BY DAVID VIZARD

DO-IT-YOURSELF: MODIFYING THE WATER COOLED HEAD

IT REQUIRES A MINIMUM OF TOOLS, CASH, AND KNOWLEDGE

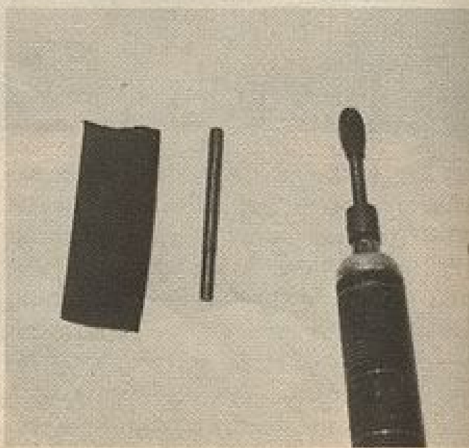
Our first confrontation with a Rabbit cylinder head indicated that it looked like it was reasonable but not necessarily exceptional for modifying. The intake port appeared to make a reasonable angle with the valve for good flow, but the exhaust port looked like it had too severe a turn for anything approaching optimum results.

It's fairly common knowledge that the better the cylinder head flows air, the higher the volumetric efficiency of the engine using it will be. Though not necessarily an end goal in itself, a higher volumetric efficiency usually leads to more torque, more power, and usually better economy. Since a modified head has so many benefits, we posed ourselves the question; "How well will the head respond to easy, simple modifications that the weekend mechanic can perform?" With the aid of every head porters favorite machine (if it isn't it darned well should be) the flow bench, we thought we would find out.

The flow bench used to measure our test results was the big Superflow 300 unit. Its repeatability and accuracy of results have impressed us on many previous occasions so we felt sure our flow figures would be as close to 100% honest as possible.

The type of modifications we would consider would be those feasible with ordinary hand tools such as cutters and emery cloth used in conjunction with a high speed electric drill or a high speed hand grinder. Every handy mechanic should have easy access to such tools. So much for the preliminaries, now on with the plot.

Obviously, before making any modifications, the very first job was to mount the stock head on the flow bench and check out just how good or bad the stock induction was. When we talk about induction here we mean the port and the valve and any effect the chamber may have on the induced charge. Column 1 of our chart (Fig. 1) shows the flow figures obtained from the first pass over the bench. Unless you are used to looking at flow figures day in and day out, these numbers may not mean a lot to you. So you may well ask, "How does the stock port with its 34.0mm valve measure up? Is it good or bad?" Some calculations revealed that at a valve lift equal to a quarter of the valve diameter (0.25D) the port and valve combination has a discharge coefficient, which in laymens terms is flow efficiency, of 56.4%. This figure is just a little better than we would have expected it from eyeballing the port, although eyeballing ports to tell whether they are good or bad is, at best, a dicey



ABOVE, the tools needed are a high speed grinder, flex shaft and emery cloth.

FIG. 1

RABBIT CYLINDER HEAD FLOW TEST

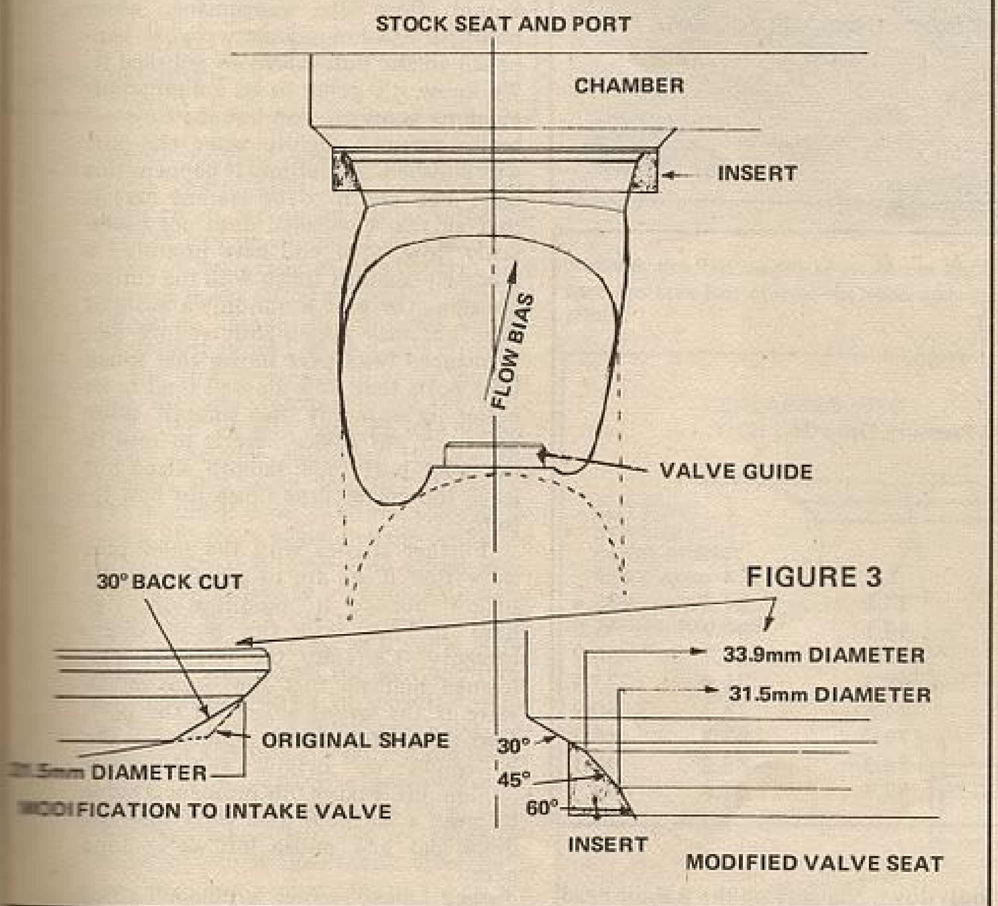
TESTED BY: David Vizard

FLOW BENCH: Superflow 300. Standard Pressure Drop 25" H_2O

INTAKE FLOW C.F.M.

Valve Lift	1	2	3	4	5
0.070	31.8	27.4	31.3	27.6	28.1
0.140	56	58.1	59.1	59.4	59.1
0.210	78	85.9	88.7	90.9	88.7
0.280	98.8	103.0	107.1	111.1	109.1
0.350	104.0	105	108.7	111.1	110.1
0.420	105	105	112.1	114.1	112.1

FIGURE 2



business. By comparison with other engines, a port with this efficiency is good. Very few production ports on vertical valve engines exceed 55% efficiency and most ports tend to be around 45 - 48%.

We can start our port modifications in the knowledge that we have as a basis, a fairly respectable port. Of course the better the port is when we start, the more likely we are to take backward steps if we don't think about what we are doing. Running an experienced eye over the port, it would appear that the original port was designed with some sort of idea of just how the air flows. Whether or not the original Volkswagen head had been developed on a flow bench, we cannot say, but the design features which have gone into it show at least some thought as to what is required. Inspection of the valve seat revealed that this would be the first area that we would need to look at. The stock valve seat suffers from several problems if we are trying to extract the maximum airflow from the port. First of all, for some reason, the valve seat has been sunk in the chamber by approximately 1-1/2 mm. Fig. 2 shows what exists in stock form. The valve seat diameter is a little short of the valve diameter for maximum air flow, so our first job was to recut it to a larger diameter and make some attempt at removing the small shrouding effect caused by sinking the valve seat insert into a pocket.

The modifications we made are detailed in Fig. 3, and this was the one job we weren't able to do with our ordinary hand tools. To get the valve seat job done it was necessary for us to go along to our local automotive machine shop and have them cut the seat to this specification. Column 2 shows the airflow results of the seat modification. Note that at low lift flow was actually reduced. This is very often the case when valve seats are narrowed. However, once the valve gets well clear of the seat, the added breathing area and hopefully the slightly more streamlined entry into the chamber starts to pay off. The flow numbers show just this tendency. From .140-in. to .280-in., the increase was quite reasonable. At 350 and 420, the gains were almost zero. In fact it would appear that once the valve hits .350-in. lift, it just shuts off any further increases in flow. This was a tendency also revealed by the stock port. Cutting the valve seat did not change this.

The next move was to put our hand tools to work. What was done to the intake port was to blend the seat and the insert into the port and generally smooth things up for the first 1/2 to 3/4-in. down the port. Also attention was paid to the port side radius, that's the tight radius on the floor of the port when the head is up the right way. Fig. 4 shows the approximate form our modifications took. Column 3 of our chart Fig. 1, shows the subsequent gains made. As you can see, removing those sharp edges from the seats paid off right from low lift upwards. Our flow increased everywhere at all lift points measured. Although peak flow figures are important, the mid-flow figures are usually more important. You have to remember that the valve only hits full lift once, but it gets to half lift twice. Designing and building a port which flows strongly in the mid-lift ranges on a street engine has the same effect as installing a cam with very fast flank accelerations, but port modifications do not suffer any of the disadvantages of such cams. You will notice that the flow has gone from 78 cfm to 88.7 cfm at .210-in. This is a significant increase in this range. Although a gain was made in the flow figure at .280-in. valve lift, the

FIGURE 4

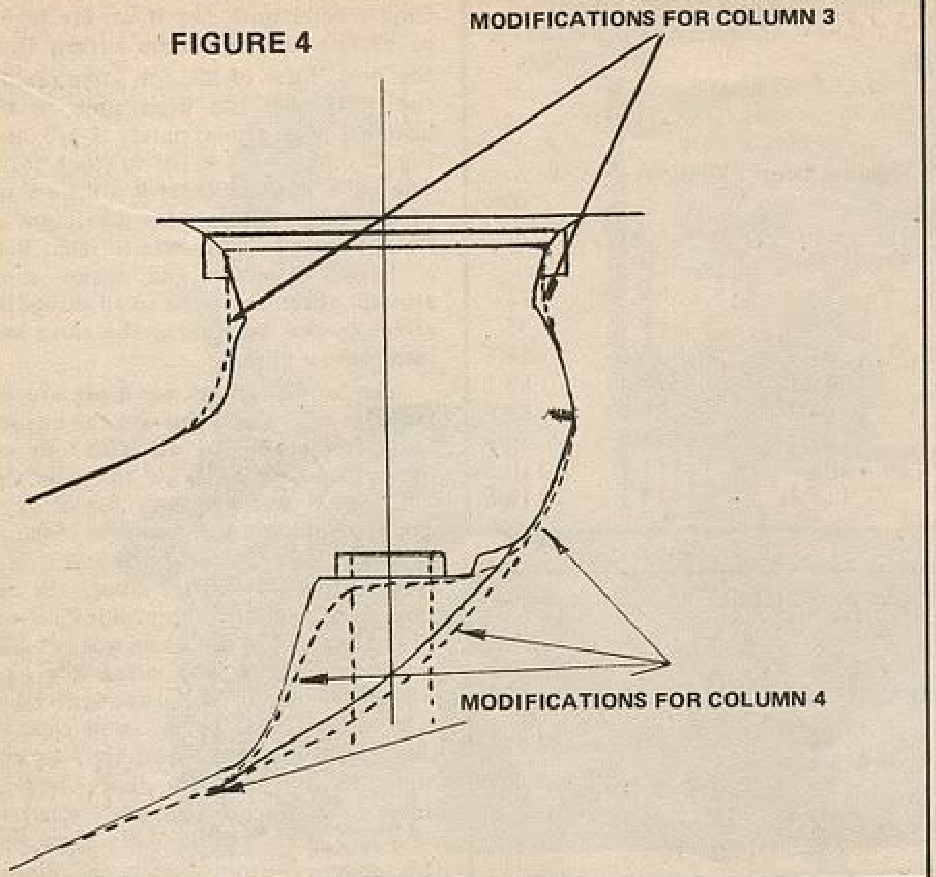


FIG. 5

RABBIT CYLINDER HEAD FLOW TEST

TESTED BY: David Vizard

FLOW BENCH: Superflow 300. Standard Pressure Drop 25" H2O

INTAKE FLOW C.F.M.

Valve Lift	1	2	3	4	5
0.061	22.0	21.3	23.8	24.3	25.4
0.122	41.8	42.6	44.1	46.2	45.5
0.183	53.2	55.1	58.3	61.2	60.9
0.244	63.7	66.7	68.3	71.9	73.9
0.305	68.8	72.5	74.6	78.3	80.9
0.366	75.1	79.2	79.8	83.3	85.7
0.427	79.1	84.0	84.3	88.2	90.1
0.488	81.2	86.1	87.7	91.6	93.5

amount of gain we were making was significantly dropping off, and the flow curve of the port was flattening out. At .420-in. lift, we had 112.1 cfm and lifting the valve any further gave no more air. It was apparent then, that something was shutting off the port. Certainly it responded to throat modifications but it suggests that what ever shut the port off at these valve lifts occurs further downstream.

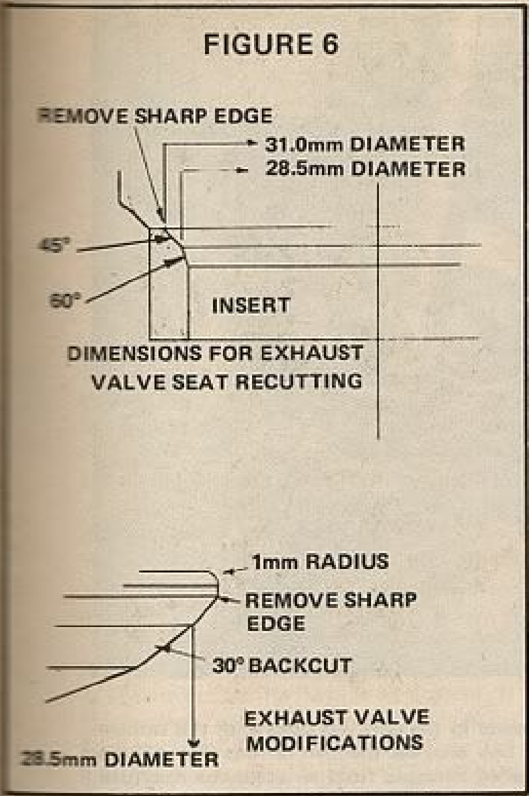
The next move was to streamline the valve guide boss and generally take advantage of the bias of the port. Let's dwell on this bias for a moment. If you look down the port on the Rabbit head, you will find that just prior to making the turn to the valve pocket, the port starts to lean towards the center of the cylinder in both the vertical axis and the horizontal axis. This is because in a vertical valve engine, the proximity of the cylinder wall tends to favor flow towards the center of the cylinder rather than evenly all around the valve. As a result, better flow can be gained by bending the port to enhance this bias characteristic. When the port was cut in the vicinity of the guide boss, we were careful to maintain or even enhance the bias towards the center of the cylinder. After the guide boss had been streamlined the rest of the port had the heavy flash marks removed, but no polishing was done on it; just a smooth finish from the cutter was all that was applied as far as finish was concerned. The nearby photos show just how the port was shaped. Back on the flow bench we found that the flow at .70-in. was, in fact, reduced compared to the previous test. At .140-in. it was up slightly and from there on we showed a positive increase. You will note, however, that the increase is relatively small compared with the increase gained by working in the area of the valve seat. This substantiates an old saying that the most important part of a port is one inch before and one inch after the valve seat.

Well, our port shape has been considerably smoothed out but we wonder how many of you out there are thinking, "Now it's a smooth shape and it should flow like gangbusters when polished." Column 5 shows what happened to the port when we polished it. We know it's going to be a disappointment to many of you but the flow actually dropped slightly when the port was polished. Sometimes it happens this way. The lesson to be learned here is that all that's polished does not necessarily flow, so if you have produced a relatively smooth finish with the cutter, polishing the port is not only a waste of time but may also slightly reduce performance. Tests have shown that rough inlet ports that flow air well tend to be better on economy than smooth, shiny ports, so our advice here is to rework the inlet port to a smooth shape but leave the cutter type finish for best results.

Further studies with the inlet port show that if we are to get much more airflow out of it, modifications will have to fall into the more severe category. Certainly the tests we performed indicate that the stock intake valve is the wrong shape for the port. Also the port shape has a problem when it comes to airflow above about .300-in. lift. Fixing this problem is going to mean a lot more hard work than the quick cut and polish job we've done here.

The most basic problem which occurs with most cylinder heads as far as the combustion chamber is concerned, is valve shrouding. On the Rabbit head, the only shrouding the valves suffer is caused by the cylinder walls and there is little we can do about that. The actual modifications required to the combustion chamber are only those necessary to eliminate the pocketing of the valves. On our project head, all that was done was to polish the chamber smooth.

Switching our Superflow 300 over to the exhaust phase, we set about estab-



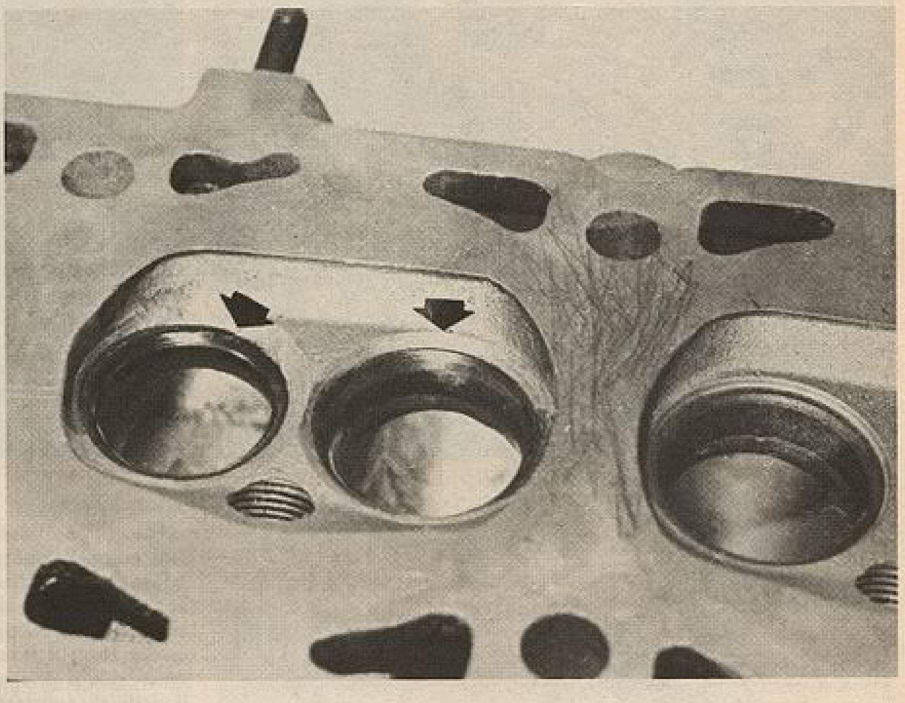
lishing the flow curve for the stock exhaust port. After the measurements were taken, we ended up with the figures shown in column 1 of Fig. 5. As more or less expected, the exhaust port showed lower efficiency figures than the intake at .305-in. lift (0.25D) the exhaust port proved to be 45½% efficient.

Our first move was to apply more or less the same technique on the valve seat area as was used on the intake. There was one exception though; the exhaust seat is so close to the edge of the chamber that it is not possible to use a 30° stone to remove the pocketing of the valve seat insert. This meant some careful work had to be done with hand tools to relieve the pocketing around the exhaust seat as far as possible. After this had been done, the seat was recut and narrowed down to the dimensions shown in Fig. 6. The exhaust valve was also back cut in a similar fashion to the intake valve, leaving a seat width to match that in the head. One step extra that was taken here was to radius the chamber side of the exhaust valve. Such a move is not a good idea on the intake as it can effect backflow during the overlap period. However, on the exhaust a radius can be responsible for quite a bit of extra flow of exhaust out of the cylinder.

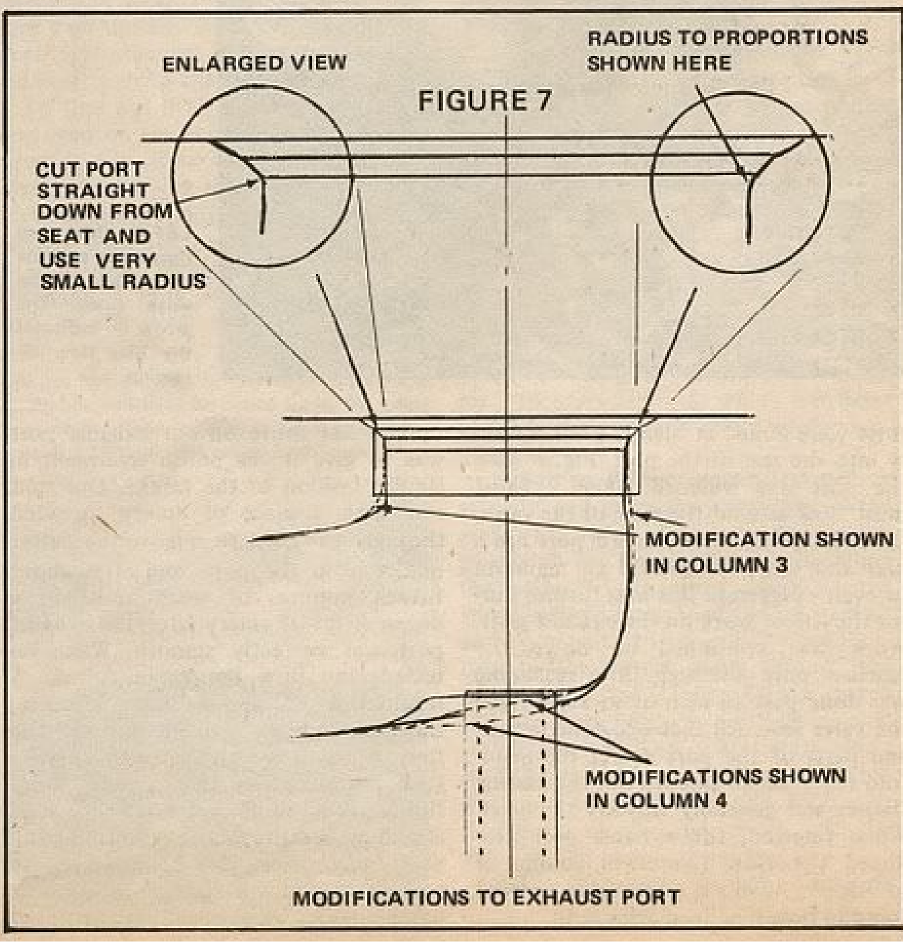
With these modifications done, the flow was rechecked and the figures in column 2 of Fig. 5 resulted. Essentially we picked up about 5% more exhaust flow throughout the lift range from .122-m. upwards. Worthwhile but nothing really drastic.

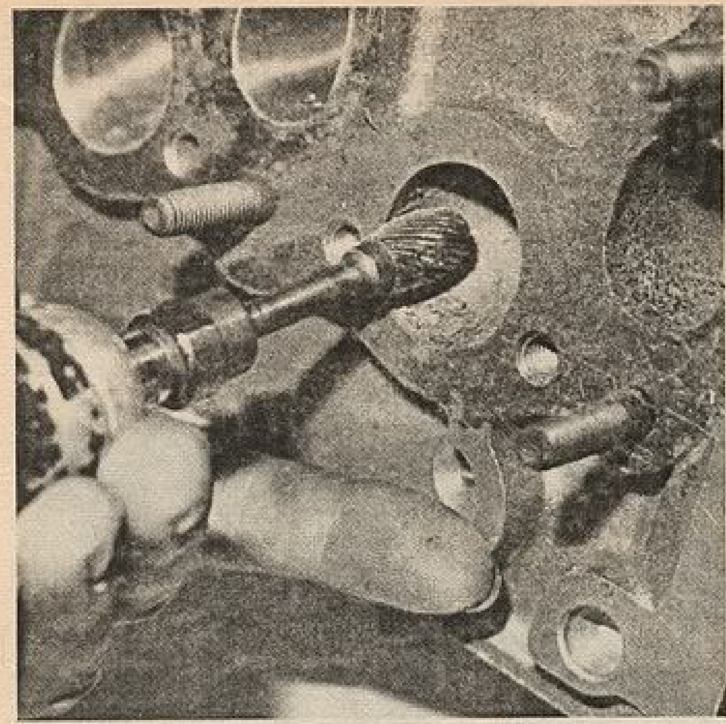
The next move was to blend the port into the seat and remove the abrupt turns on the short side of the exhaust port. Column 3 shows how we fared. This move proved to be worth increased flow at every lift station checked. Notice the figures show in this test and the previous one that flow goes on increasing as lift goes up right up to the .488-in. maximum lift measured. Although this characteristic is diametrically opposed to that of the intake, it does not necessarily imply that this is a more effective port or even has more potential when total flow efficiency is considered.

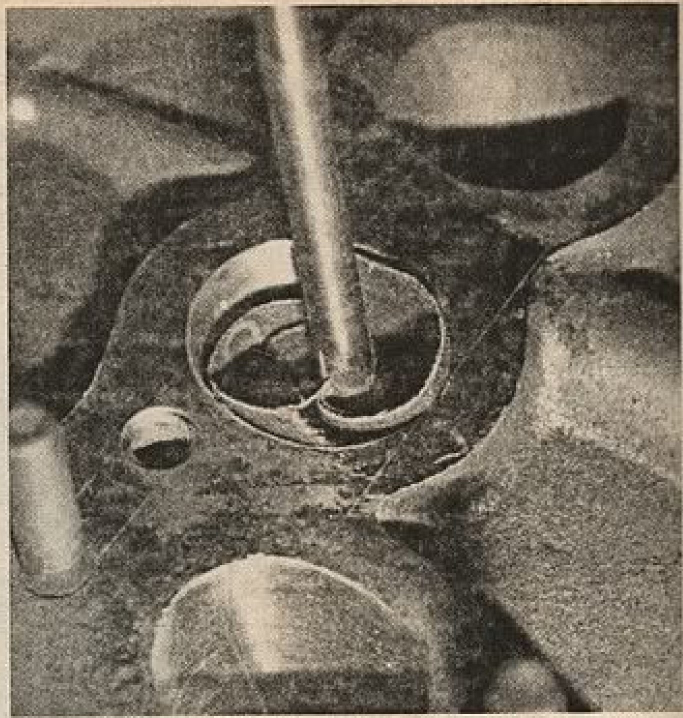
Although the exhaust guide boss in the exhaust port is small, our next ef-

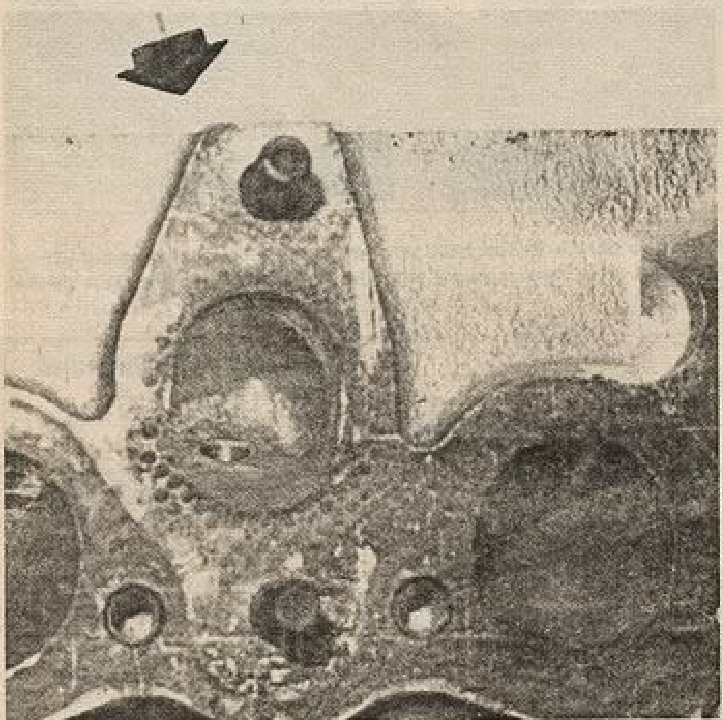


ABOVE, the first modification on the Rabbit head was to cut the valve pocketing out. Compare the area just outside the valve seats (arrows) with the stock intake on the right of the photo.









TOP LEFT, metal removal in the port was done with this carbide cutter. If you have to buy one, ask the man for one that will cut aluminum. A fine spray of kerosene from an otherwise discarded pump spray bottle will help prevent the cutter loading up with aluminum. Make sure you wear some sort of eye protection whenever you are cutting or grinding on anything. TOP RIGHT, the emery cloth is threaded through the slot in the end of the shaft. When this is driven by a typical electric drill, the finish produced is perfectly satisfactory for our sort of application. Remember what happened when we tried to polish things in some areas?

LEFT, this view shows the exhaust port shape at the valve guide. The arrow indicates the bias flow direction.

forts were aimed at blending it smoothly into the rest of the port. Fig. 7. Also the port was widened where exhaust must flow around the stem of the valve. Like the intake, the exhaust port has a bias and we were careful to maintain or even exaggerate this bias further during the throat work on the exhaust port. Work was continued on down the exhaust port although little reshaping was done past an inch or so away from the valve seat. All that was done in this, and parts of the port nearer the manifold face, was to smooth out the casting flashes and generally tidy up the port. When retested, the exhaust port produced the flow figures in column 4 of Fig. 5. Again, a respectable upward trend in flow had been achieved.

The last move on our exhaust port was to give it the polish treatment in similar fashion to the intake. Our split rod with a piece of emery threaded through was used to remove the cutter marks from the port, and after about fifteen minutes of work and half a dozen strips of emery later, the exhaust port was perfectly smooth. When retested, the flow figures in column 5 resulted. As you can see in this instance, the polish work helped increase the flow, but it is important to realize why. It is not necessary that a super shiny finish has given us that extra couple of cfm flow, but the fact that polishing the port may have just removed some irregularities or some significantly rough patches that were impeding the flow.

Using the strip of emery through the split rod works very well for smoothing out the radius on the tight side turn. This is a difficult area to get in with a cutter and even the most careful work results in a small ridge. Work with the emery and the split rod can usually erradicate that ridge and often this is where the increased flow results.

We now have the intake and exhausts reworked on a Rabbit head. The flow figures we are achieving are by no means the ultimate but there again, the length of time involved on each port with the simple tools we used means that devoting a Saturday to one of these heads can produce one similarly modified. Though more sophisticated modifications are well within the scope of the amateur, it takes more time. We will be going into more sophisticated modifications for those of you who are interested in producing your own heads, or even knowing what makes these heads work. Right now you are probably more interested in just what sort of results you can expect in terms of power increase with a head modified in this fashion. Well, experience has shown that the sort of flow increase we have achieved here is generally worth around 8hp. Fuel economy gains can be expected to be about 4% so long as the intake port is left unpolished. For a days work and the cost of some emery paper, that represents some pretty cheap gains.