.5"
- Two Cylinders, In Line
- Dry Sump (Runs in Vertical and Horizontal position)
- Air Cooled 972cc 4 Stroke
- Firing Angle 360°
- Bore: 101.6
- Stroke: 60mm
- Compression Ratio: 8.0:1
- Manifold Pressure: 8 psi
- Two Sparkplugs per Cylinder
- Two Valves per Cylinder
- Belt Driven Twin Camshafts
- Electronic Fuel Injection and Ignition
- Fuel Octane Requirement: 91UL
- Gear Reduction Box: 18.5lbs (see detail below)
- Propeller Flange: standard output flange has 75mm and 100mm bolt-circle for mounting, an aircraft standard SAE No.2 propeller flange is also available as an option

Detail Specifications:

- Intake Valve dia: 46mm / Exhaust: 40mm
- Intake Port dia: 38mm / Exhaust: 34mm
- Intake Cam lift centre: 102°
- Exhaust Cam lift centre: 112°
- Total lift Inclusive: 10mm
- Included Angle: 32°
- Piston Type: Shallow Slipper
- Piston Pin dia: 22mm
- Connecting Rod Centers: 120mm
- Connecting Rod Material: Aluminum
- Connecting Rod Crankpin dia: 50.8mm
- Crankshaft Main Bearing dia: 58.42mm
- Crankshaft Number of Bearings: 3

Feature Note: The cylinder head is designed to allow it to be rotated 180° so that intake and exhaust positions can be swapped side for side.

Gear Reduction Box Ratios:

22 x 47 = 2.136:1
23 x 46 = 2.000:1
24 x 45 = 1.875:1

Thus, for a Prop speed of 2000 rpm;
2.136 = 4272 rpm
2.000 = 4000 rpm
1.875 = 3750 rpm

Prop speed of 2200 rpm;
2.136 = 4699 rpm
2.000 = 4400 rpm
1.875 = 4125 rpm

Prop speed of 2500 rpm;
2.136 = 5340 rpm
2.000 = 5000 rpm
1.875 = 4687 rpm