Revmaster R-2300 Conversion

The little engine that could

Revmaster's breakthrough R-2300 engine offers more horsepower at a Lower cruise RPM that previous versions.

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Revmaster Aviation has finished development of its latest upgraded engine and the results are in: more horsepower at any usable RPM. The new Revmaster R-2300 (2332 cc) engine maintains Revmaster's renowned proprietary systems and parts including its RM-049 heads that feature large fins and hemispherical combustion chambers. It maintains the earlier R-2200 engine's maximum 82 horsepower at only 2950 RPM continuous, but offers 85 ponies for takeoff at 3350.

The additional power ultimately comes from a 94 mm bore plus lengthening the stroke to 84 mm, but that's oversimplifying things. "We've put a lot of energy into this redesign," says Joe Horvath, president and founder of Revmaster Aviation. "On paper it looks like just a few minor modifications, but we're really closer to a complete rework of the internals: crank specification, connecting rods, pistons and cylinders are all new." The longer stroke results in greater displacement, longer connecting rods yield better vibration and power characteristics, the lower cruise RPM allows the use of longer propellers, and the higher peak horsepower can be felt in shorter takeoffs and steeper climbs.

Strength and reliability are boosted by Revmaster's four-main-bearing, 4340 forged steel crankshaft (boasting nitrided journals) that runs on huge (as compared to a stock VW) 60 mm center main bearings. Thrust is handled by the custom-installed 55 mm #3 bearing at the prop end of the crank, formerly found at the other end. Fully utilizing its robust, proprietary #4 main bearing, the Revmaster crank has built-in oil-controlled variable-pitch propeller capability, a feature unique in this horsepower range and exclusive to Revmaster VW conversions. Unlike other VW conversions, props other than wood are usable on any Revmaster engine of any vintage.

Revmaster has been in the engine business since 1959, starting out as a remanufacturer of the early 36 HP engine that was introduced in the Volkswagen beetle. In 1960 the VW was upgraded to the 40 HP engine that has become the cornerstone of VW flight engines. Around that same time, Revmaster developed a 2000 cc version of the VW for the experimental aircraft market by first manufacturing target drone engines for Northrop Corporation. Revmaster spent about two years in this endeavor before discovering thrifty and resourceful homebuilders were using some of these drone engines in experimentals. With many of the installations being highly successful, Revmaster decided to go in that direction. Now with well over 40 years experience in the homebuilder market and literally thousands of engines sold, Revmaster is announcing the latest addition to their successful line-up, the R-2300.

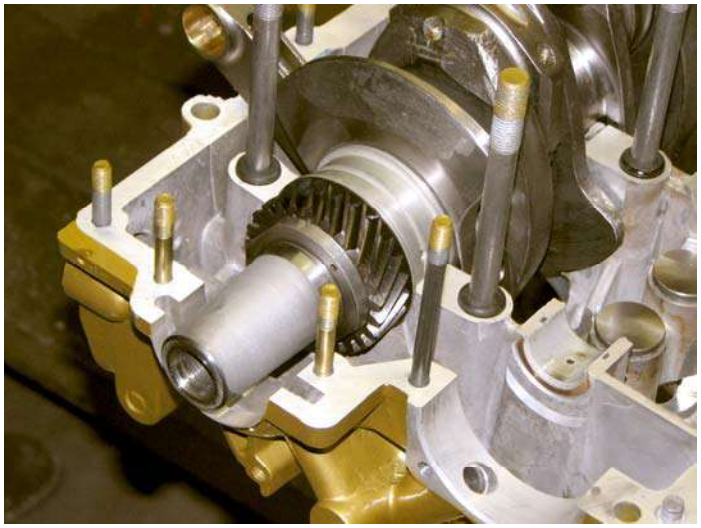
Although the Revmaster is based on the VW engine, not much of the original engine remains. From a proprietary crankshaft to proprietary heads, including a modern electronic ignition with individual coils for each of the eight sparkplugs, this is not the old shake-and-bake VW conversion of yesterday. It is more a purpose-built aircraft engine than it is an automobile engine conversion no matter how it's measured.

THE CRANKSHAFT

Connecting the propeller is always the most difficult part of adapting an automobile engine to aviation use. Not that it's particularly difficult to physically accomplish, but

rather that the loads imposed on the crank by the propeller are considerably different that those in an automobile. Potentially, the worst of these loads are gyroscopic in nature, although some might argue that torsional loads, especially harmonics that can be amplified by the propeller, are much worse if not a close second. Throughout the years, ever increasing displacements have multiplied the strength of the power-pulses and have amplified the propeller effects. And through trial and error, it's generally accepted throughout the VW engine community that the propeller used on a Volkswagen conversion should be wood and be as light as possible. This is not the case with the Revmaster and carbon fiber, aluminum and even variable-pitch propellers are open for consideration.

Throughout the decades that experimenters have been flying behind the VW engine, there have been a number of different ways used to attach the propeller hub to the crankshaft, most of which have been to simply bolt a custom hub to the pulley end of the otherwise stock crankshaft using the same method that the generator fan belt pulley is retained. It wasn't until Revmaster clean-slated the crankshaft design to include a precision taper fit of the hub to the crank that the VW conversion crankshaft was made robust enough to handle props other than wood. This fourth bearing rivals that of any certified horizontally-opposed aircraft engine.



Where the stock VW crank steps down twice to smaller diameters and has two keyways, one for the distributor drive gear and the other for the fan belt pulley, the Revmaster crank has been beefed-up and then precision-ground for the 3 degree taper.

Other VW engine conversion companies have tried to emulate the design (a short list would include HAPI, Great Plains and now AeroVee), but none have come close to the total package Revmaster has developed. This package includes, among other things, a left-hand threaded retention bolt that tightens with vibrations (not one that's prone to loosen) and the elimination of the stress riser inducing keyways that others still use.

The total package is rounded out with the installation of the previously-mentioned fourth main bearing that has

Just behind the steel cam drive gear is the #3 main bearing. Where this would be a normal plain bearing in a stock VW, Revmaster has machined the case to accept one of their custom thrust bearings they manufacture in house.

substantially more surface area than the original three combined. It replaces the oil slinger, the ignition timing gear and the comparatively insignificant automotive front bearing that's designed to carry only the fan belt loads. The case is line-bored to accept the new fourth bearing as well as the larger-than-stock Revmaster main bearings, and the adjacent engine case web is machined to accept the otherwise stock VW thrust bearing that normally resides at the opposite end.

The new, one-piece, bearing-grade aluminum alloy tubular fourth bearing is machined from a proprietary casting and is slid over the crank prior to the hub being fitted in place and the cases closed up. The bearing is held in place by essentially an interference fit between it and the case halves, locking it into place. The prop hub bolt is installed but not tightened until after the case halves are bolted together and torqued to specification.

The prop hub itself is machined from a single-piece proprietary 4130 or 4310 (steel) forging that's then heat treated for hardness to ensure the locking effect of the precision-honed 3 degree taper. The previously mentioned left handed retention bolt is 3/4-inch in diameter and is torqued to 160 lb-ft, locking the taper so securely that any form of externally applied puller will destroy the hub before it can be removed. However, through the use of carefully placed internal threads and the properly

Deep inside the steel propeller hub are a set of threads into which the drive bolt is installed. When driven in far enough, the bolt bottoms out on the nose of the crank, forcing the hub off with symmetrical loads, safely removing the hub with no damage to any of the parts involved.

sized drive-bolt, the hub can be removed and replaced numerous times with no damage to the hub, crank or bolt. When I visited Revmaster during the build of the engine for this article, the technician slid the hub into place and secured it by patting lightly with the palm of his hand. He then asked me to pull it back off, which I couldn't do. He had to use the drive bolt to pull it back off as a demonstration of the strength of the taper fit.

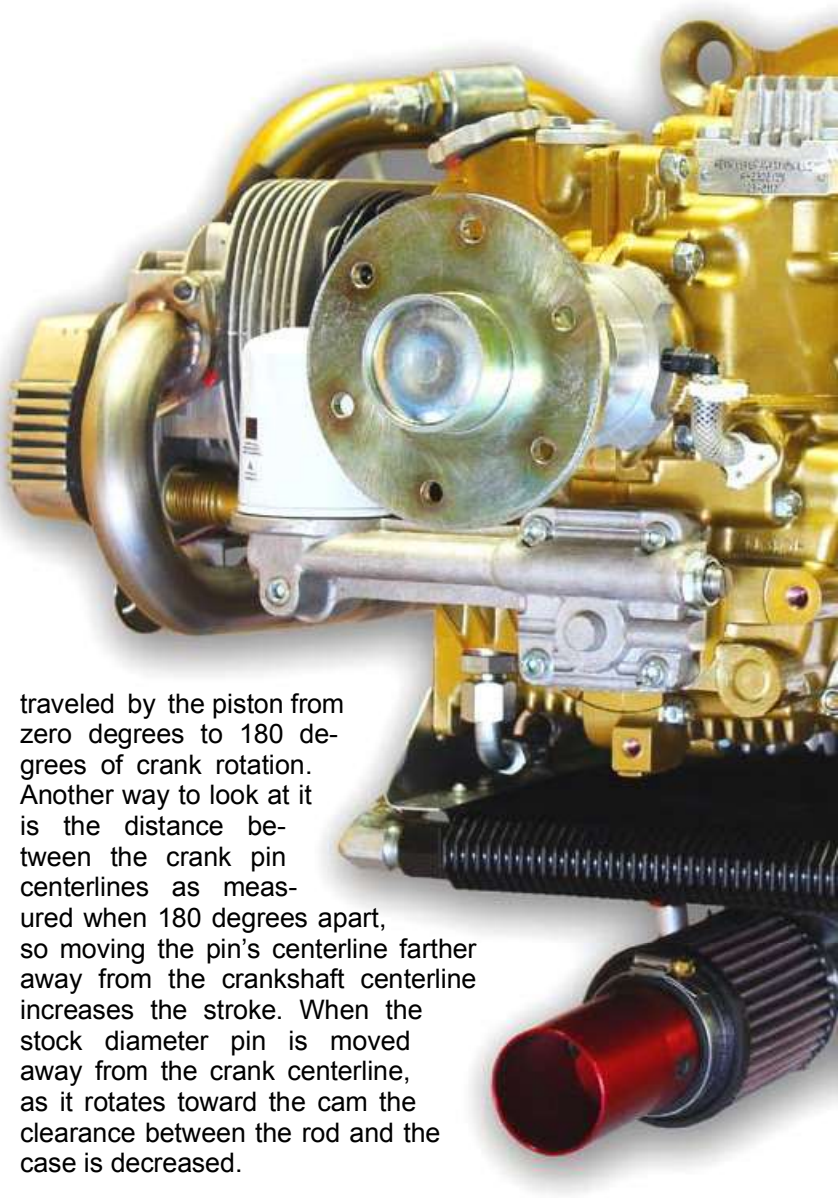
THE CRANKCASE

The crankcase starts life as a stock off-the-shelf Brazilian -made magnesium VW part. Although Revmaster can obtain aluminum cases, magnesium cases are far lighter and have thinner cross sections in various places. Once received at the Revmaster facility in Hesperia CA, the crankcase undergoes extensive machining to allow it's integration with Revmaster's other components.

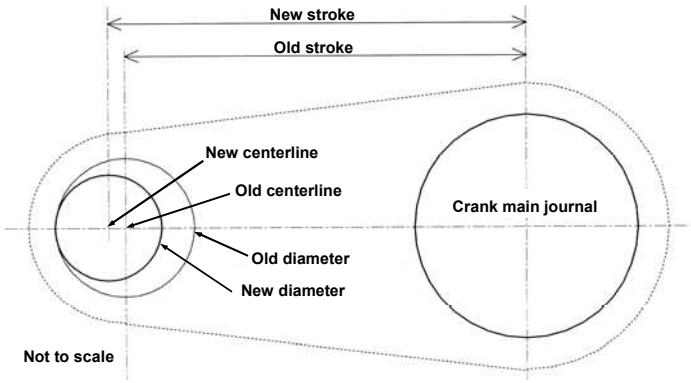
Due to the relative distance between the centerlines of the crank and the cam, it's easy to see that the engine can only be "stroked" so far. This is one reason that Revmaster opted to make their own case for the larger R -3000 engine we wrote about in *CONTACT!* issue #82. That same case can be used for the "tweener" 2500cc engine, but Revmaster feels comfortable tweaking the stock case to the 2332cc being featured in this article. Since the global market is so unreliable, the future availability of the Brazilian magnesium cases is always in question and that's one of the many reasons Revmaster developed their own case. For now, however, it's more economical to buy the off-the-shelf case and modify it, but with their own case, Revmaster is not locked in to a sole source should it ever dry up.

BORE AND STROKE

As previously mentioned, the stroke is ultimately limited by the cam location, but Revmaster has found a way around that. Stroke is usually defined as the distance

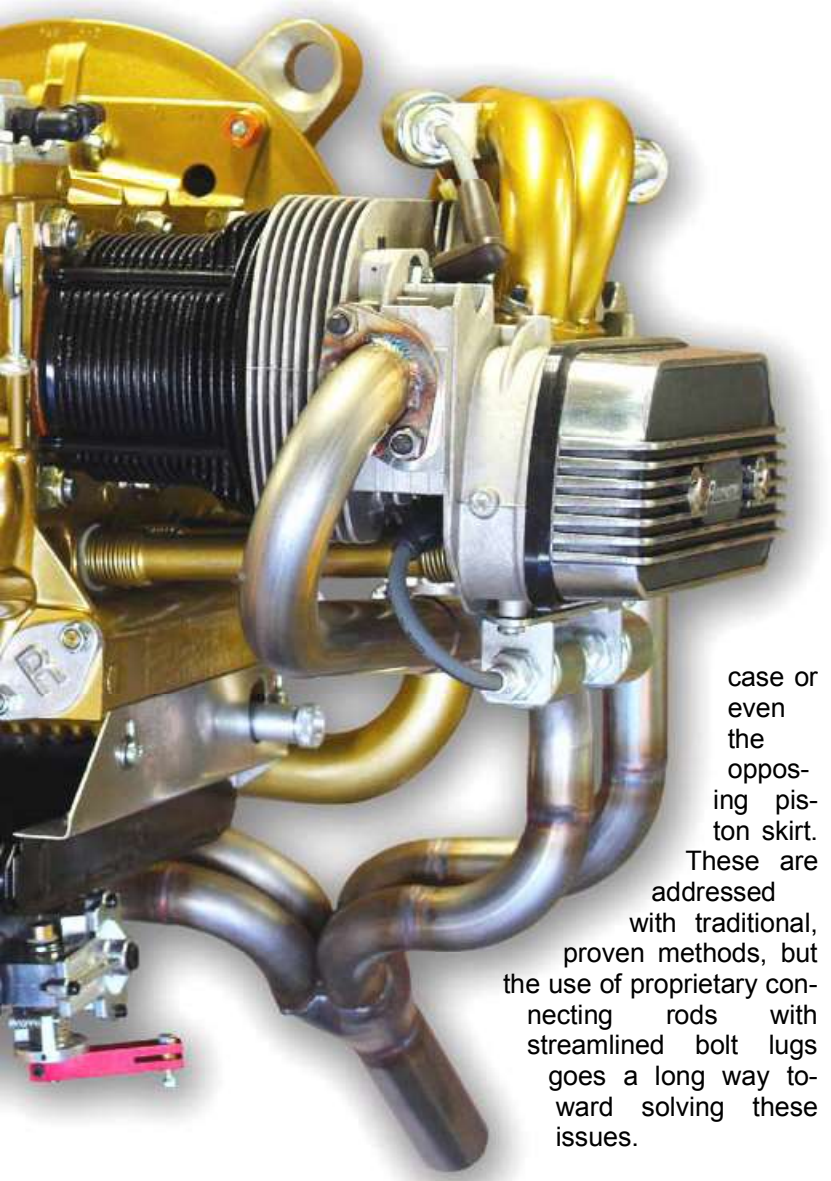


traveled by the piston from zero degrees to 180 degrees of crank rotation. Another way to look at it is the distance between the crank pin centerlines as measured when 180 degrees apart, so moving the pin's centerline farther away from the crankshaft centerline increases the stroke. When the stock diameter pin is moved away from the crank centerline, as it rotates toward the cam the clearance between the rod and the case is decreased.



What Revmaster does is to not move the stock diameter pin farther away from the crank centerline, but rather to grind the stock pin smaller in diameter, removing material from the surface of the pin that's closest to the crank centerline, resulting in the pin's centerline being moved outward as shown in the illustration above.

There are other clearance issues such as interference between the connecting rod cap or bolts and the crank-



case or even the opposing piston skirt. These are addressed with traditional, proven methods, but the use of proprietary connecting rods with streamlined bolt lugs goes a long way toward solving these issues.

There are other issues that arise when stroking the engine, the most obvious being taking care of the compression ratio, but in this instance, there is one issue that's not so obvious. When the piston is at the bottom of the stroke, care needs to be taken to provide enough support for the piston skirt. Revmaster handles this with the custom manufacturing of cylinders with longer spigots that enter farther into the case than stock cylinders. The deeper spigots do create other interferences inside the case that have to be dealt with, but Revmaster has refined solved all of them.

On the left is the special Revmaster cylinder designed to support the piston all the way to bottom dead center of the bored and stroked R-2300. Contrasting on the right is a stock VW cylinder. What's not shown is the additional machining to the spigot end of the cylinder that's necessary for clearance.

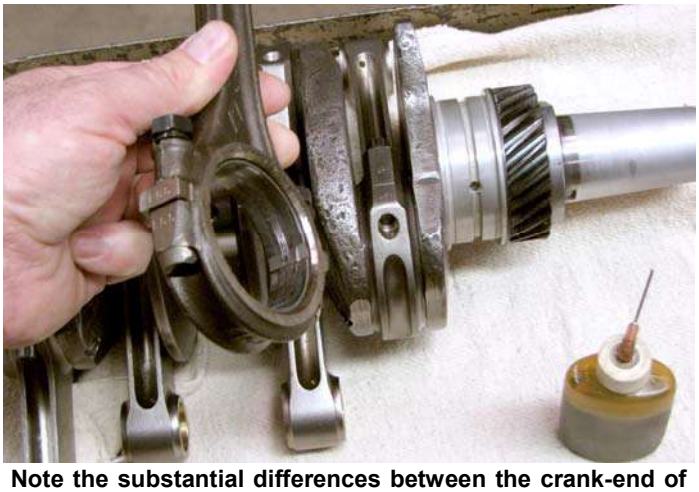
CONNECTING RODS

Forged 4340 steel I-beam connecting rods have 100% machined surfaces and utilize 9mm ARP 2000 rod cap bolts. They are balance-matched into weight groups of +/- 3 grams. The "big end" carries pressure-lubed plain bearings from a General Motors application, rotating on 2" polished and radiused journals. The small end (with bronze bushing) connects to full floating VW wrist pins that are retained by spiral circlips. Splash-style lubrication is used effectively to get oil into the wrist pins and piston lands via strategically-placed orifices in the piston interior and the rod end.

CAMSHAFT

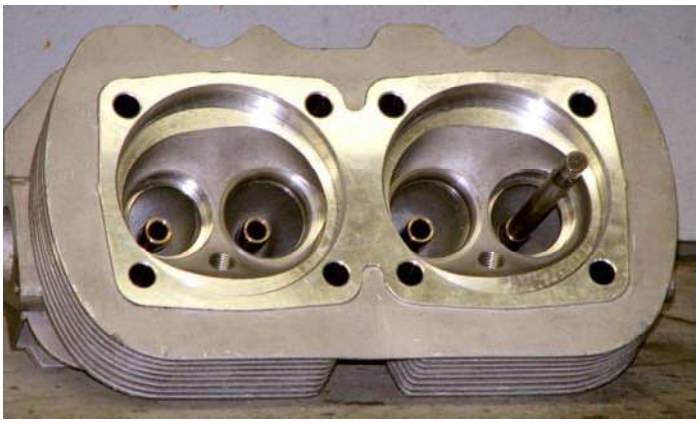
The camshaft is a chilled cast-iron unit with a lobe hardness of 60 HRC. In the casting process a "chill" (a metal piece placed in the sand mold) is used. These "chills" act as quenches which remove or "wick" heat rapidly from a specific area in the mold. The rapid cooling makes the metal near the chill much harder than the surrounding material without the chill. The hardening depth goes significantly beyond any other hardening process.

The custom grind of the R-2300 is not particularly noteworthy (270° duration with a .390" lift), being on par with a lift and duration for low RPM/high torque as one might suspect. It performs well between 2500 and 3400 RPM, with peak torque at 3200. Revmaster services the entire spectrum of automobile applications for the VW engine and will grind one of their camshafts for just about any profile for any application. The stock (aluminum) VW cam gear runs against the otherwise stock VW crank gear at the front of the engine, while the cam itself turns in pressure-fed plain VW bearings.

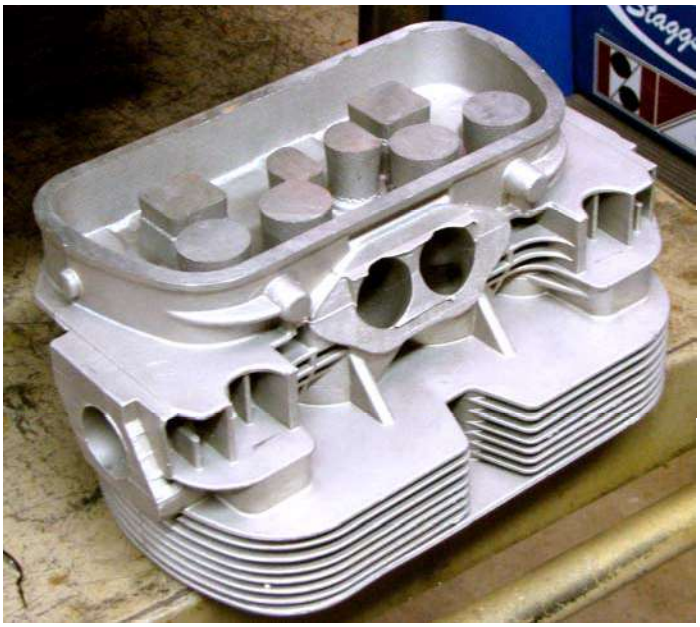


Note the substantial differences between the crank-end of the stock VW connecting rod in the foreground and those attached to the crankshaft.

Although a lot of parts that go into the Revmaster conversion are proprietary, they try to use off-the-shelf parts where ever they can. The pistons are high performance forged Mahle parts. Note how short the piston is and that when it's at BDC the rings are inside the case.



The areas around the combustion chambers have been beefed up to easily accommodate 92-94 mm bores. This particular head was built for automobile use and has only one set of spark plugs.



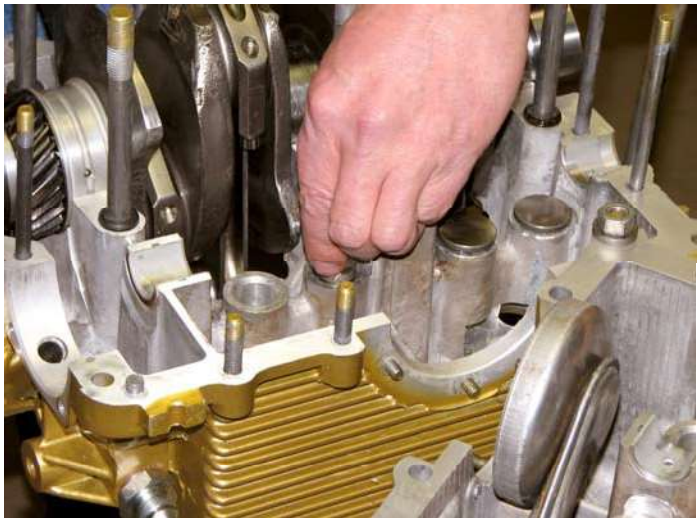
Rough casting as it arrives at Revmaster Aviation.

CYLINDER HEADS

Revmaster, through their history with EMPI, has had a big part in the creation or evolution of aftermarket VW heads. These heads are pretty much the benchmark for aftermarket high performance VW heads and aviation conversions but Revmaster has taken the evolution even further with the development of their proprietary 049 heads. With thicker sections where needed and opened air passages for better cooling, these heads are capable of dissipating the torturous heat that has otherwise peaked the VW aircraft engine at the 65-75 hp limit for sustained power.

LIFTERS AND VALVE SEATS

One of the frequently mentioned issues that plagued early VW conversions was the persistent (though incorrect) belief that the solid lifters in those engines required adjustment of the valve lash every 25 hours. The truth, discovered after exhaustive research by the Revmaster technicians, is that the original valve seat material was inadequate to tolerate the heat created in the combustion chamber once the displacement grew beyond the Volkswagen factory specifications. The hot valves had begun to lift tiny particles of metal from the seats and that erosion, in addition to destroying the efficiency of the combustion chamber, allowed the valve to sit deeper in the head. Testing proved a loss of about 0.001" of erosion per hour. The clearances at the rocker arm would then diminish or disappear altogether, causing some to believe that what was happening was that the valves were "stretching". Frequent valve lash adjustments (typically every 25 hours) became the common practice and continue to this day on VW engines that still utilize inferior valve seat material.



Installing the solid lifters in the Revmaster R-2300.

Other folks choose to modify the engine to accept hydraulic lifters, which takes care of the need to constantly adjust the valve clearances, but does not remedy the cause of the problem occurring at the valve seats. The solution is to use stainless steel valves paired with valve seats with a very high nickel-content alloy, which is precisely what Revmaster has been doing since 1985. Solid lifters work just fine and are very easy to set to the prop-

Joe Horvath showing us the inner-workings of his high volume oil pump that includes the ability to install a spin-on filter. The pump, which is driven by the camshaft, also runs an eccentric for driving the fuel pump.

er clearances. No additional maintenance beyond “check at annual” is required and the valve train has proven to be very durable since the improved hardened seats were adapted.

For installations that are tightly cowled or if high power is used for extended periods and higher than normal cylinder heads temps are an issue, another anomaly may show up besides the need to constantly readjust the valves: a repeated need to tighten the head bolts.

18 lb-ft of torque on the head studs equates to .011" of stretch. As temperatures rise and the thermal expansion of the head kicks in with the aluminum expanding more than the steel stud, there could be another .004" of stretch. Since the stud lengths are not equal, the amount of stretch is not equal either and asymmetrical pressure can be concentrated on the portion of the head where it meets the cylinder. Coupled with the softening of the aluminum head as the temperatures rise and the high concentration of pressure from the point-loading of the cylinder spigot on the mating surface, the cylinders can work their way into the head and the bolts will begin to lose their torque. If the engine is continued to be pushed during these conditions, the mating surfaces of the spigot to the head can begin to leak hot combustion gases and a hole begins to be cut into the head from the concentrated stream of hot gases, like a cutting torch.

To hedge against this anomaly, Revmaster developed for their earlier turbocharged models that used standard cylinders, a "power belt", which is a band of steel that's installed over the cylinder head end of the spigot, helping to maintain the cylinder’s concentricity and increases the contact area by 60 percent, reducing the point-loading enough to hinder the initial distortion of the softened aluminum. The test to see if the "fix" is needed that the lower head studs will need periodic retorquing. The R2033 however uses 94mm cylinders with sufficient wall-thickness already built in to the spigot, eliminating the need for the band.

Tucked neatly under the engine is the oil cooler. Efforts have been made to allow for draining the oil without having to remove the cooler. Since the engine uses a quality oil filter, there’s no need to drop the pan and clean the screen with each oil change. Braded stainless steel hoses plumb the oil to and from the cooler.

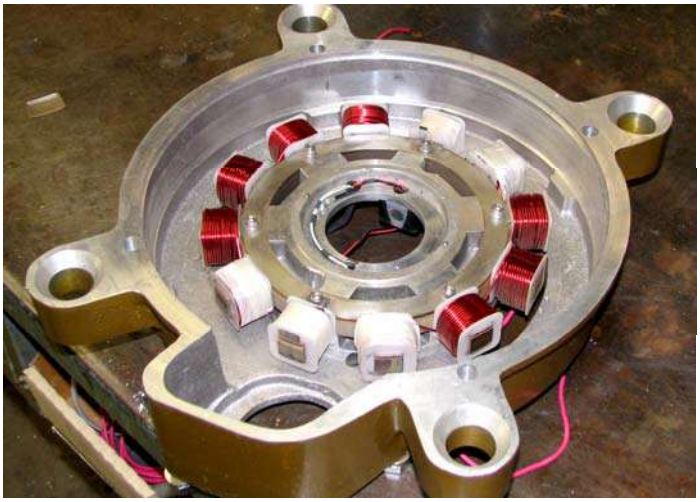
OIL SYSTEM

At the front of the engine, below the prop hub and driven from the end of the cam is the lubrication system source-another proprietary Revmaster casting. It includes the oil -pump cover section, the mounting location of the spin-on, full flow oil filter (available at any auto parts store), as well as the mount for the optional add-on diaphragm-type mechanical fuel pump. The oil pump uses 38mm gears as opposed to the stock 30mm VW gears, and can flow nine gallons of oil per hour. Besides servicing the normal oil passages for the internal engine components, pressurized oil is also plumbed to the propeller shaft housing via external braided hose and threaded fittings. Additional lines are routed to the oil cooler, which is usually mounted in a horizontal plenum positioned beneath the crankcase. Other styles and mounting locations for oil coolers can be specified by the customer.

ACCESSORY CASE

This accessory housing package accommodates four items critical to engine and aircraft operations. It contains three major operating systems: the dual alternators, the self-energized ignition source, and the electric starter, and it also provides the physical mount to the airframe. The R-2300 model is nearly identical to the proven unit currently used on the R-2100 (more than 60 of those units are now in use) and is yet another product made exclusively by Revmaster. The three electrical subsystems are independent but function as an integrated unit within one compact aluminum case. Let’s look at each component separately for the sake of clarity.

The precision machined alloy casting fully encloses the dual 18 ampere alternator package. Mounted to the interior face is a stationary twelve-pole stator ring. An aluminum flywheel incorporates twelve neodymium iron-boron magnets that are attached to the interior of the flywheel. These magnets, the strongest magnets commercially available, rotate around the 8½” diameter stator.



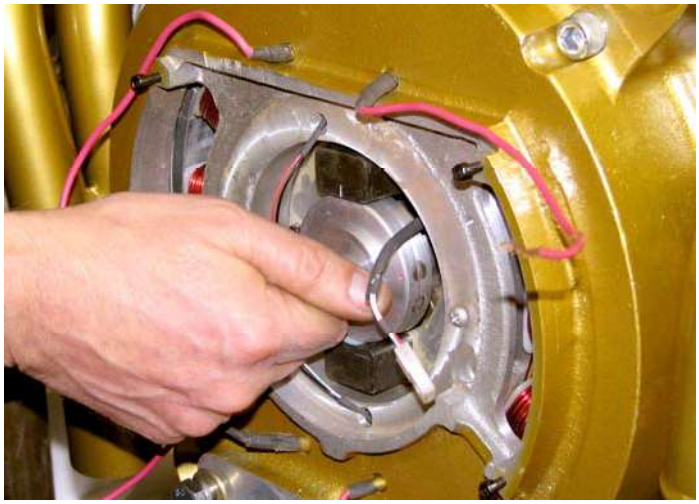
Any movement of the flywheel sends its magnets orbiting in close proximity to the stators, with 12 feet each of copper wire windings exciting the electrons and creating electrical energy. There are two groups of five alternator coils, each set functioning as an independent 18 amp alternator. The current generated from these coils is sent to solid state regulators and then to the aircraft's battery and operational power bus. In the unlikely case of a failure in one system, the other would remain unaffected.

IGNITION

The two coils which make up the ignition power source are located 180 degrees apart at the 12 and 6 o'clock positions (see photo above), separating the previously mentioned five-left and five-right alternator stator coil-groups. The ignition coils are also creating power whenever there is rotation of the flywheel, but their energy is dedicated exclusively to the CDI package.

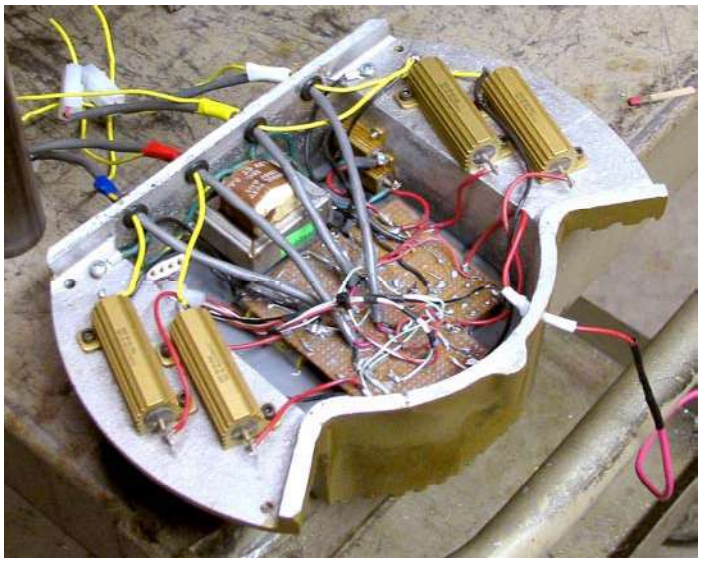
The back side of the accessory case, showing the ignition trigger sensors.

A triggering sensor mounted to the center area of the housing's interior receives a signal from a device attached to the end of the crankshaft, acting as the "distributor" and telling the CDI when to transmit the power to the eight mini coils which are positioned near the upper and lower spark plugs at each combustion chamber. Once the engine has been started, the battery is not necessary to operate the ignition.



With the accessory case installed, timing the ignition is next on the list.

The ignition advance is set at a maximum of 25° before top center. This would normally be identified as a fixed timing position but in reality the "effective advance" behaves as if the low RPM timing is at 15° BTC. This desirable situation is created by magnetic precession in the self-energized design. Lower voltage exists in the system



The "brains" behind the brawn. Once the timing is set, the electronics are wired up and bolted in place,

when the engine is turning slowly, reducing the current flow at the timing triggers. The engine likes 15° BTC for easy starting and comfortable idle but as RPM rises, so does the voltage and the ability to "snap" the timing, and the advance moves quickly to its maximum setting. Experience has proven that 25° BTC, while possibly leaving a few horsepower untapped, is a smart place to limit the spark advance because it greatly reduces the possibility of destructive detonation.

STARTER

The aluminum flywheel includes a steel starter ring that is heat-shrunken onto it. The geared electric starter motor is a compact 6" long model that weighs 8.5 pounds. Experience has established a long service life for this economical unit, which is mounted in an aft cantilever

style. Previously installed starters were proprietary and were designed by Molt Taylor of Mini-Imp fame.

Machined locations for the polyurethane-cushioned engine mounts are located in the “corners” of the accessory case casting. With the symmetry of this design, the unit can be rotated 180º to facilitate the starter motor being positioned at either the top or bottom. This can be a particular bonus for airframe designs such as the Zenith 601, whose firewall angles aft at the top, and the Sonex, whose firewall rakes aft at the bottom. Slanted firewalls present unique challenges when installing engines other than those that were originally planned by their creators, so the ability to place the starter motor in the location with the most surplus space can be a huge advantage.

DETAILS

The Revmaster R-2300 comes complete, ready to run and in fact, test run. While it’s not a kit like others offer, Revmaster will provide it as a kit if you so choose. While I was at the Revmaster facility conducting the interview and photo-shoot for this article, the entire engine was built from beginning to end (with many interruptions for questions and photos) in a little over two hours. At the peak of production back when Quickie Aircraft Corporation was ordering 100 units per month, Revmaster had a full-time staff of five engine builders knocking out 2-3 engines per day. In the big picture, absorbing the cost of building each engine right the first time, and checking by actually running it, far outweighs the headaches and problem solving with a builder who could be thousands of miles away, not to mention the damage to a company’s reputation that might come from a builder making mistakes and the product being blamed.

Everything pictured in this article is included. There is nothing more for the builder to buy or supply to make the engine run except fuel to the RevFlow throttle body injector (carb) and electricity to the gear-driven starter. Airframe-specific items like the exhaust system, baffling, engine mount, and propeller are of course not sold with the engine, but in some cases are also available from Revmaster as separate items.

Revmaster Aviation has a customer base that is pushing 40 years old. The name is trusted and respected throughout the aviation insurance community as an "approved" automobile conversion or alternate engine. Each engine (and most of the individual components) has a unique serial number and Revmaster has the complete records going all the way back to the raw materials. If anyone has ever considered the purchase of a 25 year old Revmaster, a quick phone call to Joe Horvath at Revmaster has probably netted the history of that engine, especially if each subsequent owner contacted Joe when they became the owner of the engine. When contrasted with a home brewed conversion with various parts collected from various vendors (some of whom may have gone out of business), it is easy to see how the insurance industry considers the engines from Revmaster to be more like certified engines than auto conversions. This is no accident, since back in the early days the plan was to create a certified engine from the proprietary parts and since that time, all parts have been handled with the same paper trail and quality control standards as certified parts. The R-2300 and the R-3000 may still some day be FAA certified, and will most likely be ASTM compliant for use in factory-built special light sport aircraft.

The Revmaster facility is as complete as a manufacturing shop can be, shy of having a foundry. From the initial drafting through the entire manufacturing process and including final assembly, testing, crating and shipping, everything is done in-house. Customer service is paramount and the people at Revmaster are prepared and available to assist the user in any way imaginable, from supplying all parts that they manufacture (including new old stock) to completely rebuilding an entire engine.

Revmaster is also fully equipped for thorough testing, as evidenced by the patina on the dynamometer and the Magnaflux equipment, both of which have been in use for as long as I've been alive. Numbers published by Revmaster are well documented through actual testing, not by guessing. For the sake of time, production engines are tested outside with a test club of known performance. If the engine can't swing the club to the prescribed RPM with the anticipated manifold pressure, it doesn't leave the shop. In this way, testing can be done in under an hour rather than a full day in the test cell.

The test cell is mostly reserved for specific performance research and development such as proving porting experiments after flow bench testing, intake and exhaust manifold designs, and carburetion and bore-and-stroke combinations. With the dyno, 1-3 horsepower gain or loss is easy to document and is repeatable in the controlled conditions of the cell.

Those interested in the Revmaster R-2300 or any of the products they offer should feel free to contact them at their Hesperia office. Joe Horvath will be presenting forums at the upcoming COPPERSTATE EAA Regional Fly-in, KCGZ Casa Grande, Arizona October 21-23.

From their website, www.revmasteraviation.com:
We welcome visitors;
a phone call in advance is appreciated.

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