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Practical maintenance advice for owners and pilots

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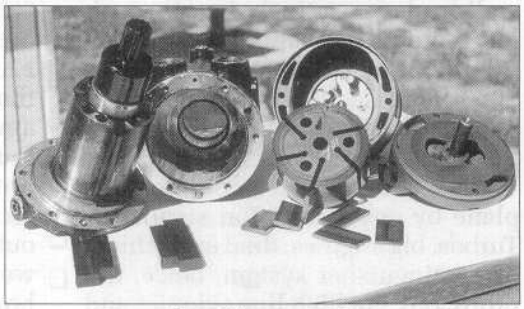

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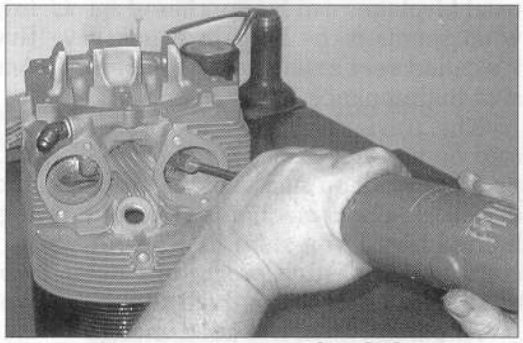

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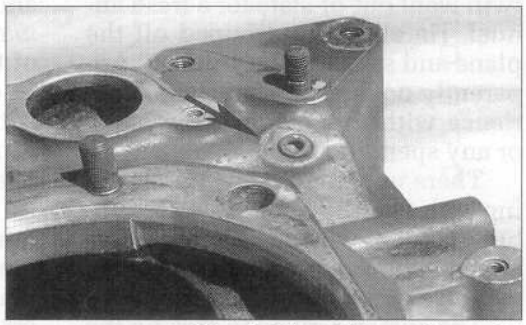

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Cyl 1 CHT	450	445	455	450	460	460	460
Cyl 2 CHT	475	470	475	470	475	470	490
Cyl 3 CHT	440	460	465	460	465	465	465
Cyl 4 CHT	445	450	455	450	455	450	540
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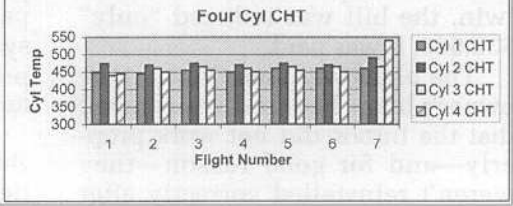

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Inside LPM

Porting & Polishing

The old hot rod trick gains greater respect through exhaustive empirical testing and years of use

by Mike Palmer

Conventional wisdom says if you want more power from your aircraft engine, you have to add new parts—like higher compression pistons or a turbocharger. But suppose I said you could get more power by removing parts.

It's also true that by removing about twenty-five cents worth of aluminum from the ports of your cylinders, you can gain a conservative 4 HP per cylinder. The operation is called Porting and Polishing (P&P).

Basically, P&P allows your engine to breathe easier, allowing it to expel exhaust gases more completely so it can inhale more air. P&P is somewhat like removing casting flash, removing obvious hindrances to airflow in a port. But it goes beyond that, removing material in non-structural areas to streamline the port. A good P&P job also goes beyond the ports.

According to the classic MIT text *Internal Combustion Engine Fundamentals*, "the valve, or the valve and port together, is usually the most important flow restriction in the engine." Knowing this, my host shop for this article, Performance Engines, also grinds the valve seats and the back side of your valves when they port and polish cylinders.

P&P is for you if you're already using the highest compression pistons allowed for your engine in an experimental or homebuilt aircraft but still want more oomph. Or maybe you want more power but don't want high compression pistons because you're worried about detonation if 100LL becomes extinct.

According to the Sales Manager, Stuart Featherstone, at this time Performance Engines will only perform the porting and polishing service for experimental engine owners. Although Performance Engines is considering applying for FAA STC approval for certificated engines in the not-too-distant-future.

Ed note: Any time there is a gain of 10 percent over rated horsepower an STC is required. Any time the configuration of the cylinder is altered in a way that could theoretically affect strength or is different from the factory original approved design drawing in any way the FAA gets very interested.

In the past there have been several overhaulers who have certainly pushed the envelope with what is acceptable to the FAA, by saying things such as if it's not specifically prohibited, then it must be OK—self serving logic to be sure.

The cost for P&P is $150 per cylinder, so if you had to choose between pistons or porting, the cost is about the same. But considering the time and attention lavished on your cylinders during the P&P operation, you're getting a deal. Included in the price is a cylinder inspection and hand-lapping the valves. The entire operation should help cylinder life, and after thousands of operations, the prognosis looks good.

It takes a deft touch and experienced hand to properly port a cylinder for optimum airflow. This technique has been around for many years but has never caught on due to FAA concerns and until now a lack of empirical data.

Performance Engines

I recently flew to Brackett Field, in La Verne, California, home of Ron Monson's Performance Engines, where I spent a full day watching a stock parallel valve Lycoming O-360 cylinder (also used on the -540) get the full treatment: porting, polishing and a five-angle valve job. If we had done a set of cylinders, we would have done the last step, flow-matching, where the worst cylinder of the bunch is touched up to match the rest, ensuring all cylinders flow equally well.

We documented our progress on a flow bench, before and after the operation. For this article, we also tested in the middle of surgery to get more insight into how the valve grind affects flow. Monson's shop is famous in Reno circles for, well, performance engines. Think of Reno as their R&D lab.

Port Whine

Since I don't race at Reno, I hadn't heard about Performance Engines when it was time to overhaul the cylinders of the Lycoming O-320 in our Glasair. I had called other shops across the country asking about porting & polishing and flow matching as a way to gain extra power. The responses I got, like my phone calls, were all over the map.

Some shops didn't think porting made any difference—although based on what I know now, that may be code for "we haven't made the

UPFRONT TIPS

- **The latest flow bench data supports P&P for HP increases**
- **Certificated engines require FAA approval for any mods not approved by the factory manual**
- **A five-angle valve job can be as beneficial as P&P for power and it also increases reliability**
- **Be sure whoever modifies an engine will stand by the longevity of the mod for warranty support**

capital investment in the flow bench and equipment required to do the job right."

For the shops that did think it made a difference, there were wild claims for increased horsepower, like 30 more HP out of a 160 HP engine. It sounded too good to be true, and at a quote of $250 apiece, I passed.

But when I decided on a set of ECi's Titan cylinders, I asked Customer Service Rep, Mr. Tim Morland, what tricks, if any, I might try to increase performance. He candidly offered that I should round any sharp corners or rough spots I could feel in the valve ports with my fingers. A mild form of porting.

8000 RPM Red line

When you mention porting & polishing in hangar sessions, the usual response is, "Yeah, that works for car engines turning eight grand. But airplane engines turn so slowly, porting makes no difference." That might be true if airplane engines were "designed" like car engines. But they're not.

In his quest to learn what works and what doesn't when porting cylinders, Monson made some rubber plug molds of the ports of a parallel valve cylinder. As you can see in the photo, there's a 90-degree turn from the port to the valve. This may be good for inducing swirl in the combustion chamber, but a 90-degree angle can't be good for flow.

It's even worse when you know that air is moving on the order of 100 mph or more inside the port, according to John Schwaner's *Sky Ranch Engineering Manual*. We buy cars streamlined for travel at 55 mph, so why wouldn't we want ports streamlined for air velocities more than twice that speed? That corner needs to be softened on the intake port. Not so on the exhaust.

On the exhaust port, one must make the best of a bad situation. In Lycoming style cylinders, the flow from the exhaust port resembles the letter "D" on its back. In other words, there's dead air at the bottom third of the port. Interestingly, the staff at Lycoming may have picked up on this when they developed the angle valve cylinder.

According to Monson, one of the reasons the angle valve develops more power is because the floor of the exhaust port is higher than its parallel valve counterpart. This allows a smoother airflow transition from the valve seat to the port opening. This results in more flow and consequently, more power.

Even though our engines turn relatively slowly compared to our drag racing friends, there's little time to fill a cylinder with air, so we should make the best of it. At speed, the intake stroke is only about one hundredth of a second long.

Remember, we have to move a car's engine worth of air through four cylinders, not eight. Even though, like automotive engines, our intake valves are larger than our exhaust valves, unlike automotive engines, our intake ports are not. Feeding air to a large valve through a small port makes no sense. (Intake runners in performance car engines are huge.) Given these restrictions, an aircraft engine is the poster child for porting help. So I gave it a try.

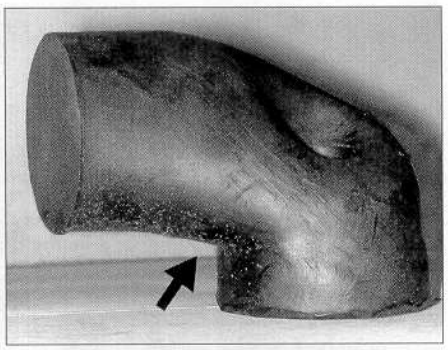
A Little Knowledge is...

With the help of an auto engine "porting kit" consisting of some rolled sanding drums and a long shank for a die grinder, I gave it a try. Armed with a little knowledge, I spent a day rounding the ports on the intake and exhaust, primarily at that 90-degree corner. But this is where a little knowledge is a dangerous thing.

Well, not dangerous, but without the benefit of a flow bench and experience, I didn't know it's best not to roll the edge of the exhaust seat as much as the inlet seat. A valuable tool on the flow bench consists of two tiny pitot "velocity probes," one bent like a fishhook for the intake and a normal one for the exhaust. These allow you to map the airflow in the ports.

Monson has spent a lot of time experimenting with non-serviceable cylinders on the flow bench, trying different things. He'd grind a bit here and grind a bit there, adding back with clay, probing along the way to find dead zones. He found that it's actually best not to roll the exhaust port too much on a parallel valve. That keeps a vortex from forming at the floor of the port.

Even though there's that letter "D" flow, it's best to keep it so that the exhaust remains attached to the top of the port. This is the expertise you're paying for. There's no way you could know this without the proper



A casting was made of the interior area of cylinder intake so restrictions could be better analyzed. That 90 degree angle at bottom is a real drag—literally.

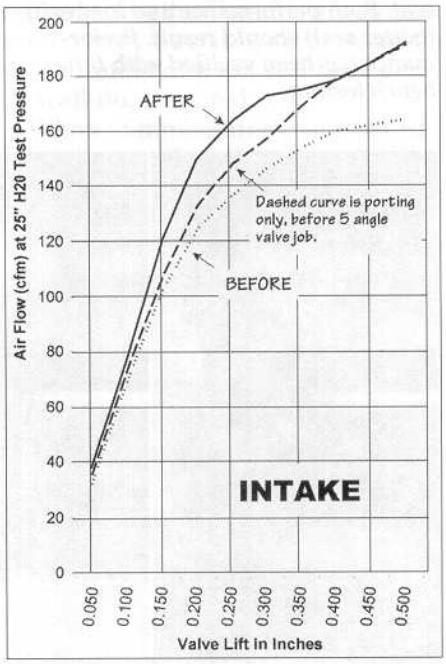
equipment. Now, let's see how the pro's port.

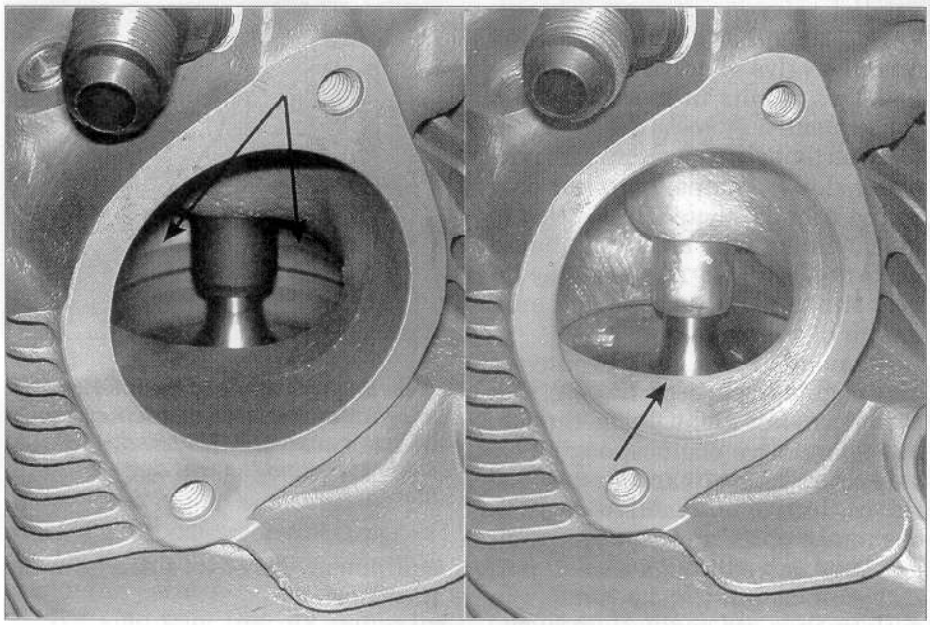
Benchmark

Jon Marquette, who has been manning the P&P department for six years at Performance Engines, was my guide. Markette started by checking a stock O-360 parallel valve cylinder on the flow bench. He collects this for all customer cylinders to show before and after data.

The cylinder is mounted on a custom jig and the air pressure differential is set at 25 inches. That's about

Extensive flow-bench work has been done on many cylinders to develop before and after empirical data to show the positive effects of P&P as well as a 5 -angle valve job.





This is one of the best before and after photos we've seen to show exactly what happens when a cylinder valve area is fully ported. The ported cylinder is on the right with arrows reflecting areas where most metal was removed to improve breathing.

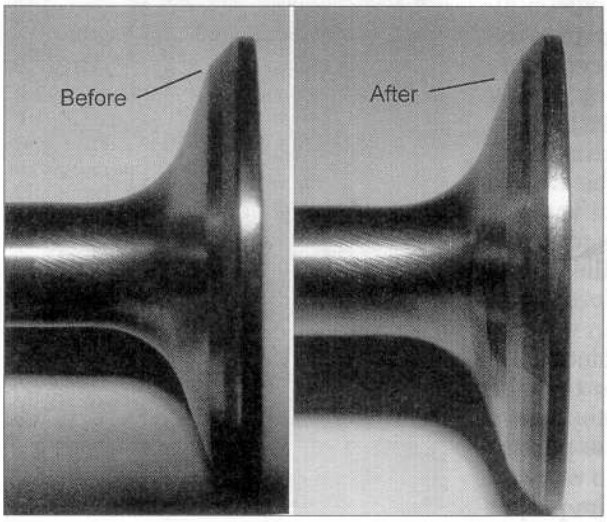
what a cylinder would see at sea level on the inlet side, taking into account induction losses. The flow direction can be changed from suction to pressure, for the intake and exhaust measurements respectively.

After a leak test, the appropriate valve is opened in 50 thousandth increments up to a half inch, to simulate cam operation in various stages of lift. Air flow, in cubic feet per minute (CFM), is noted on a digital display.

All that air screaming into or out of the cylinder during flowing makes a loud roar. Interestingly, as the process of porting moved along, it seemed the noise wasn't as loud or as harsh sounding. It seems as the airflow became smoother, the sound did too.

After completing the run, Markette opened the valve past the cam's maximum half-inch lift to show that, past this point, the valve is not the bottleneck in airflow. The bottleneck is the port itself. (Which is why they sell larger valves and seats for competition engines.)

Below, while difficult to really see, the 5-angle valve job makes for a superior sealing ability of the valve to the valve seat. Both performance and longevity (better seal) should result. Performance has been verified with flow bench testing.



After taking these measurements, we moved from the flow bench to the work bench. We did only one cylinder for this article, but on your engine, Markette would note which cylinder flowed the worst in a set, so he could come back later and match its flow to the rest.

Art and Science

This is where real craftsmanship comes in, coupled with the right tools. Markette made the grinding process look easy. Like watching surgery on TV, the ease at which he worked is a testimony to his skill.

Using a variable speed electric rotary tool (not unlike a Dremel tool on steroids), he deftly started nibbling at the ports. Controlling the speed of the tool with a foot switch, it was like watching a sculptor perform a ballet. The "torquey" tool, coupled with sharp cutters, allowed precise work at low speeds without the tool skipping around, tearing up the port.

After a coarse grind, he switched to a finer, smaller cutter and continued to shape the port as they've determined best. The grinding is very conservative and amounted to a very small pile of shavings, most of which came from the 90-degree corner.

The exhaust port is not radically altered. The ports are then polished with rolled sanding drums and a proprietary final process to smooth them out.

Polishing it Off

These guys have been doing this so long that they know to polish differently for fuel injected engines versus carbureted. Carbureted engines require some surface roughness to keep the fuel atomized. If the walls are too smooth, which you might think is a good thing, the fuel will drop out of suspension, which isn't a good thing.

Fuel injected engines don't have fuel drop out problems, so their walls are polished smoother. Either way, the ports are a lot smoother than stock, investment castings notwithstanding, and this improves the longevity of the cylinder.

The smoother surface helps keep hot exhaust gases from transferring heat to the walls of the port, keeping the cylinder cooler there. Since the exhaust port is a prime candidate for heat related distress, anything that helps this area stay cool is welcome.

They keep the gases flowing toward the top of the port, allowing heat to transfer to the outside fins much easier. When I put my hand near the exhaust port during flowing, I could feel the air deflected downward.

After porting and polishing, it was back to the flow bench for an intermediate measurement. We wanted to document what changed with just this operation. Interestingly (see chart), we found that P&P primarily

affects airflow at large air volumes, when the valve is open widest.

There's not much improvement in airflow when the valve is just cracked open, and the cylinder isn't flowing a large volume of air at that point. That makes sense. But in operation, the valve spends more time in transition off its seat than it does full open. Can anything be done to improve airflow in this region?

Valve job

This is where the fancy five-angle valve job comes in. Markette told me that about half the power improvement from porting and polishing comes from modifying the cylinder, and about half comes from modifying the valves. The flow data corroborate that.

Stock valves have one angle: 30 degrees for the intake, 45 degrees for the exhaust. That makes a corner, as you can see in the before photo. It may not seem like much, but they have found that there's quite a lot of drag as air tries to twist its way through the narrow channel formed by back of the valve and the valve seat when the valve is partially off its seat.

After much experimentation, a five-angle valve job was chosen. Actually, the valve gets only two angles on it. The seat is cut with three, for a total of five. This allows air smooth passage at partial valve lift.

For clarity, I've shown only the results for the intake port, but the exhaust port shows similar gains. As you can see from the chart, there's an appreciable increase in flow, on the order of 20 percent. The more air you can get into a cylinder, the more power you can make.

Bonus Round

In addition to the improvement in performance from the five-angle valve job, there's another longevity improvement simply from getting a custom valve job. Even new factory cylinders often have concentricity problems between the valve and seat. Often, the valve doesn't center on the seat.

This can put a lot of stress on the valve, and in an extreme case, an unseated exhaust valve will cause a hot spot that might cause the valve face to crack. By grinding the seat to match the valve perfectly, you get much better valve life and a good seal at the seat. Moreover, the seat will be self-cleaning this way.

Rocket Science

I started this article by saying there are two ways to increase power from a cylinder: increase compression or port the cylinder. Technically speaking, the former increases the thermal efficiency of the engine; the later primarily increases the volumetric efficiency. The difference is where the gain in power comes from.

When you increase compression, you extract more power from the same amount of fuel. Your fuel economy goes up, or another way of saying that is, your Specific Fuel Consumption (SFC) goes down. You'll burn the same amount of fuel at full throttle while making more power.

Contrast this with porting, which allows the cylinder to breathe better during intake and exhaust, and also allows better scavenging during valve overlap. You make more power here by burning more fuel. While there might be a slight decrease in SFC because the induction system is less "draggy" SFC will stay about the same. That means you'll burn more fuel at full throttle while making more power. EGTs and CHTs will also be higher as long as you make that extra power.

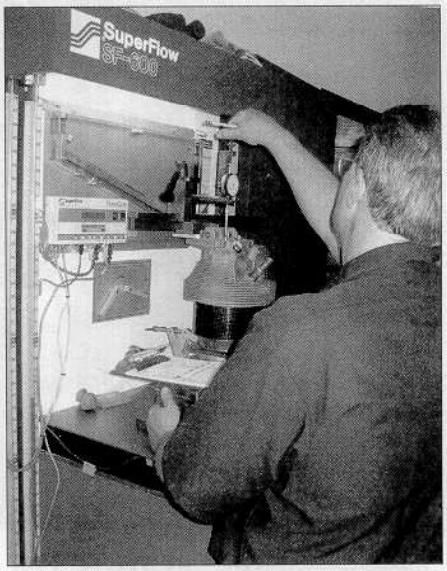
You can always throttle back in cruise after using that extra power to climb to altitude, which is where extra power pays the biggest dividends anyway.

If you've wanted to try running lean-of-peak in cruise, but your engine runs too rough, flow- matching should help the cylinders ignite more uniformly in this chaotic part of the curve.

Markette quotes four HP as a minimum gain for conservative porting. "You mileage may vary." Think of these numbers in terms of potential. There's a minus 0, plus 5 percent factory tolerance on the horsepower output of your engine. If you had an O-320 rated at 160 HP, wouldn't you rather be on the plus side, making 168 HP instead? Think of P&P as ensuring your engine goes to the top of the class—with extra credit.

Having said that, Markette says a 6 HP increase per cylinder is the norm and some do better. For the latter, I suspect this is like having a quadruple bypass heart operation. If your arteries were really clogged before, you're going to feel a big difference afterward. Cylinders vary widely in consistency—probably the reason for the variation in factory power output.

The worse your stock cylinders flowed before, the better they'll feel after.



The significant difference not found in other shops is the flow bench testing of each cylinder to assure the performance improvements are there. These benches are very expensive.

Warranty Woes?

If you're having brand-new cylinders worked by Performance Engines, how will porting and polishing affect the manufacturer's warranty? Porting and polishing has been with us for some time, but it was formerly deemed more of a hot rod trick and not well documented.

When manufacturers were asked about the benefits of porting & polishing and why they weren't doing it, they said they didn't do it because they were worried about removing material from classically crack prone areas. But that could be code for "We're not going to take the time for this level of old world craftsmanship."

Doesn't removing stress risers by polishing help prevent cracking? It's hard to know if cracking ever was a valid concern or simply an excuse. But a lot has changed since then. Aftermarket cylinder makers have

(Continued on page 24, 3rd column)

(Port & Polish con't from page 15)

beefed up crack prone areas and are using different (better) alloys. But frankly, there isn't very much material removed in this process, as you can see in the photo. Cracking shouldn't be a concern.

Still, I asked about how P&P affected warranty, and the answer is "It depends." First, you should know that Performance Engines has ported thousands of cylinders in the past many years, and for engines they build, they offer a 100 percent warranty during the first year regardless of time in use. That should tell you something.

Anecdotally, from years of reading LPM, I've observed that a manufacturer's warranty is only as good as the manufacturer. Even if a cylinder is stock, if it cracks under warranty, it seems the factories are quick to say you did something wrong—leaned too aggressively, shock cooled the engine, etc.

Whereas the aftermarket manufacturers tend to stand behind their product, as ECi did when it made good on our ten-year-old Cermicrome claim. If you had a cylinder ported and it cracks at the base where no work was done, you're much more likely to get warranty coverage from the aftermarket.

Kudos

Many thanks to the folks at Performance Engines giving me a full day of their time. An FAA engine repair facility, they have an impressive shop with all sorts of specialty equipment for engine work. They can dynamically balance parts and grind custom cams.

In addition to building stock and race engines, they also sell a wide range of stock and race engine parts, including their own forged high compression pistons, their own Allison valve seats that resist seat deformation when hot, larger valves and seats and much more. Visit them on the Web for more info at www.performanceengines.com or phone at (800) 816 1485.

Mike Palmer is an ATP and former CFII. It took him 10 years to build his Glasair with a friend. The Glasair now has 2200 hours, and he is always looking for ways to improve upon it.