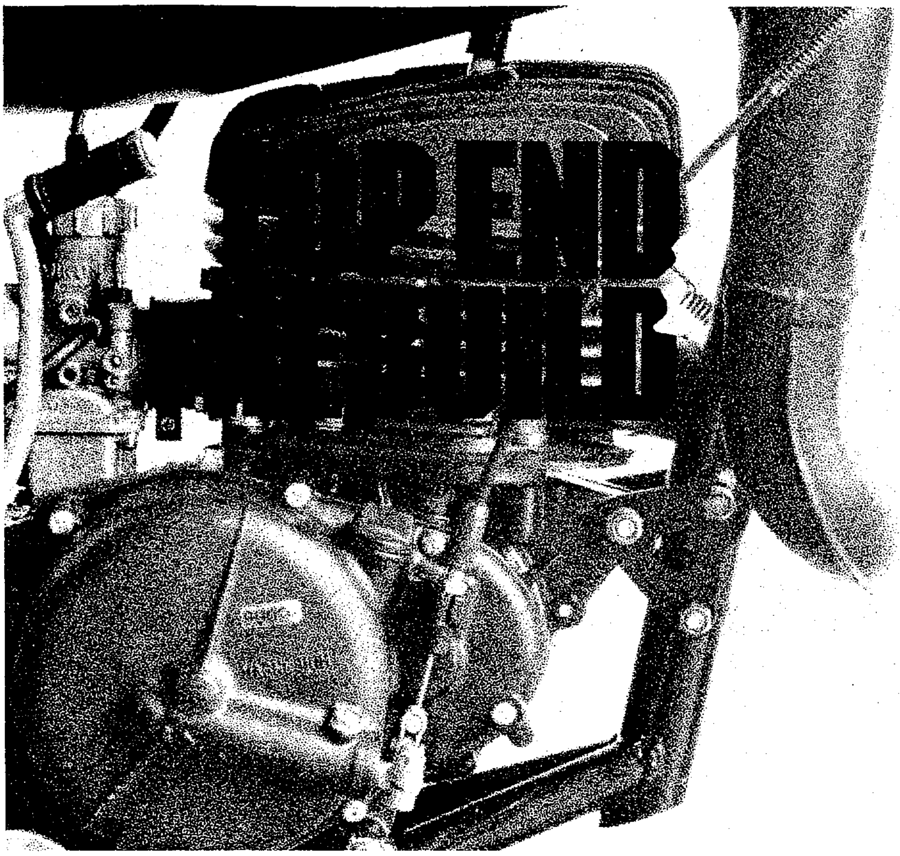


Doing it right will give you better performance, and more miles before you have to do it again. By Gordon Jennings

● PISTON SEIZURE is the malady that seems most often to strike off-road motorcycles. Sure, the active dirt pounder occasionally will find himself fixing a busted gearbox or spavined suspension, but if he's riding a bike powered by a two-stroke engine it's the stuck piston he'll come to know best. It's a problem so familiar to our desert enduro riders that they think of it as being not much more unusual than spark plug fouling. Indeed, some of the desert rats are firmly persuaded that piston sticking is like measles: new or freshly rebuilt engines should be exposed to mild seizure early in life so they'll acquire some measure of immunity to the ailment in their maturity. It is expected that a new bike's engine will, in their words, "tighten just a little," while sipping its first three or four gallons of fuel and that thereafter, if the piston hasn't over-tightened, it will be ready for action.

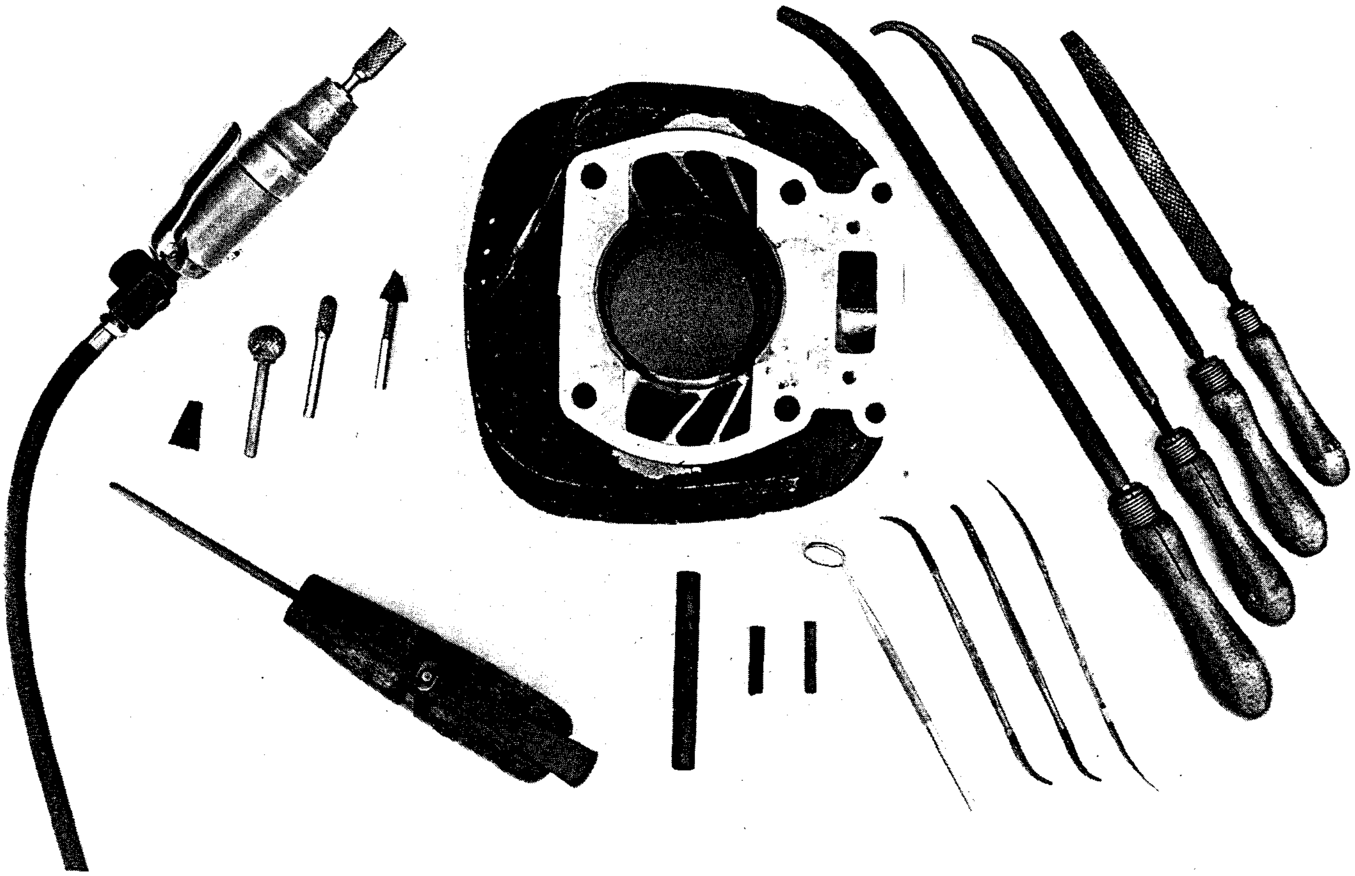
We will agree that a partial seizure does produce enough piston/cylinder clearance to accommodate all but the extremes of piston expansion. But we also view it as an unnecessarily harsh, even brutal, means of shaping a new piston to suit its bore—about like driving a spark plug home with a sledge rather than screwing it into place. There is a better way of getting a two-stroke engine broken-in and ready for active duty, and there are small touches you can add to a top-end rebuild that will make your bike run a little quicker and a whole lot longer. In fact, (and some of you aren't going to believe this) it is possible to make most two-stroke engines so reliable they'll keep running in perfect health until their rings wear out—and then need nothing but fresh rings and decarbonizing to be ready for another season. Sound improbable? It isn't, as you can discover by heeding the following warnings and advice.

Let us first lay to rest the widely held notion that two-stroke engines won't seize if their pistons are fitted with a lot of clearance, or given that clearance by being hammered during break-in to the point of a slight seizure. Neither of these ideas is valid, though the latter—if you get lucky—comes close. In reality, a really loose fitting piston is the kind most likely to seize. Researchers in Japan found that a 66mm x 64mm two-stroke engine making 33 bhp with its pistons fitted at the manufacturer's recommended .002-inch would produce only 30 bhp after the piston/bore clearance was opened to .004-inch, and the engine seized after a few minutes of running. A further increase in clearance, to .006-inch, dropped this engine's power output down to 27 bhp—18-percent down from its tight-piston peak—and caused it to suffer an almost immediate, very severe piston seizure. Also, lest you think this was only a laboratory exercise and without parallel in the "real world," be advised that road racing's sharper tuners have found the same to be true on the race track: a Yamaha TZ750 with pistons fitted to very close .00016- to .00018-inch clearances will run faster and more reliably than one that's a little loose.

You are entitled to wonder why a tightly fitted piston should give a horsepower edge and have a lessened tendency to seize? After all, it does seem that a tight fit would produce more power-reducing drag—and leave less space for piston expansion. The explanation for this apparent contradiction lies in the areas of sealing and cooling. Combustion chamber temperatures commonly are around 3500°F., well above the melting point for aluminum-based piston alloys, and the reason pistons don't melt is that they are able to lose heat into the cooler cylinder walls. Heat transfer from the piston out into the cylinder is more rapid when the adjacent surfaces are in very close contact. Equally important, tightly fitted pistons provide a vastly better gas seal than those even slightly loose, which means they have a smaller volume of high-temperature gases leaking down past their skirts. Both the heat-transfer rate and volume of gas leakage influence power, and the tendency to seize. Heat radiating down from the underside of the piston raises the temperature of the air/fuel charge in the crankcase; combustion-gas leakage heats and dilutes the charge; both heating and dilution thin the charge ultimately trapped in the upper cylinder and cause a reduction in power.

Interestingly, it is not thermal expansion that causes piston seizure nearly so much as it is a failure of lubrication. To a great extent the outward expansion of the piston in its cylinder has been made a self-limiting process. A correctly fitted piston quickly expands to assume what virtually is a zero-clearance fit in its cylinder as the engine comes up to working temperature. Then, close contact having been made, heat transfers from the piston out into the cylinder walls fast enough to keep it from getting hotter and expanding more. There is a balance, and it is one not seriously effected by throttle or load. Once the piston is in contact with the cylinder both expand and contract with the changes in temperature that come with variations in throttle and, for that matter, cooling air velocity. Many years ago this balance existed only within narrow temperature limits, due to the great differences in the thermal expansion rates of ordinary cast iron and the aluminum piston alloys then available. Today, metallurgists have all but eliminated the once-broad iron/aluminum expansion differential, and piston/cylinder bore running clearances can be maintained under all but the most abnormal of operating conditions. The limit can be exceeded by doing a mile or so in deep sand at full throttle, full load, and with hardly a breath of cooling air passing over the cylinder. It can also be passed if an engine begins to detonate, which will put heat into a piston faster than it can be transferred to the cylinder. But under any-

PHOTOGRAPHY: ROBIN RIGGS



Ne used an air motor and rotary files to speed some of our clean-up work; it can all be done with ordinary rat-tails, rifflers and fine-grit stones.

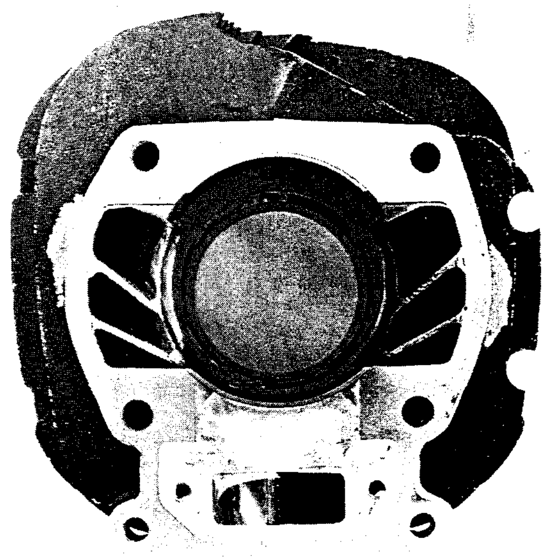
TOP END REBUILD

:hing resembling normal operating condi- :ions there is no reason for a properly broken-in, well-lubricated engine to seize.

In the real world, there are more well-lubricated engines than those that get a proper break-in, and that's unfortunate because the damage done in hammering a new engine can offset the lubricating efforts of the best and most lavishly-provided oil. Generally, people have the idea that new pistons *wear* into shape in their first hours of running, and that's wrong. You could fit pistons with absolute precision and they'd still need a break-in period. Pistons come out of the manufacturing process with a lot of locked-in stresses, and will try to distort like mad the first time they are heated. Give a piston enough time, heated and confined in the cylinder bore, and its internal stresses will be relaxed without changing the shape it is supposed to have. But if you force a new piston to take too much heat, too soon, it may try to become square or triangular instead of round, and nothing good can come of that. What generally happens when the break-in process is forced too fast is a widely distributed distortion of the whole piston, with a final relaxation into a really sloppy fit.

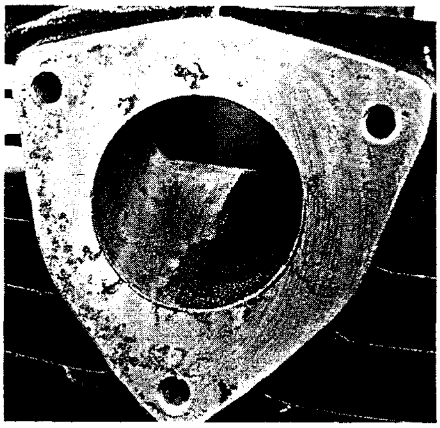
One symptom of piston distortion, which you may find even when no trace of seizure is apparent, is that the piston's wristpin will no longer slide freely in its pin holes. Another sign of piston distortion we've seen all too often is an uneven discoloration of the piston skirt below the rings. This also can mean that the rings aren't sealing properly, and we'll have something to say on that subject a bit later. You should be aware that a piston's rings are not enough, acting alone, to keep combustion gases in the upper cylinder where they belong. Rings handle the worst of the job, but it takes a second line of defense, in a really tight fit between the piston and cylinder bore, to make the seal completely effective. So when the break-in period is made only a very little longer than the first warm-up and the piston becomes permanently distorted—tight here and loose there—the hot gases tend to sneak down along the areas not in close contact with the cylinder. The leakage heats and dilutes the charge in the crankcase, which is bad for power, and if there's enough leakage the piston will seize no matter what kind of clearance it was given when assembled.

That piston skirt discoloration we mentioned is a sign of leakage, and a portent of disaster. It's cooked oil, and oil that hot either fails to lubricate well or turns into gums and varnishes that won't lubricate at all. Most engines will tolerate some combustion gas leakage, for a while, with only (only?) a loss of power to show their distress. But the leakage is unhealthy, in two ways: where hot gases force down

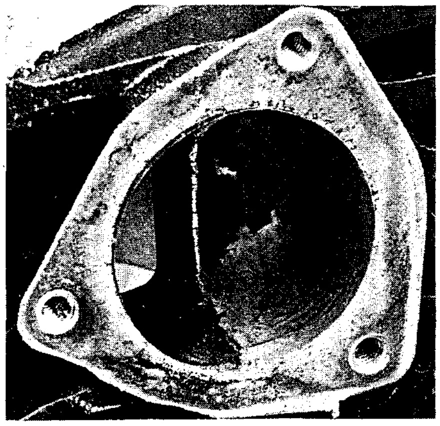


This cylinder's left side has been reworked lightly for improved air flow through its numerous ports.

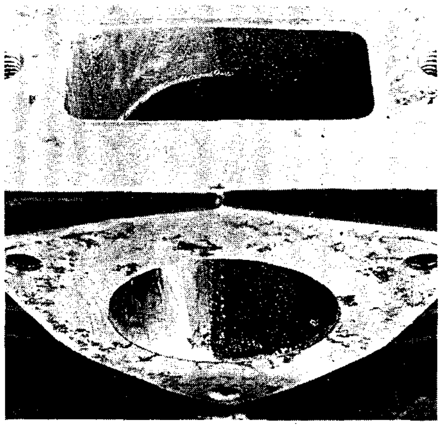
the skirt there is an interruption of heat flow from the piston into the cylinder, which tends to raise the piston's temperature; and those gases tend to scorch away the film of oil that lets the piston slip freely up and down in the cylinder. Put the two together and you've got an over-expanded piston crowding the cylinder walls really hard, while at the same time you're losing the lubrication between them. And is this combination of blow-by



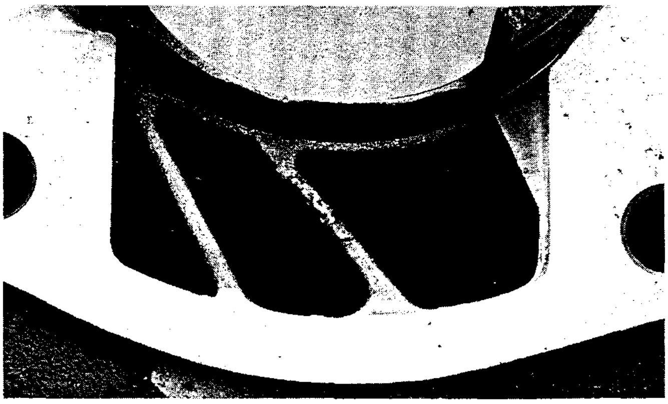
Sand-cast ports' interiors are rough, and will flow better when their walls are smoothed by filing.



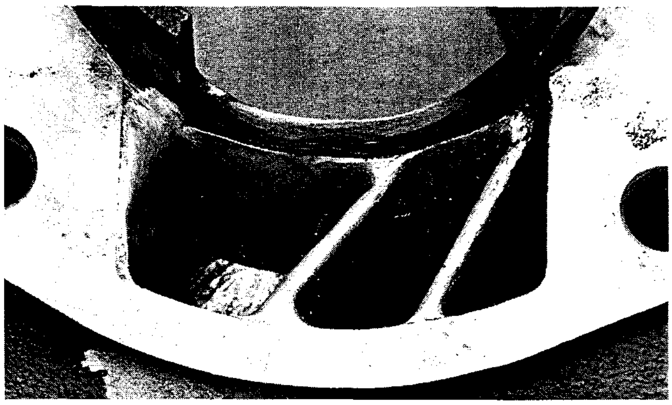
It's especially important that an exhaust port's walls be smooth, but don't thin the bridge.



You can remove enough metal to match port/manifold edges; changing port shapes asks for trouble.



Roughness around the transfer entry tends to block flow up into the cylinder.



Work inside the transfer tunnels is most difficult, but also most effective.

Polishing isn't necessary, only a smoothing of casting flaws and a correcting of mismatched edges.

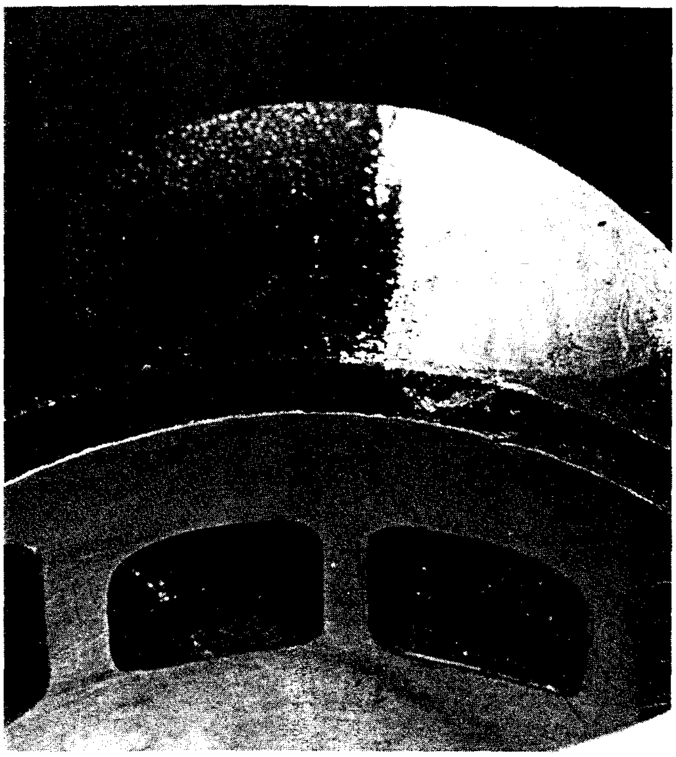
and expansion enough to make a piston seize? Does a bear growl in the woods? Without that tight fit we've been talking about, fire will leak down around a piston's skirt and it definitely will be seizure-prone. Forced break-in can leave a piston too misshapen to seal properly; giving a replacement piston an "extra couple of thousandths just to be safe" has the same bad effect. The result in either case will be an engine with a self-destructive eagerness to seize, repeatedly, with each successive seizure being worse than the one before as the piston becomes progressively looser.

Sadly, proper fitting of an engine's piston is no iron-clad guarantee of long-term reliability. Most new engines will give good service if they get a nice, gentle break-in, but sooner or later they're going to need a top end rebuild. Mostly, the time for rebuilding can be termed "sooner," because the average motorcyclist does much better as a rider than he functions as a tuner. Riders commonly try to use spark plugs one or two heat ranges too cold, then switch to smaller carburetor main jets and/or mix less oil with their fuel in an attempt to avoid plug fouling. Many also cling to the wholly erroneous belief that lots of ignition advance is the shortest road to more performance. So we have plenty of off-road bikes running with lean mixtures and advanced spark timing, either of which is a powerful initiator of detonation, (the great melter of pistons) and these bikes often get exceedingly thin lubrication. In light of all this, it is surprising that the seizure rate isn't higher, and that even more time isn't being devoted to rebores and the fitting of new pistons.

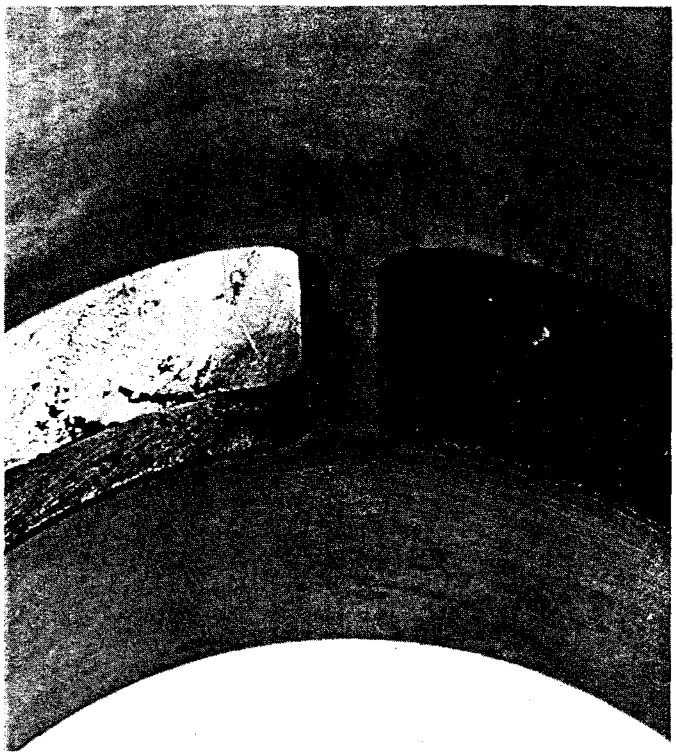
Things being the way they are, many of you will soon (if you aren't right now) be doing a top end rebuild. It is even possible that what we've said here will persuade you to fit that nice, expensive new piston to manufacturer's specifications. Do that, and you'll be a long jump ahead in the reliability game. But getting the piston/cylinder bore clearances right is only half the rebuild job; there also is the matter of smoothing around the port window edges, which is something nearly everyone either neglects or does wrong.

You probably will have noticed that new cylinders for two-stroke engines have small bevelled chamfers ground around the edges of their port windows. This chamfering is done to protect the piston rings, which are pulled past the port windows as the piston unmasks and recloses the ports. Without the chamfers there would be virtually a knife edge surrounding each port to shave material from the sealing faces of the rings. At one time it was common practice to make all the port windows rectangular, and—as rings would bulge slightly out into the wide exhaust port—generous chamfering was needed to keep the rings from actually snagging and breaking. Today's cylinders have arched, ellipsoid shapes for any windows wide enough to create a snagging problem, and chamfers no longer serve their once-important function of coaxing piston rings back into their grooves. But manufacturers still are faced with the problem of breaking those sharp port-window edges, and chamfering is the method still used simply because it is quick and does not require more skill, care and finesse that the average factory worker can be expected to give.

Because port chamfers are very shallow, they usually get removed in the reboring process, leaving you with a full set of knife edges around the port windows. You may think that this merely presents a



After the port clean-up and reboring, the port window edges are rounded off.



A little porting work can accomplish a lot even when the timing isn't changed.

TOP END REBUILD

chore; it should be seen as a fine opportunity to shape up those port edges the way they'd be done at the factory if nobody there was worrying about labor costs. Think about it and you'll realize that chamfering only produces less-sharp edges. That is to say, the sharp corner between the 30-degree juncture of a chamfer and the cylinder wall is less sharp than the approximately 90-degree break between cylinder and port. And what you *really* want is a smooth, gentle radius instead of a hard edge. Any sharp corner will tend to force through the cylinder's oil film and make direct contact with the ring; a radius spreads the load a bit better, stays lubricated, and leaves the rings with nothing but normal scrubbing wear to survive.

One of the nicer aspects of working a radius, rather than a chamfer, into port window edges is that no power tools are required. You can do the job with a small fine-toothed file, or with a round abrasive stone. The latter is best, and it's quick work with even a very fine-grit stone, as the *radius* you want is very small—no more than one millimeter, or 0.040-inch. A larger radius is fine, too, taken strictly from the standpoint of ring-life, but tends to make the transition between port-open and port-closed (or vice versa) a little less crisp, the timing a little less sharp. This last is *important*, as two-stroke engines get a lot of their power from intake and exhaust wave activity, and the waves are stronger and more sharply defined when the ports are opened and closed cleanly.

People who give close attention to wear patterns in engines will have noticed that many two-strokes' rings show signs of having been savaged by their ports. That part of the ring adjacent to the exhaust port, particularly, often is badly battered, with its sealing face rounded and notched. These same people will be amazed at the appearance of rings taken from a two-stroke engine with carefully radiused port edges—because the rings will look like they came out of a solid-cylinder four-stroke, with absolutely smooth, unmarked contact faces. They look like, and will be, rings that will last many, *many* hard miles.

Not unexpectedly, the effect of having good ring sealing is the same as that of having a nice, tight fit for the piston itself. Both hold the fire of combustion in the upper cylinder, where it belongs, and that is perhaps even more important to the rings than to the piston itself. You have to remember that the top ring's upper surface is always exposed more or less directly to 3500-degree combustion gases. The only thing that keeps the ring from wilting into a piece of bailing wire is its contact with the cooler cylinder walls. Gas leaks deprive the ring of that contact, while exposing it to more heat. It may be supposed that the best of rings would eventually fail, if overheated, but that seldom happens. Long before the ring itself can come to grief the engine will suffer terminal piston seizure, because you can't overheat the ring without overheating and carbonizing the oil around it. The carbonized oil quickly glues the ring solidly in its groove, which destroys its ability to seal against the cylinder wall, and with the seal gone there is a great blast of fire down the piston skirt. Sudden and catastrophic piston seizure then occurs.

So now you know the why and how of fitting pistons and shaping port edges, and if you only take the job that far we think you'll be well satisfied with the results. And the really ambitious among you can go one important step farther: to correct the worst of any manufacturing defects in your engine's cylinder ports before you bolt everything together. Peer around inside those ports and you'll discover places where the port tunnels and the windows in the cylinder sleeve don't quite match. This happens because two-stroke cylinders are fairly intricate castings, and the molds in which they are cast have lots of separate pieces to slip slightly out of alignment.

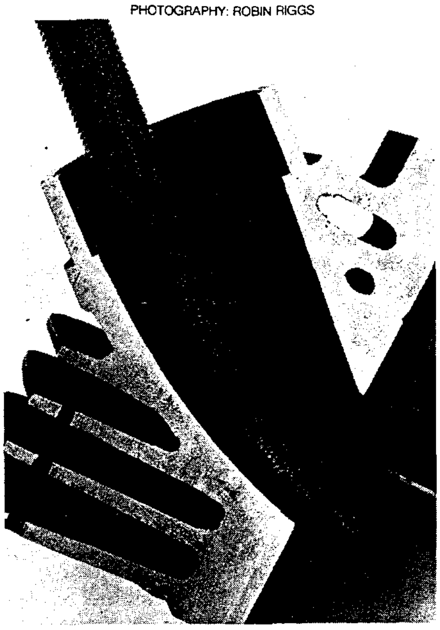
The most common and serious port tunnel/port window misalignments are in the transfer system. Pretty generally the cylinder sleeve will be right, and should be left alone unless you really know what you're doing. But there usually are spots where the port tunnel just misses in joining with the window that is either cast or machined in the cylinder liner. Don't worry yourself over the places where the tunnel walls are displaced outside the window opening, as these wide-of-the-mark areas have only a trifling effect on flow through the port window. The spots that need your careful attention are those where metal around the transfer tunnel overlap and partially block the port window, as even a half-millimeter overlap will choke the flow somewhat. But the worst effect of these partial blockages is that they create sharp, outward-opening steps in the transfer outlet "nozzle," and such steps promote turbulence in the scavenging flow through the cylinder. The turbulence results in an abnormally high rate of mixing of exhaust gases with the fresh charge, which has a terribly depressing effect on power. Two-stroke engines never capture more than about 80-percent of the contents in their cylinders at bottom-center, due to the delayed closing of their exhaust ports, and they perform much better when that trapped charge is what came up from the crankcase and not residual gases that should have gone out their exhausts.

We've used a Suzuki RM250 to demonstrate the effectiveness of all the clearance, port-edge, and port apperture preparation described here. The Suzuki was one of our test bikes, and one that was punished pretty hard when new. It's reaction to the punishment was very much what you'd expect: the bike's strength began to ebb very soon, and then after a number of partial seizures it tightened hard and would not restart. As a quick (and dirty) means of getting it back in service the cylinder bore was honed clean, about .0015-inch oversize, and a new standard-bore piston installed. This loose-fit piston suffered terminal seizure almost immediately, so the cylinder had to be rebored and a first-oversize (the only available oversize) piston fitted. It was at that point the staff technician persuaded *Cycle's* ace off-roader to do the rebuild by the book, as a demonstration piece for this article.

The results? Even our resident sceptic is now convinced that pistons should be fitted fairly tight, port window edges rounded instead of chamfered, and all the rest. The porting work alone simply could not account for the improvement. Casting flaws were smoothed away, and the port window overhangs removed, but there wasn't any polishing or changes in port timing. The whole job could have been done in a couple of evenings, using only the collection of bent files shown in our photographs—and bent files are just about the only tools that will reach into transfer ports. In any case, and even though the porting work was far from perfect, the engine was all but transformed. We got about the same dyno readings as before, with a one-horsepower gain at the peak, which shows that the work had its effect on performance at wide open throttle. But more remarkable was the improvement in general feel, and mid-range, part-throttle running. The engine had become happier and more crisp, which was not entirely an unexpected product of the porting work: you choke off a two-stroke engine's scavenging flow as you close its throttle, and any overall smoothing of the flow pattern will be revealed most strongly in part-throttle operation. And taken overall, this was one project that we can describe as being a total success: first because the job had to be done anyway, and doing it right costs no more money and only a few hours more time than simply slamming the parts together; secondly, the work done did make the bike run better and it promises to run longer before we have to think about Top End Rebuild-III. ◉

PORT FILING

Or, how you can sharpen your bike's performance with a $20 investment in rifflers and rasps.
By Gordon Jennings



PHOTOGRAPHY: ROBIN RIGGS

● Until you've tried it, do-it-yourself porting looks like the kind of work that should be easy, inexpensive, and a sure-fire way to coax more horsepower out of a motorcycle's engine. That's how it looks before you start; the reality usually is nothing but frustration, expense and disappointment. First you'll find those high-speed power tools which porting work seems to require cost at least $50, and you can plan to spend an added $100 to acquire a two-stroke cylinder capability. Then, after making the investment, you'll discover that power-tool porting is a difficult art. And self-schooling often leads to a final expense, which is the price of a new cylinder or cylinderhead to replace the one ruined with that fancy metal working equipment.

You'll be pleased to know that there's a vastly less costly and, though laborious, much more satisfactory approach to porting. Some of us here at *Cycle* have been hacking away at various kinds of ports for years, and hard experience has taught us that distinctly superior results may be had by doing the work entirely by hand, using a special set of files. Some of the files we use are toolmaker's rifflers, whch unfortunately are obtainable only on special order in many areas. But the most useful are common, coarse-tooth rat tail files, available at any hardware store. These we convert into porting tools by heating and bending their tips into the shapes you see in the accompanying photographs. We also use a "half-round" rasp (which is really more nearly sixteenth-round, but let's not argue with the file trade's nomenclature) for substantial localized widening of the port walls when that seems indicated.

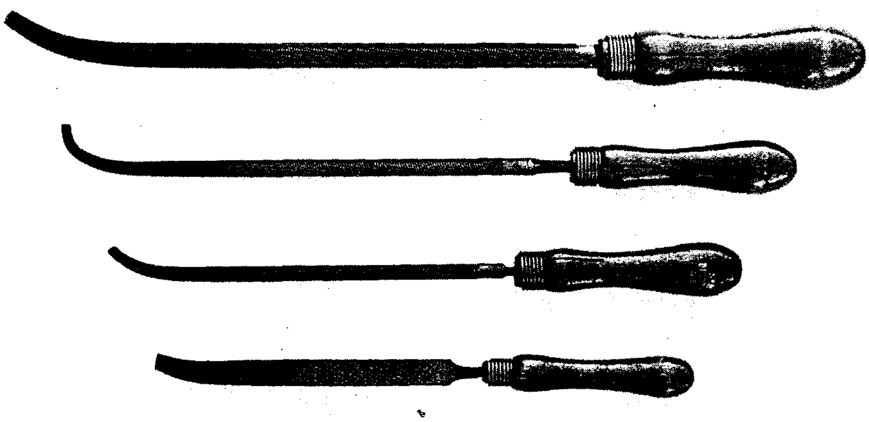
Why the preference for hand files instead of power tools? It's simple: unless you do enough porting work to be really proficient you'll tend to make mistakes, and the rate at which a high-speed rotary file slashes away metal converts any misjudgment into a major disaster. Hand files are much slower—sometimes agonizingly slower—and thus provide not only good control but also a strong incentive to stop when a minimum of material has been scuffed out of a port, which is preferred practice in any case.

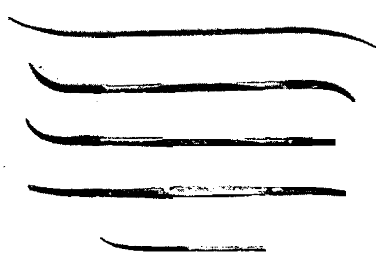
Slips and bobbles aside, the greatest advantage of hand files is that they tend to produce smoothly curved surfaces. Left to its own devices (as it nearly is, in an inexpert hand) a high-speed rotary file will whack all manner of humps and hollows in a port's walls. That's a very bad thing, as a port's shape has far more influence on its air-flow characteristics than surface finish. So even if your file leaves cross-hatching all over the inside of a port, its flow will be better than through one that has been given a mirror finish over a bunch of ripples. And you can make a filed port very smooth, satin finish, by adding the final touches with fine-tooth rifflers and emery cloth.

We must warn you that it's fairly easy to ruin a set of files in the course of modifying them for porting. Files are made of very hard, high-carbon-content steel, and will snap before bending unless they are heated dull red. The trick is to get the file's core hot enough to bend without overheating its teeth, which melts their cutting edges and leaves the file too dull to be of much use for anything. This heating is, therefore, best done with a very soft flame, and an old-fashioned plumber's blow-torch works very well. We don't have one of those, so we use an oxy-acetylene welding torch with a large tip and hold the file well away from the hottest part of the flame. Avoid hurrying the heating process, as that will make the file's surface hotter than its core—which is the part you're trying to soften for the bending operation. Finally, don't just jam the heated file between the jaws of a vise and pull, as that tends to blunt the file's heat-softened teeth. Do your bending against something softer: a layer of sheet lead wrapped over the vise jaws, or even a pair of hardwood blocks.

Both the sizes of files selected and the curves bent into them will be decided by the specifics of the ports you're trying to rework. Largish rat tail files, bent into long, gentle curves, are suited to shaping two-stroke engine's uncomplicated exhaust and intake ports, and the outer portions of the same ports in four-stroke engines. But you'll need smaller files, more tightly curved, for working around tight places like the under-valve pockets in four-strokes, and up around the tops of the transfer passages in two-stroke engines, where only the most specialized right-angle-drive power tools are effective.

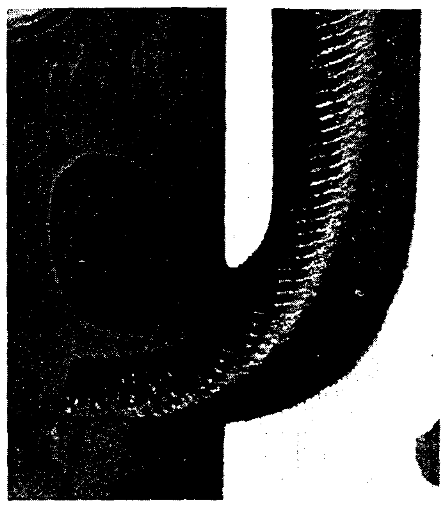
The above speaks strongly in favor of hand files, as it is the tight spots that matter most. In two-stroke engines, for example,





even fairly bulky and cumbersome power tools work reasonably well inside the intake and exhaust ports, and at the transfer port entries. But those are not really problem areas, as thoughtful consideration of the typical two-stroke will show. Ports are streamlined shapes, turned inside-out, and streamlining becomes more important as air velocity rises. And where in a two-stroke engine does air have to move most rapidly? At the constricted windows where the transfer passages open into the cylinder, of course. Time-area/volume calculations indicate an exit velocity of at least 300 feet per second for the transfers' mixture streams, and that is easily twice their speed at the transfer passage entries. Viewed in that light, it becomes apparent that only small dividends may be expected from cleaning up the transfer tunnel entries, which is as far as most people's ambition takes them. The large improvement comes from careful attention to the removal of casting flaws and the correcting of port/cylinder window mismatches up at the tight end of the transfer passages; the hooked tip of a file is virtually the only tool capable of doing that job.

In four-stroke engines' intake ports you'll often find an obvious opportunity for improvement around the bosses cast in to support the intake valve guide. These



PORT FILING

bosses almost invariably are cast thicker than necessary just to allow some latitude for casting-core shifts and other manufacturing errors. With a bit of filing, you can narrow the intake port's valve guide boss, blending its shape into that of the guide itself, and improve the air flow past that point. Those who work with power tools, which can scoop out a lot of aluminum very fast, will be tempted to press out the intake guides and remove the bosses entirely, or to slash away everything and leave just the valve stem sticking into the port. Don't you do it: the rockers that work most valves exert a substantial side thrust on the valve stems, and the stems have to be supported against that thrust. Cut away the bosses and the guides may come loose; shorten the guides and you'll have a wear problem on your hands.

Be very careful about removing any metal from the exhaust valve guide bosses. Much of the heat pouring into the exhaust valve from the hot combustion gasses exits through the valve stem, into the guide, and from there into the surrounding metal. Remove the metal and you block the heat's escape path, which in the extreme case will overheat the guide, carbonize the oil, and cause the exhaust valve to stick open.

When you're working with a two-stroke engine, any departure from the stock port configurations can get you into a world of trouble. Remember that the ports have to be closed by the piston, and hold their dimensions to the areas swept by the piston's skirt. That is to say, just because you notice that

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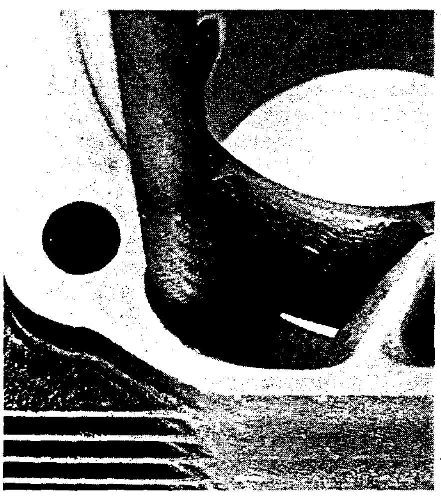
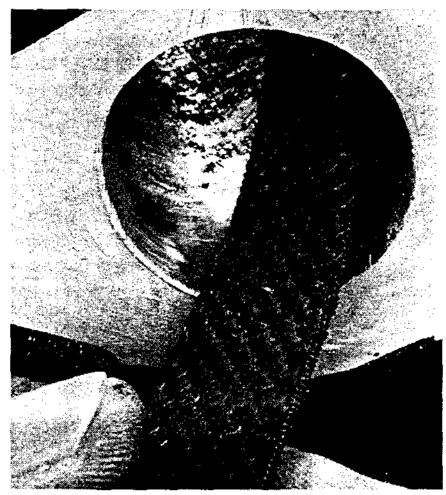
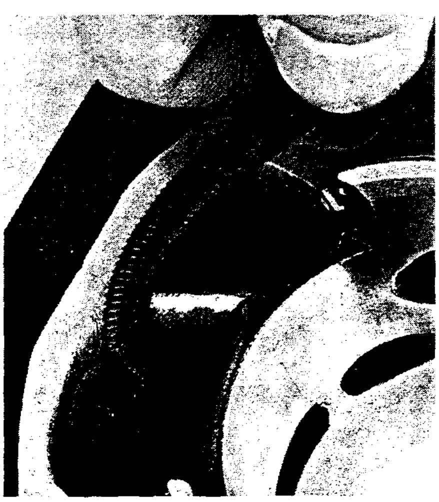


The hooked tip of a reworked rat tail file will reach the important transfer port outlet area.

Thick cast bosses around intake valve guides are common in stock parts, and should be streamlined.

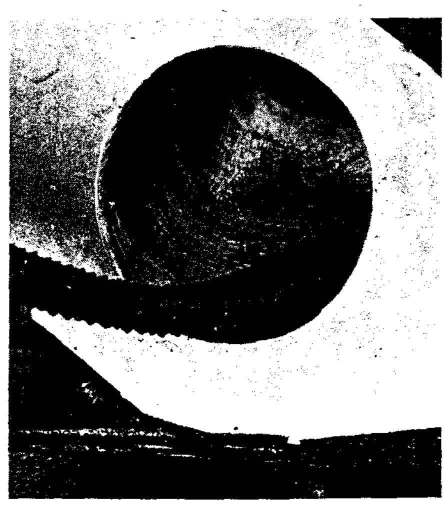


Flow-improving pockets and arches can be carved in ports with a suitably curved half-round rasp.

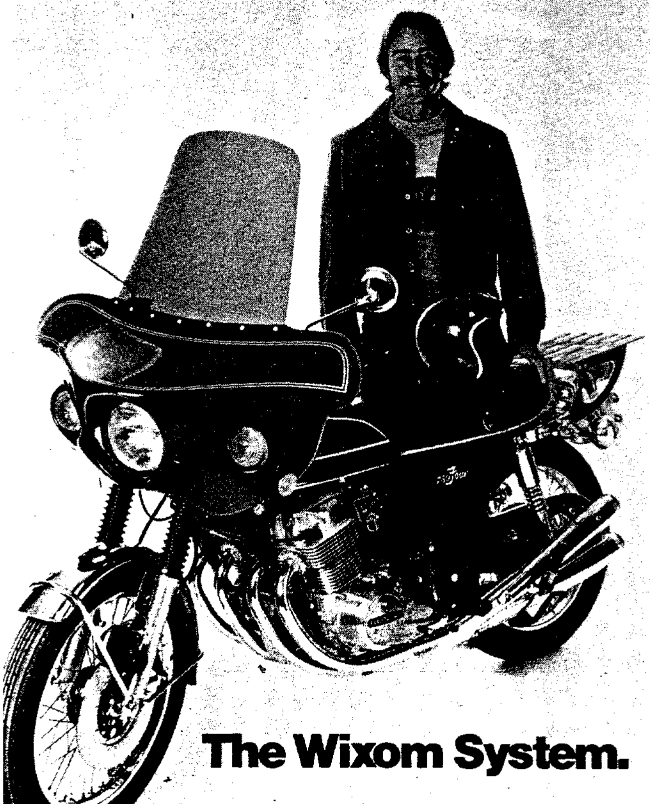


Hard-edged transfer port dividers can be rounded nicely with the inside surface of a hooked file.

Large-diameter, slightly curved files are a good choice for cleaning up intake and exhaust ports.



A bent, coarse-toothed rasp is being used here to round a sharply-angled intake port entry.



PORTING .... *Continued from page 36*

the piston crown drops below the lower edge of the exhaust port when it's at the bottom of the stroke you shouldn't assume you've found a sloppy mismatch needing correction. It may be that the exhaust port floor has been purposely left high to match the position of the piston skirt's lower edge at top center, and lowering the port floor would have the crankcase breathing from the intake *and* exhaust when the piston reaches the top of its stroke.

A particularly depressing (and conclusive) mistake you can make is to over-widen a two-stroke's intake or exhaust ports. If you over-do things on the intake side, and make the port so wide that it overlaps the piston's transfer cutaways—which are the high, rectangular arches below the wrist-pin—the piston skirt won't close the port and the engine won't run. It rarely is possible to widen an exhaust port enough to create an entry into the crankcase without first cutting into the flanking transfer ports, but widening here can still cause problems. A two-stroke's piston rings bulge out into the ports passing over them, and bulge farther in a widened port. Racing two-strokes have exhaust port widths up to 70-percent of bore diameter, and that works only because the port windows' elliptical shapes help ease the rings back in their grooves without snagging. Don't widen exhaust ports without rounding the windows. And don't raise the top edges of intake ports so far that the pinned ends of the rings can spring out into the port window opening.

The worst mistake you can make with a four-stroke engine's ports is to over-enlarge them, and that also speaks well for hand files: the work is such slow going that you won't be tempted to go too far. The best thing you can do for most engine's ports is to look for casting flaws, and to clean up the areas in which it is clear that the port contours owe more to manufacturing convenience than to any considerations of gas flow. We found that just this much was worth 1¾-bhp in a 250cc Yamaha DT-1 engine.

And the best thing that can be done for your reshaped files is to stop scuffing aluminum at frequent intervals and scrub the metal particles out of their teeth. Let the teeth get really clogged, and they're almost impossible to clean. You can get all the files you need, including three or four rifflers, for about $20; take care of them and they'll last long enough to do so many ports you'll begin to know where the horsepower is hidden. ◉

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