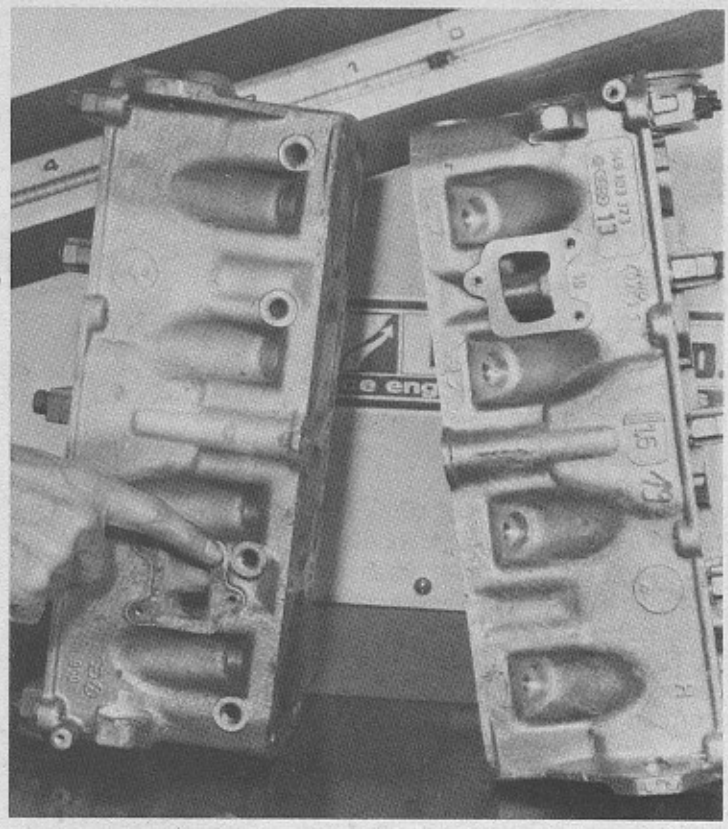
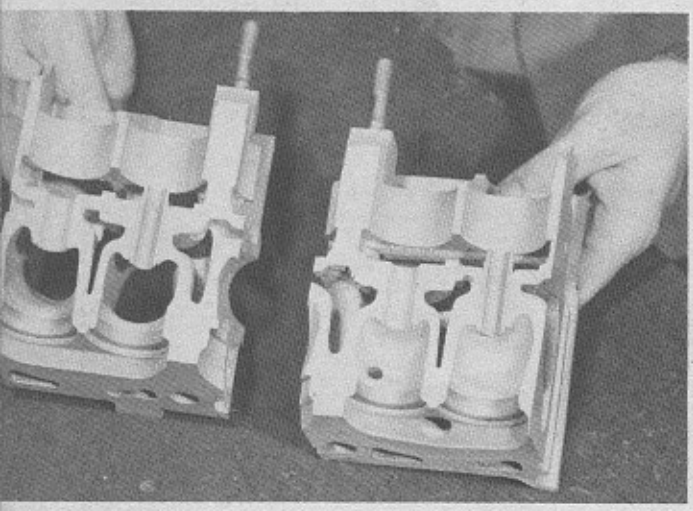
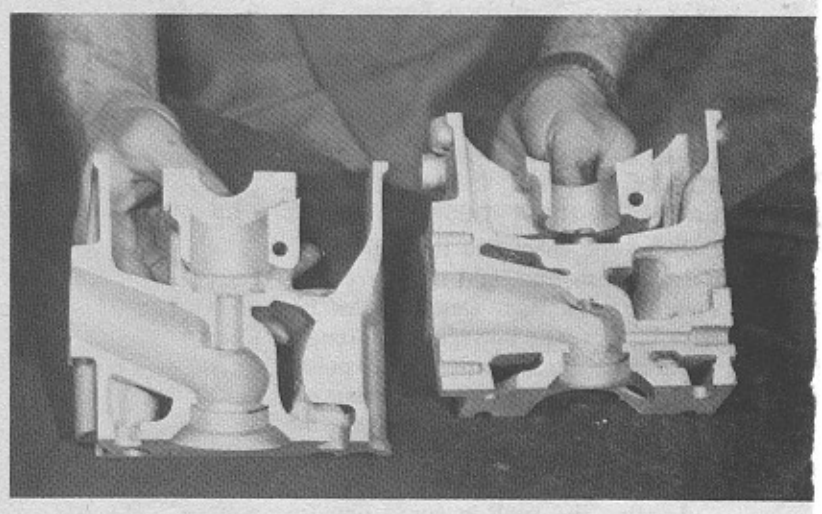
You can cut new ports with a big auger, lean on the grinder and achieve monumental telephone number flow figures. The only problem is that later the engine doesn't run any too well. The other alternative is to do a serious engineering study, come up with an intricate analysis, get tremendous dyno figures, and go lay a goose egg at the track because the car won't come out of a turn.

Somewhere between those extremes is the development engineer who has done countless heads, studied the effects, logged them both in his records and in his photographic memory, and also has the knack for sensing what the correct shape should be. When Drake Engineering of Irvine, California, and of Indianapolis fame, set about to develop the best in Super Vee engines so the Rabbit ears would flip back into the sprint position, they pooled resources with Mullen and Company of Carson, California. The flow work was backed up with extensive dyno testing, and the result is one of the fastest engines on the circuit.

We first met Bob Mullen when he was still doing flow research. He finally decided the corporate meetings were





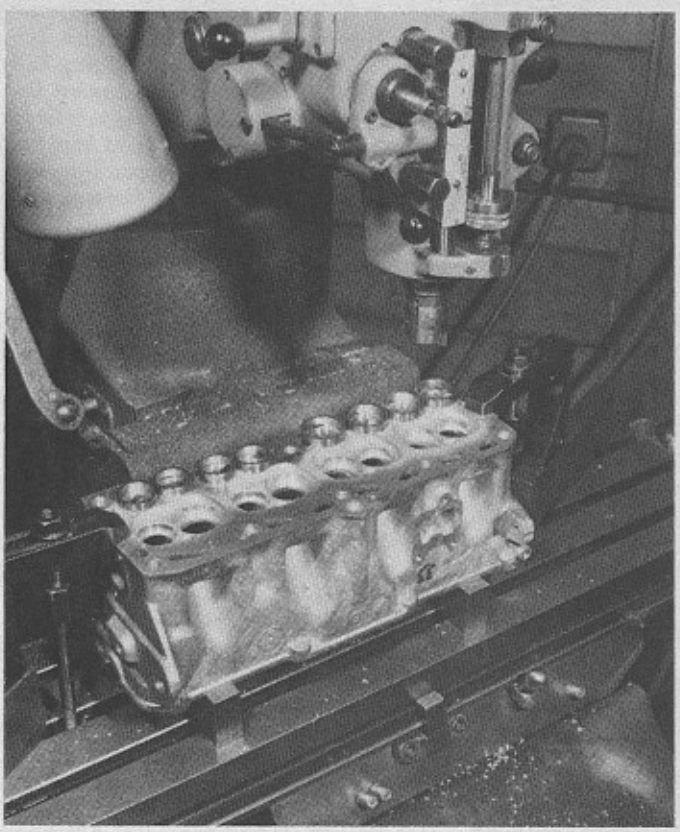


TOP RIGHT, all four of the air inlet passages into the exhaust ports are plugged off. BOTTOM LEFT, cross-section shows the location of the water jackets and the available wall thickness. BOTTOM RIGHT, the inside radius, where the floor turns toward the seat can be improved thanks to larger valve seats.

WATER-COOLED HEAD MODS

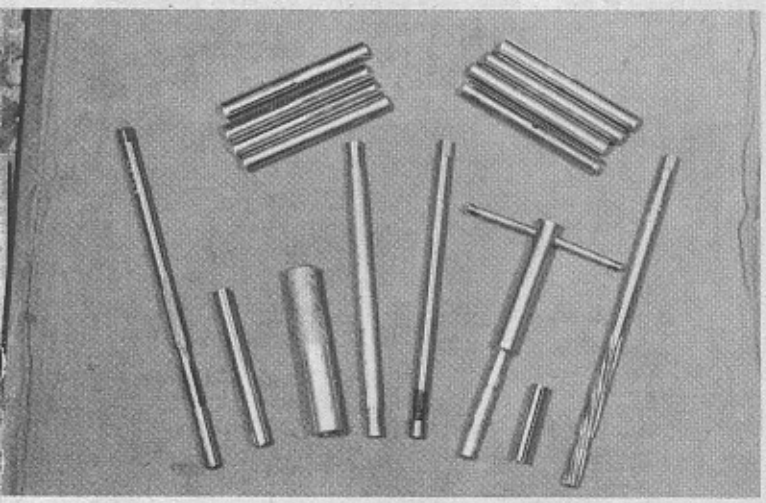
BY ALEX WALORDY

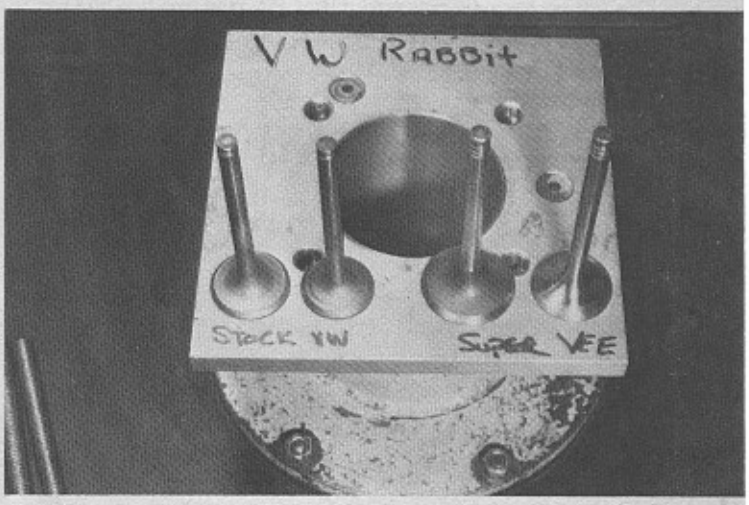
THE WATER-COOLED ENGINE RESPONDS WELL TO PROPER HEAD MODIFICATIONS



is also not adverse to turning to the computer when the occasion arises, which helps him optimize the flow and come up with all sorts of magic numbers to tell him where he is at and also to predict the cam that will work best with the head. He tells us the hardest job in head work is to just be objective and take the data as it comes. Bob has all his data cataloged and notes, graphs and charts from the first head he ever flowed.

Flow is measured at different valve lifts, and you soon find out that the two are not directly proportional. An engine may have a very poor flow at low valve lift and be excellent at the top end, or it may completely run out of steam at higher lifts and actually lose flow. Keep in mind that the valve shape itself is a guide for the incoming or outgoing gases, and the underside of the valve has a major effect on flow. By the same token, the shape of the combustion chamber wall around the valve may improve either low or high lift flow, but not necessarily both. Mullen plots the flow at different valve lifts, distributes it according to the cam timing, and the area under the curve tells him how effective the overall flow is averaged





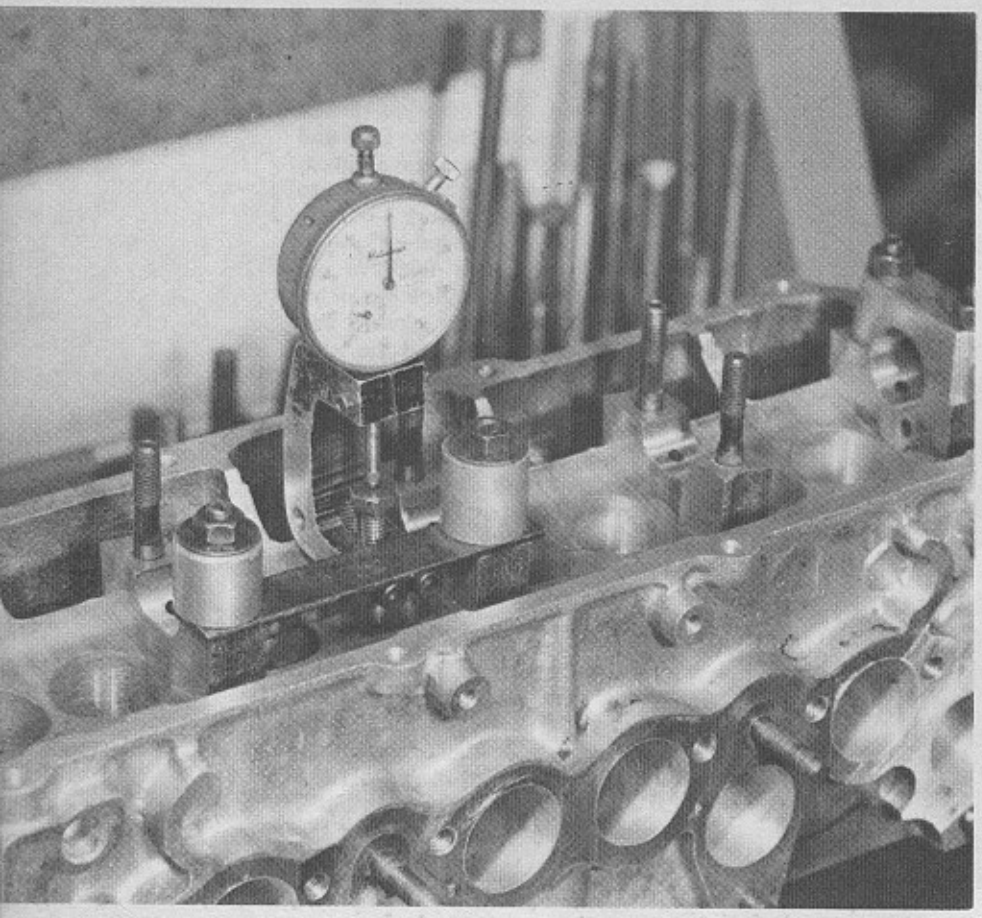
TOP LEFT, a mill is used to bore out for the larger seat insets for the 40mm intakes and 34mm exhausts valves. BOTTOM LEFT, this set of tools drives in the valve guide insert, expands it, and reams it to near finished size. BOTTOM RIGHT, the valves are not only larger in diameter, but also longer to accommodate valve train modifications and taller springs.

something he could do without and opened up his own shop. It wasn't long before his Hemi heads became a Chrysler part number, and he is well known for his work on V-8s as well. Hans Herman, Drake's head of engineering and development, suggested we pay him a visit and look into their joint project. Drake Engineering did quite a bit of tooling, developed a complete valve train, everything from seats and valves to cams and springs to match the flow work, and now make the heads available as a complete assembly.

The interesting part of it all is that while the current work concerns the 1600cc Super Vee engine, it will apply almost directly to Rabbit engines for off-road, road courses and whatever else you wish to do with your Rabbit, especially if you fatten one up to 1800cc or more. In other words, the engine will not object to the increase in port size.

Mullen designed and built his own flow bench and turned it into quite a sophisticated unit, which can read out directly any flow, without switching to different measuring elements. Apart from being a very practical engineer, he through the event. A little work on the computer shows what can be gained, and where, when these tradeoffs are made.

Our example set of heads was designed with one purpose in mind; to work with a 32mm restriction. Super Vee rules call for a restriction between the inlet and the throttle to even out the score between air-cooled and water-cooled engines. Hans Herman of Drake Engineering designed a very clever manifold shaped like a nozzle, which funnels down to this restriction, and back out again to ensure peak flow. Any restric-

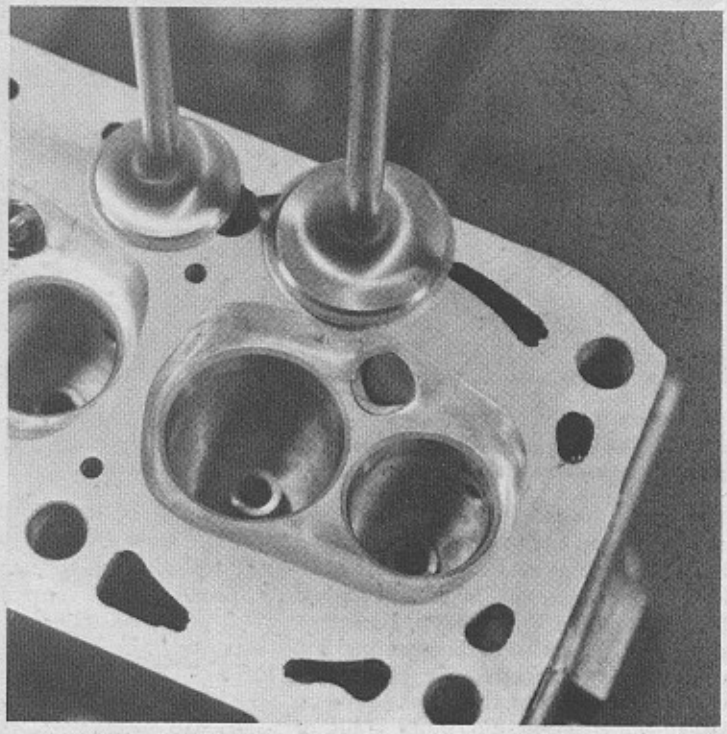


This fixture gives a direct read out of the valve position and can also check the height of the valve stem when setting up the lash.

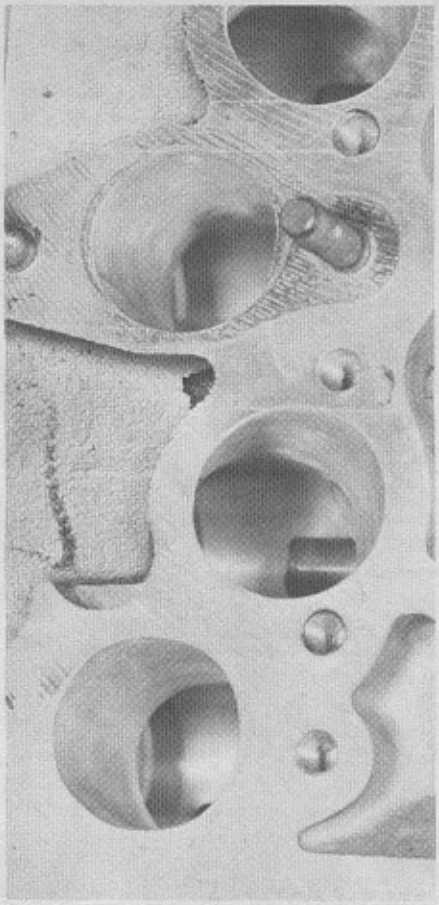
tion acts just like a venturi and the efficiency of the venturi is measured by how well the pressure is recovered downstream of the throat. Since the manifold is circular in cross-section, and fairly small, the cylinder head ports begin in the same fashion. The idea was to maintain a high velocity, good ram action, keep the fuel in suspension and have not only maximum horsepower, but also good mid-range torque. Since the Drake manifold is a casting, they had to play it safe and make the throat of the restriction slightly smaller than what the rules called for, so as not to accidentally get thrown out on a technicality. Later, the restriction can be opened to the exact 32mm size, and Mullen does so on a mill. He even manufactured a 32mm plug gauge which can be used to check that the restriction does not exceed the class rule size. A little more detailing can be done on the manifold, such as thinning out the butterfly rod and counter sinking the screws. That is enough to make it match the head flow.

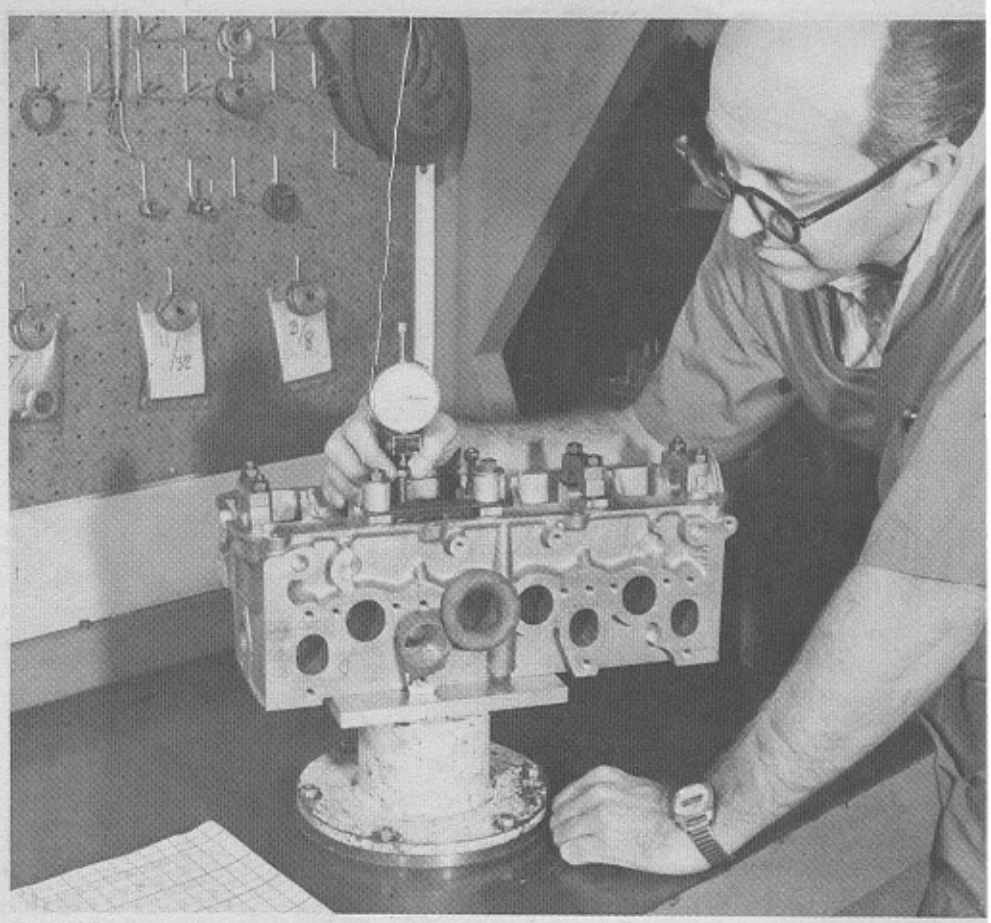
We asked Bob if flowing the head by itself was different than flowing it with the manifold. "Actually no," he told us, "had the manifold been peculiarly shaped, it could have the effect of redirecting the flow, but here the manifold is a straight shot and will only help, as was proved by subsequent testing." In normal practice, a clay entrance is formed around the port that

The hone is fitted with an expander that controls the stones and backing strips, and determines the size of the guide. The snugger the valve can be fitted without sticking, the longer the valve job will last.

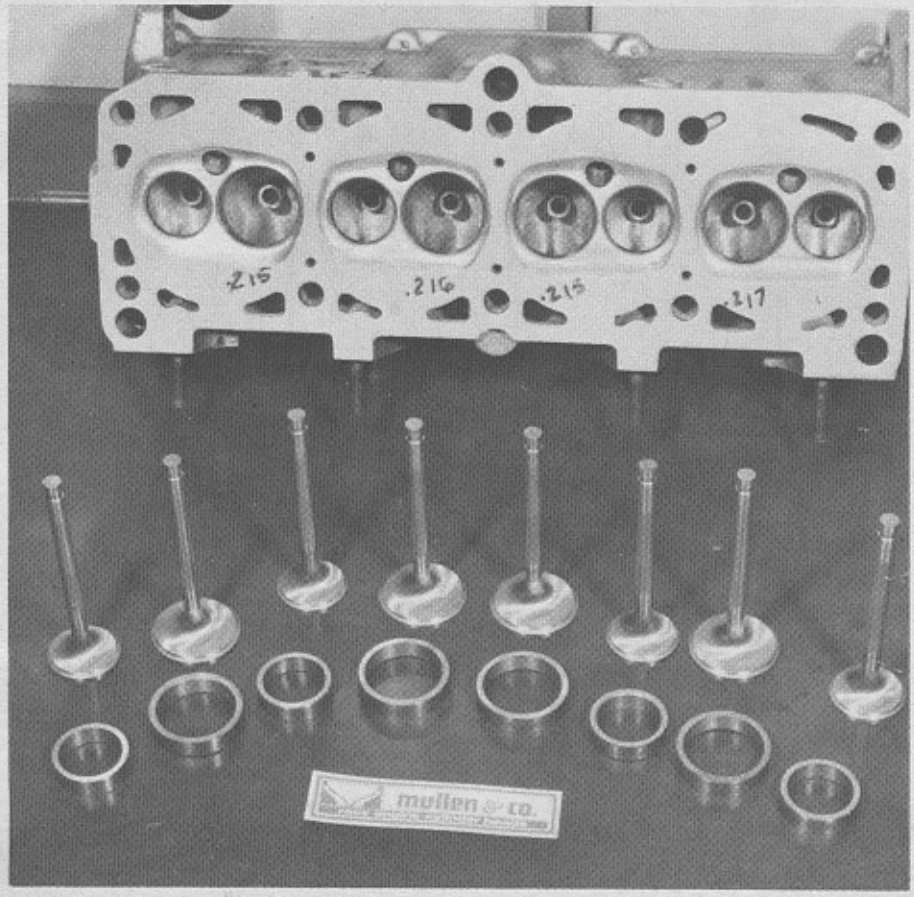


Reworked combustion chamber retains the original squish area, but has been opened up along the roof to unshroud the valves. OPPOSITE PAGE BOTTOM, the valve seats are taller than stock which brings the valve further out into the combustion chamber; improving flow.





LEFT, scribe marks define the new port shape. RIGHT, with the bench generating flow through the port, Mullen uses a probe to locate high velocity areas that need opening up.



is being flowed, simply to eliminate turbulence created by a square edge. The rounded clay entry gives the same flow results as bolting on a manifold, but still allows you to do some test work with a probe or by adding or taking away clay.

The general idea in using the flow bench is to locate and open up the high velocity areas, so as to make fuller use of the port cross-section. Keep in mind that air does not flow evenly across the full manifold section. It may prefer to stick to the inside curve or the outside, and it will often not flow where you want it to. In some racing classes, you gain flow by filling in a dead area with weld, but for Super Vee you are not allowed to add metal—you can only remove it. You make the best use of the area where air is already flowing.

The stock Rabbit intake port shows a fairly rapid rise in flow to a .300-in. lift, and then flow levels out regardless of further lift. A series of changes eventually raised that. For comparison, 40cfm flows to 56.6cfm at .600-in. lift. In the process, the oval intake port was increased to nearly full round. Similarly, the stock exhaust port flows 25cfm stock and has now been raised to a 43cfm flow at a .600-in. valve lift. In other words, the exhaust now flows better than a stock intake. You can just about insert a 1.300-in. valve into either the intake or the exhaust ports at the manifold flange.

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HEAD MODS

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Some initial testing on scrap heads showed that opening up the port way out only made it unstable—one minute it flows 40cfm, the next 36cfm while a more moderate port like this one is very stable. It is designed with little change in the cross-section areas and even those are very gradual. Switching to larger sized valves gives more swing room for the tight inside bend between the floor and the bowl. Think of a car coming into a turn and swinging out slightly in the opposite direction just to widen out the corner. Increasing the radius works the same way along the "hump" of the port. Jim Razor, who is in charge of the porting at Mullen Company, is a master at using belt sanders, flapping paper, cartridge rolls and carbide cutters to sculpture flowing curves within the confines of the port.

The area of the port directly under the valve is called the bowl or pocket, and this is the section where the most significant flow gains were achieved for the Rabbit. A stock head has some sharp machined edges just below the valve seat which can be removed to good advantage, but there are also many things to be done in terms of seat angles and throat angles, and the way they blend into the pocket itself. On the exhaust side, you try to gather in and organize the exhaust flow to keep it from becoming turbulent, and this calls for a contraction or a throat, achieved by grinding a 70° angle from the seat on down.

On the intake port, the contraction is made further upstream with a 75° cutter, and practice showed that it flowed better than with a 70° cut. For best intake flow at maximum lift, you would cut a topping angle of 20-25° to blend with the 45° seat. Here, for best flow throughout the range, beginning with low lifts, the topping angle is omitted. You don't want to create a dead area by carving out too much from the back wall because this results in turbulence and cuts flow. Instead, Jim Razoe kept a nice slope for the back wall, but removed material from the sides of the bowl to gain some added flow. This is a tricky part of the job because of the close proximity of the water jacket—you need some cylinder head sections as a guideline before diving in with a cutting tool.

You can compare what an ideal valve and port configuration with a particular valve size would flow in relation to the actual port, and the result is what is called a coefficient of flow. Bob Mullen tells us that on the Drake heads this turns out to be a lot better than on many V8s.

Racers seem certain that ports should be polished and shiny, but Mullen is a

lot less than fully convinced. The results are hard to pin down, for or against. On a flow bench, you can't tell, and sometimes even a dynamometer results show little difference. On the other hand, testing done on some Chrysler Hemi manifolds showed a three-mile per hour difference in top speed at the drag strip in favor of a rougher port, and yet gave nothing on the dyno. A rougher finish can help pick off fuel from the manifold walls, and put it back into the air stream. There are times when blending and doing away with an edge at a valve seat angle can hurt by causing flow separation and turbulence.

The seats are taller than on a stock VW and brought even with the flat floor of the chamber in an effort to raise the valves in the chamber. Here, flow is the main consideration, rather than adding piston to valve clearance for street safety. In addition, the larger diameter seats are dressed to the correct throat angles and blended to the bowl. The engine definitely likes compression, and here again the tall seats help. Mullen goes a step further and controls all seat depths to within a couple of thousandths. With all of the valves at the same level, it requires very little work to even out the cc of all four combustion chambers. A special jig with a Mitutoyo dial indicator rests against the cylinder head deck and checks the valve height within the chamber.

Some of the first tests were made with big valves, but a stock combustion chamber shape. Here, the intake would not go over 51cfm; quite a bit short of later flows. Best results came from flattening the roof of the chamber around the valve area and at the spark plug. This helped over the entire lift range and raised the flow to 56cfm. Low lift flow went up dramatically, which fattens up the area under the curve and gains overall. Combustion chamber walls are not leaned back away from the valve, so as to keep the squish area nearly the same. Instead it is the roof of the chamber that is opened up. By the same token, the protruding spark plug boss is also cut back which calls for using a double washer at the plug to back it out of the hole—you don't want plug threads picking up carbon while exposed in the combustion chamber.

Mullen machines his own valves from the same blanks that are used for his American engine valves. Both intakes and exhausts are stainless steel, and flow bench testing shows that the Rabbit likes a very flat underside for best results. The valves have a thick margin on the outside diameter, which gives enough material to reface it, but is also dished slightly along the top to lighten it. Here, the top has practically no effect on flow. One major item was to leave enough radius and structural material on the underside of the intake for strength.

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HEAD MODS

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You have just so much space within the confines of the combustion chamber, and the way it is divided up depends on an engine builders preference. For instance, on Drake heads, the intake and exhaust valve sizes are 1.575 and 1.375-in. On other engines, Mullen has used a 1.615 and 1.315-in. intake and exhaust, tipping the scale more toward a larger intake. On the Drake head, exhaust flow turns out to be a more than adequate 73% of intake. In fact, this is better than on some of the Ford and Chrysler race heads that Bob helped develop.

Valve guides are the key to any good valve job, but here they also turned out to be in the way of achieving the desired port shapes. No problem, they were simply pressed partially out of the way, the guide boss removed, and then pressed back in with a bit of Loctite for safety. It turns out that the 5/16-in. American sized valve stems in the blanks Mullen stocks are just a shade smaller than 8mm VW valves. To make up the difference, and also to provide a good compatible wear surface, the stock guide is bored out and the reducing sleeve pressed in. The sleeve is then expanded, reamed, and finally honed to a very close tolerance. Mullen has found from experience that the valve job lasts a lot longer if the guide is snug, and the valve cannot move around. Once a valve starts seating in different positions, because of a loose guide, the seat pounds out more quickly than it should on both the valve and the head.

Any good race head requires many compromises, some of them quite fine, to the point of your not being able to see them unless you know specifically what is needed. For instance, to what extent can you combine high and low lift flow, and how do you match the cam to what the head wants? In general, you can't optimize both, so you strive for the highest lift cam with which the engine will live, and then tailor the port accordingly. Here, you also have a restricted intake, because of class rules, and so the cam becomes all the more important. Drake developed a .550-in. lift cam and some special lifters which do not have a separate insert at the top as on the Rabbit head. These inserts have a larger effective diameter, since no retaining lip is needed for the insert, and they are also quite light. Valve lash is handled by small caps that fit between the cup follower and the step. Since the cam is reground, its base circle is smaller (the reference circle that passes through the no-lift portion of the cam is called base circle). Now there is room for a longer valve stem and longer valve springs, and Drake has had good results with both. ●