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YAMAHA SR500E HOP-UP PART 2

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IS MOTORCYCLE INSURANCE A DEAD-END STREET?

THE SPECIAL MAGIC OF THE CALIFORNIA CUSTOM

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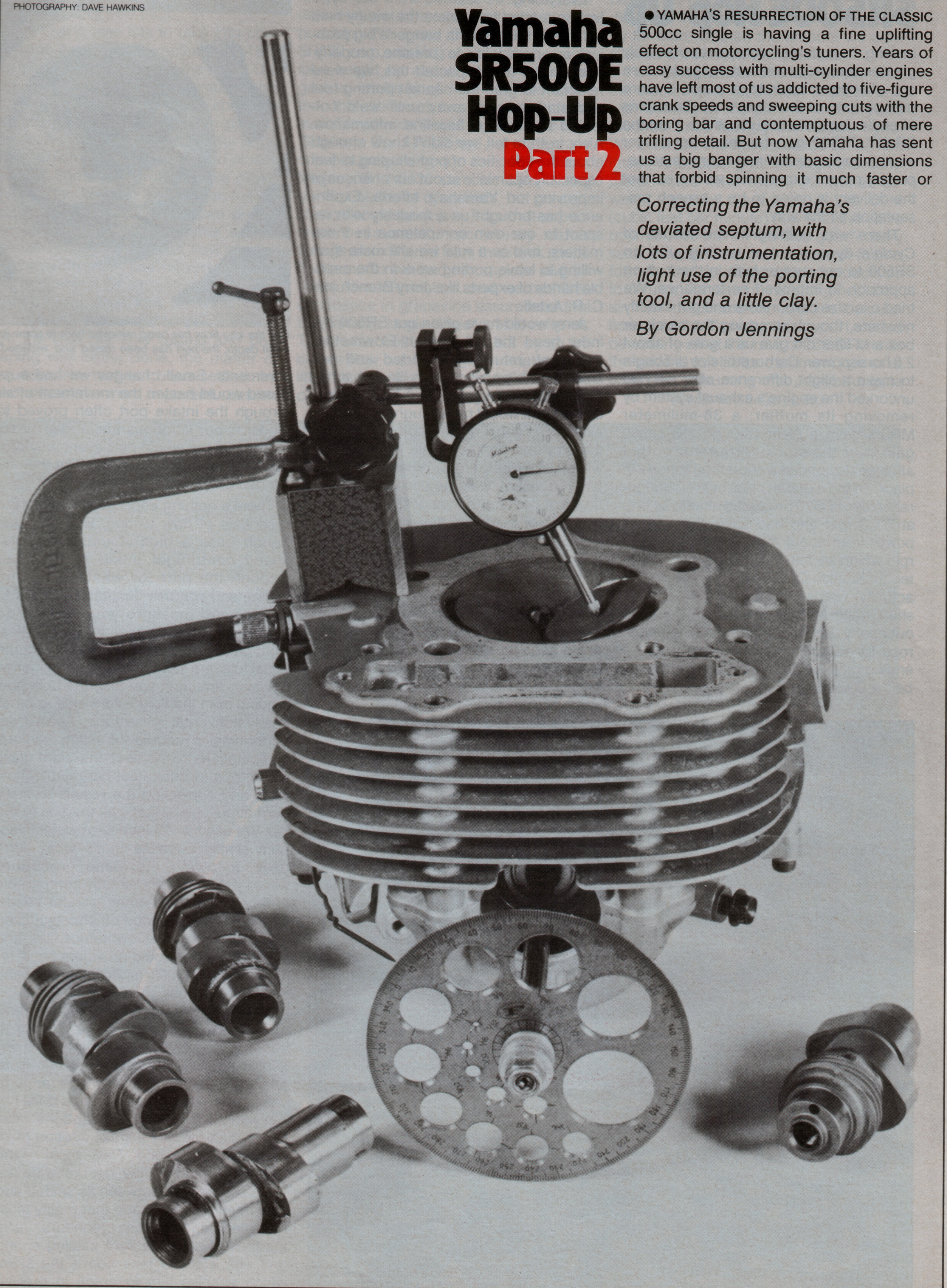


Yamaha SR500E Hop-Up Part 2

● YAMAHA'S RESURRECTION OF THE CLASSIC 500cc single is having a fine uplifting effect on motorcycling's tuners. Years of easy success with multi-cylinder engines have left most of us addicted to five-figure crank speeds and sweeping cuts with the boring bar and contemptuous of mere trifling detail. But now Yamaha has sent us a big banger with basic dimensions that forbid spinning it much faster or

Correcting the Yamaha's deviated septum, with lots of instrumentation, light use of the porting tool, and a little clay.

By Gordon Jennings

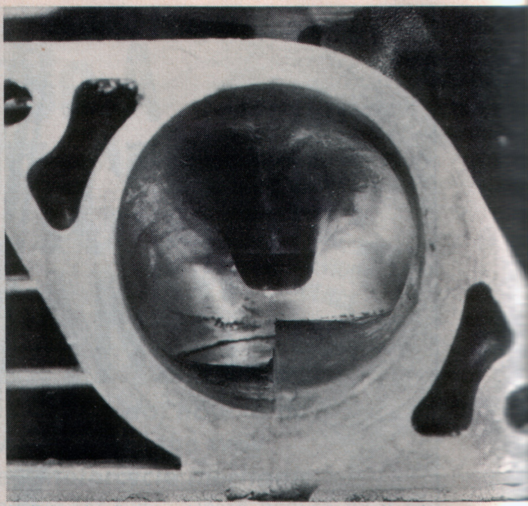
SR500E Hop-Up

making its cylinder volume appreciably greater, and we are at last obliged to turn our attentions back to a purer if more difficult form of the tuner's art. Examples of earlier bangers assure us the Yamaha SR/XT/TT500 can be made to deliver more than its present mid-twenties horsepower; recent experience warns us that the delivery is going to be a breech presentation all the way.

There was nothing in the results of *Cycle*'s dynamometer testing with an SR500 to encourage faith in the bolt-on approach to improved performance. We tried oversize carburetors and got exactly nowhere, though removing the stock air box and filter did give us a gain of about 2.6 horsepower. Carburetor size did begin to make a slight difference after we had uncorked the engine's exhaust system by removing its muffler; a 36-millimeter Mikuni gave a clear (though still small) gain over the stock-carburetor output after we'd clamped a short megaphone in place on the exhaust pipe. In this configuration our SR500 produced almost 34 bhp at 7000 rpm and had solid above-stock power from about 4300 rpm to the 7500 rpm which we felt was the engine's disaster threshold. Our final bolt-on (bolt-*in,* actually) was a Megacycle #5120 camshaft, which inspired the Yamaha to pump out nearly 38 bhp, but the peaking speed rose to a worrisome 7500 rpm and the engine gave decidedly limp performance below 6000 rpm.

Everything we learned from our dyno testing tended to validate the widely held belief that the Yamaha banger's big problem is an inability to breathe properly. Though we had expected this, we were reluctant to grab the nearest porting tool and start carving away, until we'd collected some hard baseline information. Also, truth to tell, we didn't know enough about the specifics of port shaping to feel especially optimistic about our chances of improving on Yamaha's efforts. Experience has brought us a modesty with respect to our own competence in these matters, and as a rule we are more than willing to leave porting work in the capable hands of experts like Jerry Branch and C. R. Axtell.

Jerry would have given our SR500 cylinder head the full Branch Flowmetrics treatment, returning it ported and polished to within an inch of its life, if that had been what we wanted. But having Jerry do the work would have taught us (and, by extension, you) almost nothing beyond the fact that he knows his business . . . which we already knew. What we wanted, and requested, was the use of Jerry's air flow test bench. And we got it, along with the kind of bemused smile an indulgent uncle might give a somewhat retarded nephew who had just asked for a chemistry set. The reason for Branch's smile was to become all too apparent in the days that followed as we daubed and molded clay, shaved away metal, and reeled with the surprising discoveries made in the course of fumbling through dozens of modifications and some 600 flow mea-



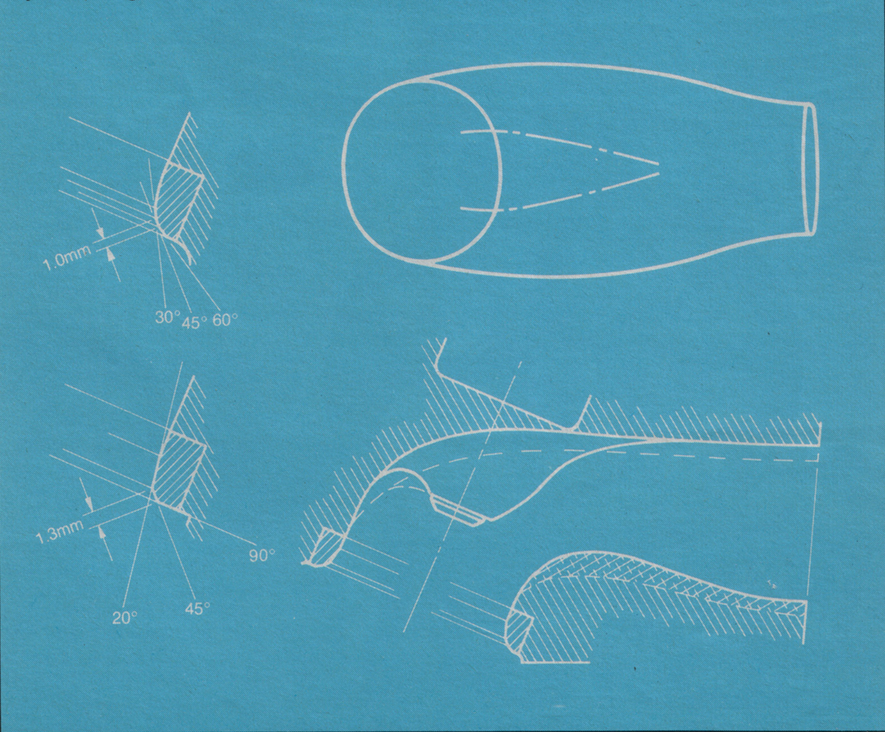
Half the clay floor has been removed here to show its 7mm depth; the port has been raised and widened.

surements. Small changes we had supposed would hasten the movement of air through the intake port often proved to hinder it; our laborious trial-and-error reshaping of the whole port eventually produced a passageway quite unlike the one we had anticipated.

There's nothing especially tricky in the essentials of flow testing. Branch's test bench uses a high-volume, variable-speed centrifugal pump to draw air through the port (or whatever) being tested, and you use fluid-level gauges to control and measure your work. You crank up the blower speed until a vertical sight-glass registers a receiver vacuum equal to some standard number of inches of water, and then you take the bulk flow reading from the fluid level inside another nearly-horizontal glass tube. Apart from performing a couple of mildly tedious computations to convert the sight-glass readings into cubic-feet-per-minute flow rates and correcting the results to standard atmosphere, that's all there is to the job. We used a "12-inches-of-water" vacuum simply because that's what Jerry uses; following the same procedure would yield numbers directly comparable to those taken with other cylinder heads. The latter are recorded on sheets tucked away in the Branch Flowmetrics files, and this information would provide a basis for judging the SR500's air flow capacity and our own progress . . . if any.

Flow test work begins to gather complexity when you try to make it relate to conditions in a running engine. One essential step in accomplishing this is to take flow readings over a whole range of valve-open positions. An engine does not run without its intake valve, and the valve is at full lift for only a small fraction of its nominal open period. Thus, most of the cylinder-filling air flow occurs with the valve somewhere between its seated and fully open positions, and that reality must be reflected in the test procedure. Jerry fits the valve with a light closing spring and rigs a screw jack above the stem, which enables him to crank in precise

Shown here is the modified SR500 intake port, with dotted lines to indicate the original. Yamaha's valve seat is wide and surrounded by sharp edges and abrupt angles. We narrowed the seating area, rounded the seat throat, made the angles less abrupt—and lost flow volume. Only the carving of a channel around the seat helped.



amounts of lift. He takes flow readings at lift increments of .050-inch.

Flow testing also has to take into consideration the major characteristics of the cam lobe profile that moves the valve. The most obvious of these is maximum valve lift: there's no point in fretting about air flow at valve openings the cam doesn't provide. Another, more subtle factor is the rate at which the cam opens and closes the valve. Some cam profiles move valves very rapidly, keeping them near full lift through more of their total open period than other cams with a gentler action. When an abrupt cam is used, flow at small valve openings is less important than what happens at full lift; with slower opening and closing rates, flow at the lower lifts assumes a greater importance.

At the time our flow testing and port shaping was being done, the matter of cam selection had not been settled. Indeed, one of the most important reasons for going to the flow bench was to obtain data that would make a rational choice possible. We knew the stock Yamaha SR500 cam, working rockers that amplify lobe height by about 1.42 at the valve, gave an intake lift of .400-inch. We knew, too, that some of the accessory cams available provide lifts of slightly more than .500-inch. Our SR500 had not shown any conspicuous liking for the .469-inch-lift Megacycle #5120 cam we tried during our first series of dyno tests, but no conclusion could be drawn from that experience because the accessory cam's timings also differed from the stock specifications. So we had incomplete and inconclusive information, and we had little confidence in grapevine assurances that the Yamaha single "likes" lots of valve lift. There was nothing to do but try to increase flow out to .500-inch intake valve lift; that was the absolute maximum we could conceive of using. To cover all bases, we decided to check the flow to .600-inch lift in case there was reason to try for more lift than the amount we considered convenient and prudent.

Flow test number-one was made with the stock 34mm carburetor in place and with nothing in the port or on the valve touched since leaving the Webco dyno. We even left the valve's baked-on oil film intact. And, pulling air through the complete intake tract with a 12-inches-of-water vacuum, there was a 110 CFM (cubic feet per minute) flow with the valve opened .400-inch. Was that good? Jerry said it wasn't: he has a rule-of-thumb formula (the details of which he declines to divulge) for determining engines' bulk air flow requirements, and his calculations said the Yamaha intake port should be moving air at the rate of 132 CFM with the valve at full-lift for maximum power at 6500 rpm. Assuming that Jerry's formula

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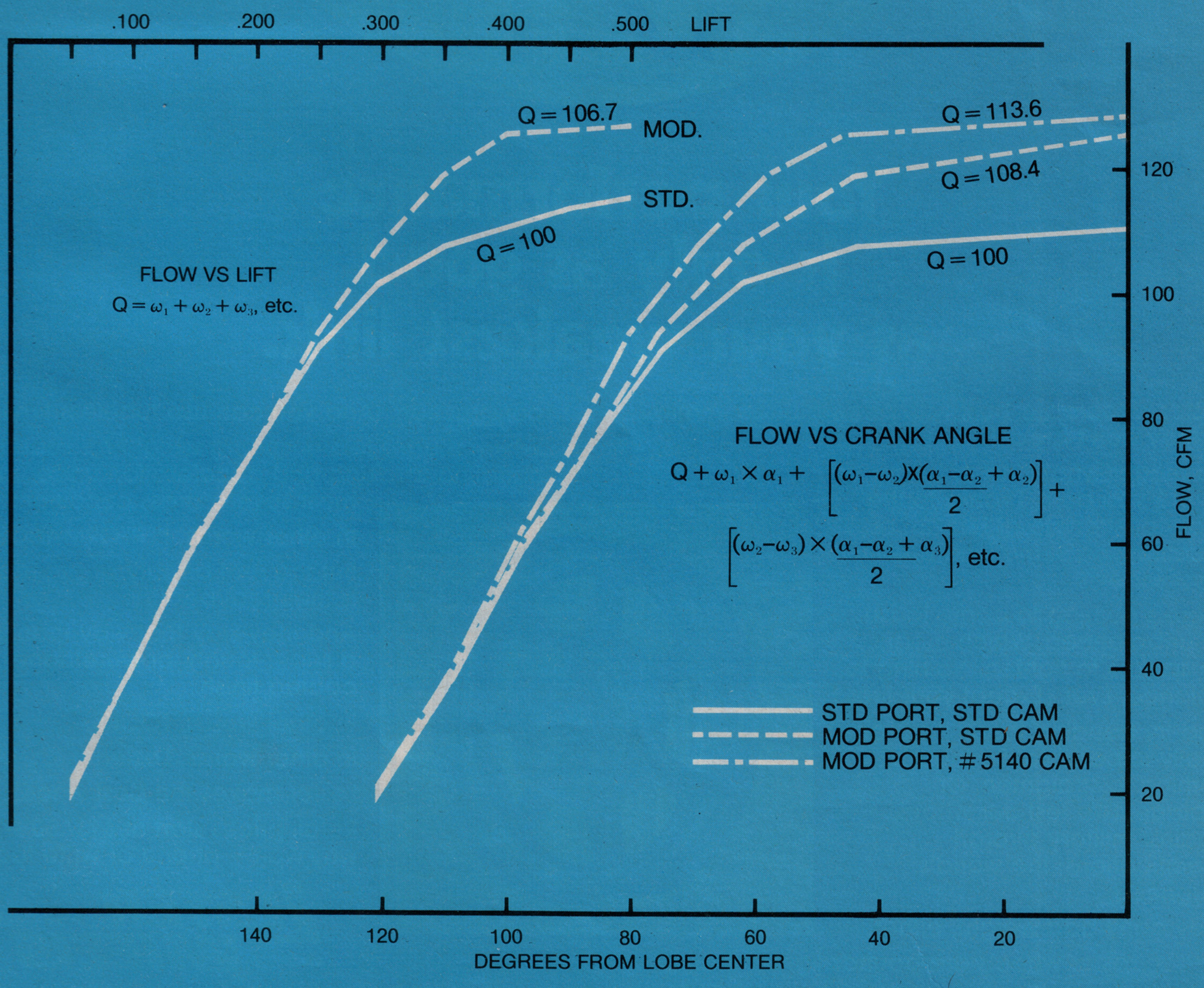
Assessing flow gains: Maximum readings don't count; it's the areas under the flow curves you want, and plotting flow vs. crank angle provides a more accurate view of what has been accomplished. An overall flow value, "Q," for the flow vs. lift curves may be arrived at by simply adding flow numbers. (Flow at .050 plus flow at .100 plus flow at .150, etc.) Using this method, Q for the modified port is 6.7 per cent better than stock up to .400-inch lift. But valve movements in a running engine include a long period spent very near maximum lift, as may be seen in the flow vs. crank angle curves. Using a more lengthy equation to determine areas under the flow/angle curves, the Q value for the modified port emerges as 8.4 per cent better than stock; and when the whole curve is shifted upward to reflect the higher lifts of a Megacycle #5140 cam, the value for Q rises to become 13.6 per cent above standard.



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was valid—and he swears it has proven accurate in predicting the air appetites of a large sampling of engines—we had a starting point representing just 83 per cent of the optimum.

Our prospects of pulling big horsepower out of the SR500 with increased valve lift began to look dim when we plotted flow readings from .050- to .600-inch lifts on graph paper. The lift/flow line was essentially straight only to .250-inch, where the flow reached 91 CFM; from there it began to flatten, giving ever smaller increases with each .050-inch movement of the valve away from its seat. Flow at .500 lift was just five CFM better than down at the .400 opening, and pushing the valve .600-inch away from its seat brought it to only 118.4 CFM—a rate still well below the projected requirement. So sheer valve lift could not be expected to take care of the air-flow problem, and our single experiment with a longer-duration cam indicated that cylinder filling obtained in that fashion resulted in an unacceptably narrowed power range.

A larger intake valve might have seemed attractive if we had found a straight-line relationship between valve lift and air flow. But, as noted, the lift/flow gains began to diminish above .250-inch lift. This strongly suggested that the limiting factor was the port shape itself, although we had to consider the possibility that the stock 34mm carburetor was imposing an upper flow limit. Tests made with other carburetors did much to discredit this last notion: we tried a 36mm Mikuni, a 36mm Dell'Orto and a "38mm" (36mm throat) El carburetor and found only slight gains in flow. The difference was in the order of 3.5 CFM at .400-inch lift, non-existent below .200-inch lift, and negligible among the three carbs tested.

One of the things that has always stirred our curiosity is the efficacy or lack of same of a "racing valve job." Yamaha's shop manual specifies a seating-ring width of 1.2mm, noting the seat should be trimmed with cutters to make contact right in the middle of the valve's 45-degree seating face. The manual also recommends trimming the lower valve seat face with a flat cutter, making a surface 90-degrees from the plane of the valve stem and using a 60-degree cutter to open the valve seat throat. Well, we knew better than that and went to work: we cut into the seat with a 46-degree tool to give ourselves working room, then put a small 120-degree (included-angle) bevel on the downstream side of the seating area, and finished by making a 60-degree valve throat cut deep enough to leave us a one-millimeter seating ring out at the edge of the valve head. The valve itself was cleaned up, all the baked-on oil scrubbed away, and some nasty ridges removed by chucking it up in a drill press and spinning it against files, stones and emery cloth.

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SR500E Hop-Up

The finished job was a pleasure to behold, dazzling to the eye and a satisfaction to the tuner's soul. But it wasn't effective.

The reader will appreciate that after years of preparing racing engines in precisely the above fashion, after buying a very expensive set of adjustable cutters and laboring long into many nights to achieve precisely the seating-area shape applied to the SR500, we were totally convinced of the rightness of this ritual. We *knew* it would help ease air past the intake valve, especially at the lower lifts. And we were jubilant to find a one-CFM improvement with the SR500's intake valve cracked open .050-inch. Wonderful, we thought, screwing the lift to .100 . . . where it proved to be slightly worse. All the subsequent checks at higher lifts brought ever-worsening news: our fancy racing valve job had depressed the flow rates at all points above .050-inch and put us 3.5 per cent behind scratch at .400-inch lift. It was not a propitious beginning, and the worst of it was that we couldn't get back to a stock valve-seat configuration. The metal was gone and could not be uncut.

Our reworking of the SR500's intake port was (fortunately, in all probability) tightly circumscribed by a combination of solidly supported theory and the existing metal in the cylinder head. A major enlargement of the intake port diameter was almost impossible, as Yamaha's casting techniques are quite good and do not surround the various cylinder head cavities with excessively thick walls. In any case that approach to flow improvement would have been a mistake. Large-diameter intake ports will yield big numbers on a flow bench, but those who have let themselves be seduced by steady-state testing's promises will find disappointment in the dynamometer room. Only the inertia of high-velocity air keeps the flow going the right way through an engine's intake tract during the late part of the valve-open period, after the actual intake stroke has been completed and the piston is on its way back up toward top center. All present-day engine designers recognize the importance of maintaining high intake air velocities, and they disagree only on the speed at which frictional losses within the port offset the gains from the "ram-charging" effect.

Intake port air velocity will vary greatly during the valve-open period, and the velocity is exceedingly difficult to measure. But a "mean" velocity is easily calculated (you divide intake cross-sectional area by the cylinder bore area and multiply the result by piston speed) and is widely used in establishing appropriate valve and port diameters. The SR500's intake port has a manifold-face diameter of 35mm, from which we calculated mean intake air velocities of about 270 and 380 feet per second at 5000 and 7000 rpm respectively. Those values are, if anything, low for a modern racing engine; they are a trifle high for an intake port with a shape that owes much to convenience in carb location and as-cast interior walls.

We noodled with the numbers, considered making the Yamaha's port a millimeter smaller by slathering in some epoxy, fretted over imponderables, giving fleeting thought to opening the port a little (an option rejected on grounds it was sure to narrow the powerband unacceptably) and in the end decided to stay with the stock intake diameter. The 35mm size gave calculated air speeds well within the appropriate range established by ram-charging theory; it also was one selected by Yamaha's engineers, who presumably did not fix upon that size just as a whim. We did not plan to shift the SR500's peaking speed upward by more than a few hundred revs, at most, and therefore had no reason to conclude that bigger would be better.

Those who think of port modifications only in terms of removing metal may be surprised to learn that all our early flow-bench experiments were made solely by filling areas of the SR500's intake port with modeling clay. More surprising was that the highest flow reading seen in all the days of changes and testing came when we simply jammed a stick into the port and waggled it around until we found a position that was right. That reading was 131 CFM at .400-inch lift, with an absolutely stock port and a 36mm Mikuni carburetor. This astonishing improvement never was equalled by anything else we did. We'd have glued the stick in place

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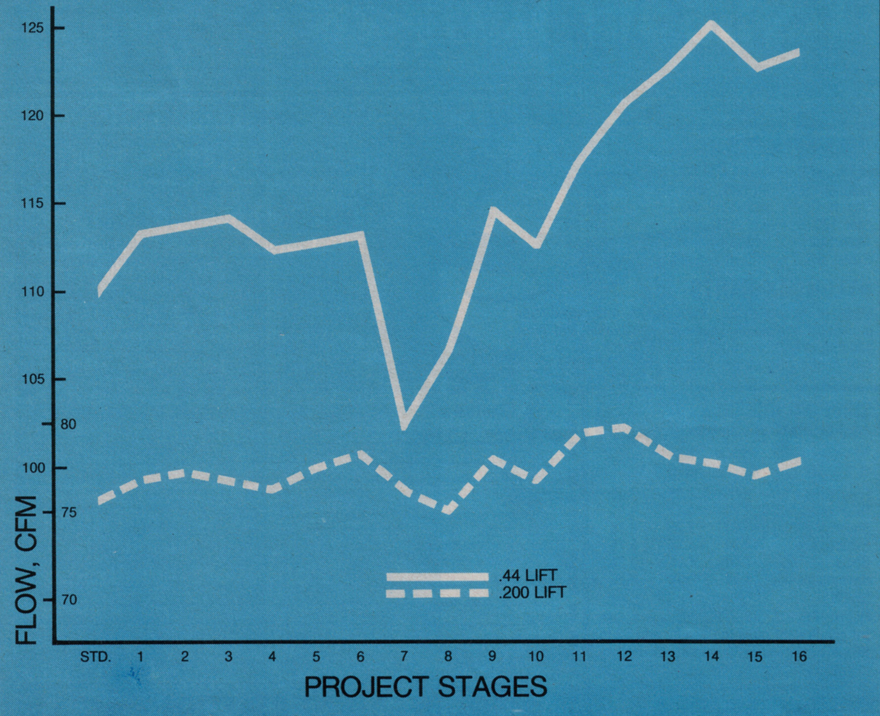
Change wasn't all progress: This chart shows how 16 major modifications, plotted in chronological order, influenced flow rates at .200- and .400-inch valve openings. ***Stage-one*** gives flows for the stock port, with the stock carburetor and manifold removed and a Branch 36mm Mikuni kit installed. For ***stage-two,*** an EI 38/36mm carburetor was substituted for the Mikuni. An Axtell 36mm Dell'Orto was fitted for the ***stage-three*** test. ***Stage-four*** combines the 36mm Mikuni with a "racing" valve job which depressed the flow. A longer port floor/valve seat radius was molded in clay for ***stage-five*** and tested with 36mm Mikuni in place. Clay added on the port floor gave it an up-draft angle, and ***stage-six*** shows the result of angling the manifold to suit the new port centerline. For ***stage-seven*** we reversed ourselves, using clay to make the port flatter instead of more arched, with results that eliminated further consideration of the flat-port approach. ***Stage-eight*** was the first actual port enlargement, with metal carved out of the port roof and sides; testing was done without claying over the port floor, and flow was below that for the unmodified port. For ***stage-nine*** the clay floor arch was added, and a large flow improvement obtained. ***Stage-ten*** entailed molding a nicely rounded port throat in clay, which looked right and tested wrong. At ***stage-eleven*** all the clay was shifted to the port floor, for a "D" shape and a big gain. ***Stage-twelve*** was where we arrived by following the D-port concept further, cutting metal and adding clay. ***Stage-thirteen*** was where we raised the port entry just three millimeters with encouraging results. Progress stalled, then, until we arrived at ***stage-fourteen***—replacing the 36mm Mikuni with one having a 38mm throttle bore; the bigger carburetor gave virtually no improvement when tried earlier. ***Stage-fifteen*** wasn't supposed to be a major change: we just blunted a sharp edge in the valve seat throat and were appalled at the drop in flow. Fifteen led to ***stage-sixteen,*** an only partially successful attempt to restore flow by further blunting that seat edge into a curved surface.



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and headed straight for the dyno but for one problem: the stick ruined the flow at all other lifts unless repositioned to suit the altered general flow pattern. So to make the stick work, we'd have had to mount it on a ball-swivel and hooked it to the camshaft with rods, bell-cranks and Lord knows what else to keep its position correctly aligned relative to valve lift. Casting a new cylinder head would have been easier, though not as appealing to those who adore Vincents and are in other ways addicted to oddity.

The lift-phased-waggle-stick idea provided a few moments of lunch-break amusement, and it was the inspiration for layering clay on the intake port floor. We reasoned that turbulence trailing away from the stick was helping the air make the tight downward turn into the valve seat throat, and we hoped that molding a less abrupt turn in clay would have the same overall effect. However, when the clay had been carefully smoothed into place, its most immediate result was to deepen our confusion. We did find a flow improvement at lifts up to .200-inch, but this was offset by a sharp drop at greater valve openings. Adding more clay farther away from the valve to fill the shallow dip in the port floor and relocate the pre-seat hump nearer the port entry helped—but not much. The reduction in area was limiting full-lift flow too severely to be compensated by what we fancied was an improved shape.

Jerry's instrument probes, belated cerebration and willy-nilly experimentation lofted us over the barrier we had erected for ourselves. Our problem in a nutshell (an especially apt simile) was thinking only in terms of a round port while ignoring the fact that the SR500's port wasn't and forgetting certain valuable hints about the nature of compressible-fluid (i.e. air) flow clearly stated in all books on the subject. What the books say is that when air flowing through a conduit reaches a bend, as in a pipe elbow or intake port, centrifugal force . . . effectively . . . causes it to compress and slow in the bend's outer portion while losing pressure and gaining speed at the inside. Further, the pressure differential within the bend causes an overall distortion of the flow-streams from outside to inside along the bend's walls. The net result of these forces and shifts in flow is an attempt, by the bend, to break the straight, reasonably unified movement of air through the conduit into a pair of contra-rotating spirals, with an overall reduction in flow rate.

It should be apparent in the above brief description that flow will suffer as the bend radius tightens, and that there's more restriction with greater bend angles. A table of loss coefficients for refinery pipe fittings gives a 25 per cent reduction in flow for a 30 per cent shortening of one

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bend's radius, and it shows that a 90-degree elbow presents more than twice the restriction of one making a 45-degree turn. These relationships strongly recommend a port shape that turns no more than is absolutely necessary to clear the intake valve spring seat, and one that curves gently. Unfortunately, these recommendations cannot always be followed; especially not in the design of a tall, single-cylinder engine like the Yamaha SR500, and most particularly not when a tall, slide-throttle carburetor is to be fitted on the intake port. The SR500's top frame tube could not be placed much higher without giving the bike the silhouette of a step-ladder, and its carburetor had to be located under that tube. To such exigencies the Yamaha owes its low, abruptly turned port.

One's first impulse when grappling with the Yamaha intake's manifest reluctance to flow air properly is likely to be a plan for disaster. You look inside the passage, note that it starts and ends round but bulges into a rough oval at the valve-guide boss; instantly you begin to think about making it round. That fat aluminum stalactite surrounding the valve guide appears to be the worst obstruction to progress since the filibuster. We had good reason for not removing it because we once got into trouble with a similar ploy. Valve rockers' tips move in an arc, tend to put a push/pull load on the valve stems, and this tendency can be upgraded into an overpowering force when high-lift cams and ultra-stiff valve springs are fitted. Memories of a valve guide that worked loose due to high loads and inadequate support kept us from acting hastily.

Checking air velocities inside the port soon had us wondering if our first-impulse plan to attack the valve guide boss would have yielded any flow improvement to compensate for the reduced guide support. According to books dealing with fluid mechanics, the air should have been moving most rapidly along the port centerline and slowest at the walls. Jerry's velocity probes said it wasn't. There was a fairly even velocity distribution out at the port entrance but not inside, where the instruments showed air moving terrifically fast along the walls and relatively slowly at the centerline. All indications were that air was going around the thick guide boss without a hitch, though of course the velocity readings became progressively higher as we slid the probe's tip around the port sides to the floor. The valve stem itself seemed to occupy an area of practically still air. So out of respect for valve-guide loadings and because there seemed to be little advantage in removing the guide boss, we only did a bit of smoothing and narrowing at this point.

A far more drastic approach was taken in removing metal from the areas flanking the guide boss. The experiments with clay

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stub manifold's mounting holes we shifted the manifold upward to match the relocated passage, and we assumed even this slight change would tell us if more ambitious port-straightening efforts would be rewarded.

All the clay had to be scooped out of the port prior to this final assault on the metal and carefully reapplied when the grinding and buffing was done. The whole process was a bit of drudgery we'd happily leave to the servants (if we had any), but on this occasion the tedium was amply rewarded. The flow was up at all lifts, rising to 123.7 CFM at .400-inch, and reaching 126 CFM at .500-inch, which were rates comfortably above baseline. Flow was also appreciably better than before the port entry was raised three millimeters, and this has us wondering what miracles of breathing might be possible if we opted for a more radical modification along the same line. Converting to short Harley-Davidson XR750 valve springs would provide room for a quarter-inch elevation of the spring seat pocket; the space created could be used to tilt the port centerline into a downdraft relationship with the valve. It would almost be worth all the machining and heli-arcing to see what would happen to the flow.

We found some fairly significant things happening to the SR500's intake flow just with the changes we did make. The most important discovery was that flow at very low valve openings could not be greatly improved except at the cost of intolerably depressing high-lift flow. A two-CFM gain at .050-inch lift became a 20-CFM loss at .500-inch lift when we added a thin, rounded ring of clay to create a slight venturi above the valve seat. On the other hand, all of the successful changes made farther upstream from the valve gave better flow at all valve openings, with especially large increases beyond the point (.250-inch lift) at which the stock port began to offer serious resistance. After we'd finished our work, the SR500's intake port would flow air at rates closely tied to valve lift up to .350-inch, where the area of the valve/seat aperture equalled the seat throat area. Openings beyond .350-inch lift produced diminishing returns: the flow rate at .400-inch lift is only 2.5 CFM lower than that at .500-inch and just 4.25 CFM less than the .600-inch lift maximum of 127.6 CFM.

The above data makes it clear that flow through the *Cycle*/Yamaha intake port is not much influenced by the presence of an intake valve hovering a half-inch from its exit. Once the valve head moves more than .400-inch away from its seat, flow proceeds almost as though the valve had been removed. We tried that, flowing air through a completely unobstructed port, and the reading we got verified something we'd been told: that when port and valve shapes are properly matched, completely removing the valve actually will cause a slight decline in the flow rate. The valve *stem* simply does not exist from the air's perspective. A lump of clay had been used to seal the valve guide while open-port flow was checked; removing the clay and stabbing the inverted valve into the guide put the stem down in the port, and there was absolutely no change in the flow reading. Jerry told us that was a common characteristic in smooth-flowing ports, adding that the Yamaha valve's shape must be awfully good. He said some valves stall intake flow so badly that readings jump upward as much as 25 per cent when they are removed from the port. In such instances he can get large improvements by using a different valve; he didn't think we could hope to better Yamaha's lightly tuliped valve-head shape.

The final stage of our porting project was to measure very carefully the shape that had developed during the days of changes and flow tests. The clay would have to be replaced with epoxy before we could try our fancy, revised port on the engine dyno, and we didn't want to rely on memory alone in reproducing the bench-developed shape. Also, we wanted to check the cross-section areas at various points through the port. The entry diameter had been held at 35mm but the port interior's dimensions were unknown, having been generated as we carved and clayed according to the dictates of the flow bench. So the head was chilled in a refrigerator to harden the clay, and we made numerous measurements—which were then transferred onto graph paper as scale cross-section drawings. Simply counting the graph paper squares gave us the areas, and an interesting fact: the flow bench had chosen a virtually constant-area shape. The port was round at its entry and widened to 48mm where it turned downward toward the valve, but the steadily increasing width was offset by a reduction in height. The areas did increase around the valve guide, immediately upstream from the valve seat throat, which has a 41mm diameter and thus a larger area than the 35mm port entry.

Where do we go from here? There's a lot more graph paper in our future, because the next step is to continue with plotting lift curves from as many Yamaha 500-banger cams as we can find. The results of our dyno tests would seem to indicate that something very near standard Yamaha valve timing will give us best overall horsepower. Flow test numbers tell us to look for a cam profile that pushes the intake valve out to .500-inch lift or a little more and pushes it fast. If we use the half-inch lift the SR500 still will be six CFM below its projected air requirement, but that's a lot better than the 22-CFM shortage estimated for the stock setup. Being 4.5 per cent behind in your breathing is nothing when you've started with a 16.5 per cent deficit. Maybe this Yamaha SR500 hop-up project of ours is getting somewhere after all. ◉