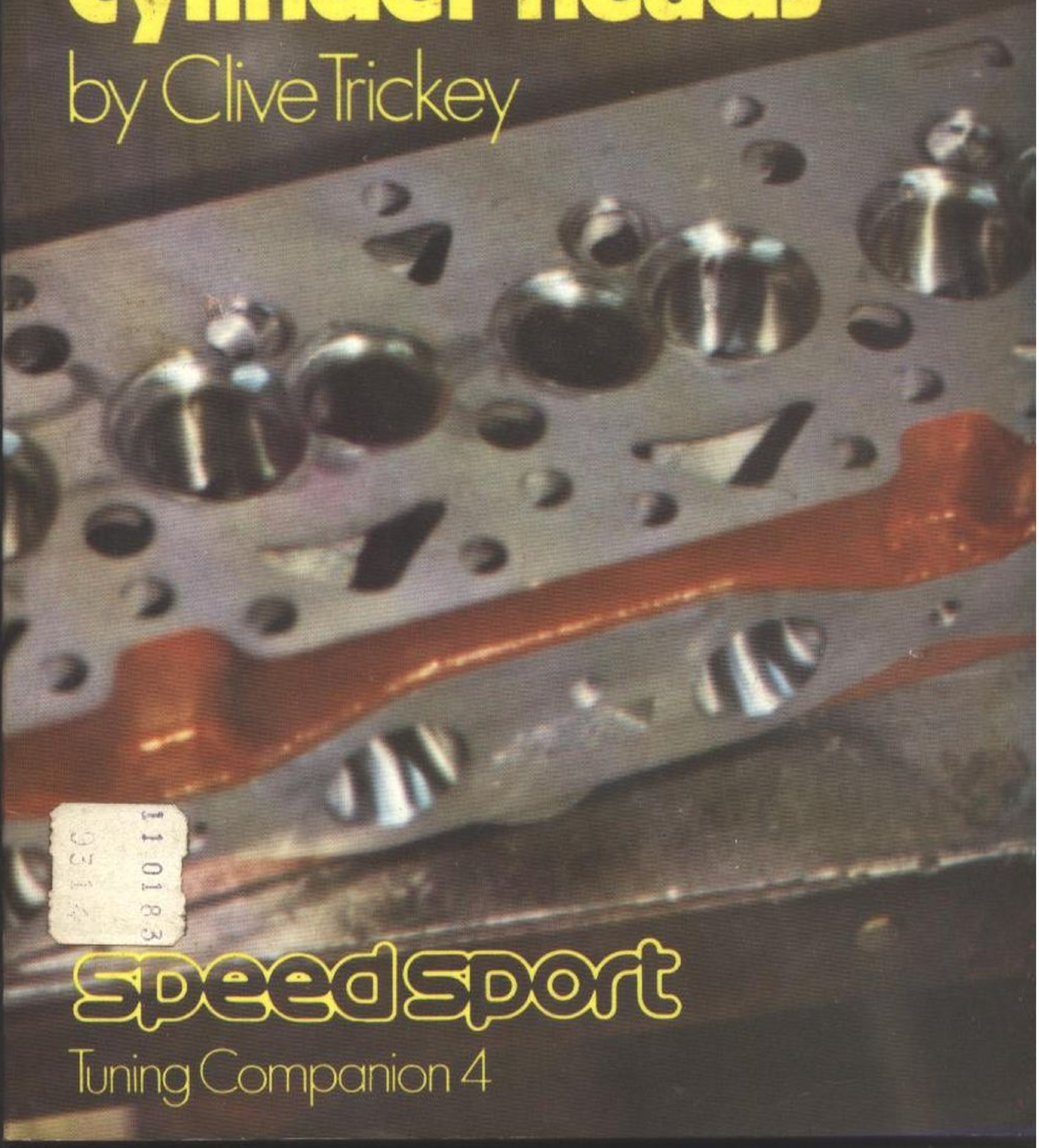
Modifying production cylinder heads

by Clive Trickey



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MODIFYING PRODUCTION CYLINDER HEADS

Clive Trickey

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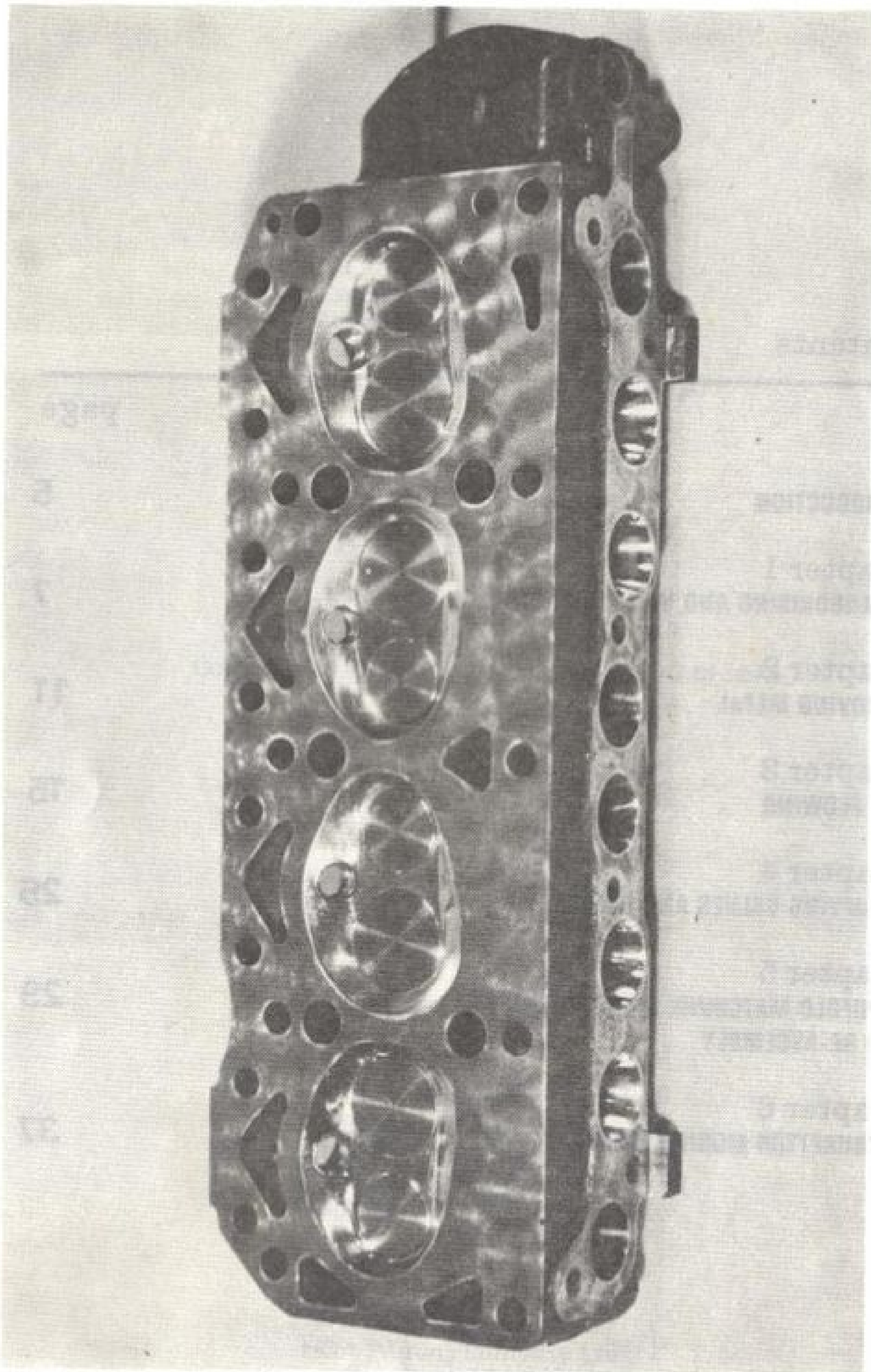


A fully modified cylinder head

INTRODUCTION

The rapid increase in 'do-it-yourself' modifications brings with it a need for more detail and specialised information. This new book covers all the stages of head modification which are feasible for the amateur who does not have vast knowledge or vast amounts of money. He will find that, when taken carefully, modifications to the head are not only relatively simple but bring excellent returns in performance.

The 'head doctor' should have a fair reserve of patience and not a little artistry in his make-up, for various operations required to bring a head to its final, gleaming condition of spotless efficiency are delicate and fussy rather than rugged battles against unyielding metal. So, having the correct attitude now fortify yourself with the correct technique.

The ensuing pages do not pretend to detail the official works recommended methods of working; they do however explain how I have carried out various operations to my own satisfaction.

The average "do-it-yourself" mechanic/tuner must seriously consider two factors before carrying out any work. The works-recommended methods are not only based on considerable experience but are carefully evolved to prevent damage to the article being worked on and thereby ensure the reliability and safety of the component or indeed the whole vehicle.

On the other hand to do every job the "works way" would involve the purchase of several thousands pounds' worth of equipment which is usually out of the question.

Careful thought can evolve a "do-it-yourself" method involving little or no expense but at the same time proving every bit as effective as the "works-method", though perhaps taking a little longer.

Unfortunately there are times when no amount of thought or improvisation can provide an answer (unless one is fairly clever and can make fairly "complicated" tools oneself) and then another set of facts must be considered. "How much does the special equipment cost? How much will a fully equipped garage charge to do the work? How often must the same work be carried out?"

The answers to these questions and their effect on your policy will depend on the use to which your car is being put.

Necessary Tools

Most people possess sundry hammers, mallets, pliers, tin snips, pincers, steel rules or straight edges, screw drivers, hacksaws and files, all of these tools being essential to the "do-it-yourself" enthusiast. Many, unfortunately, lack the equally essential high-quality spanners. How often does one see the amateur struggling, often unsuccessfully, with a cheap "tin" box spanner, adjustable wrench or pliers? How often do such tools merely "butcher" nuts and bolts without even shifting them, leaving only skinned knuckles and further problems as a reward?

One **must** possess or at least have access to a **complete** set of open-ended chrome vanadium spanners of reputable make, and preferably also an equivalent set of ring spanners. The cost? About £2.50p for the open-ended and about £4 for the rings. Other essentials are a decent plug spanner (approx. 25p) and a set of feeler gauges (25p).

This comprises a "basic" tool kit though I would say that at about £6 a small socket set is a very useful semi-essential. The set should include a two-way ratchet, T-handle, two extensions and a universal joint, together with about ten AF socket from 7/16 inch upwards. Always buy the best tools available of well known and reputable manufacture, always buy chrome vanadium spanners and sockets, they are far less expensive in the long run and much more reliable than cheap imitations, usually having the advantage of a lifetime's guarantee. Such a tool kit will enable one to carry out 75 per cent of all jobs that arise and will thus quickly pay for itself.

Having considered the "basic" tool kit, let us now investigate some of the tasks ahead together with any special tools needed. I shall not explain the routine, such as removing nuts, bolts, accessories etc., as cylinder head work assumes the head to have been already removed from the block.

chapter 1

DECARBONISING AND VALVE GRINDING

The simplest of the "major operations" is of course the de-coke, which anyone can do, providing that he has access to a valve-lifter; the simpler type costs about 50p and is perfectly good enough although a little slow in operation. Other than the spanners needed to remove the cylinder head, etc. from the block, the only other essentials are a valve sucker (about 7 1/2p from any garage) and a tin of valve grinding paste (20p a tin at most garages). Regarding the valve suckers, do not be tempted to buy a "value for money" double-ended type of sucker.

Buy a simple single-ended sucker of the correct size with a good stout handle.

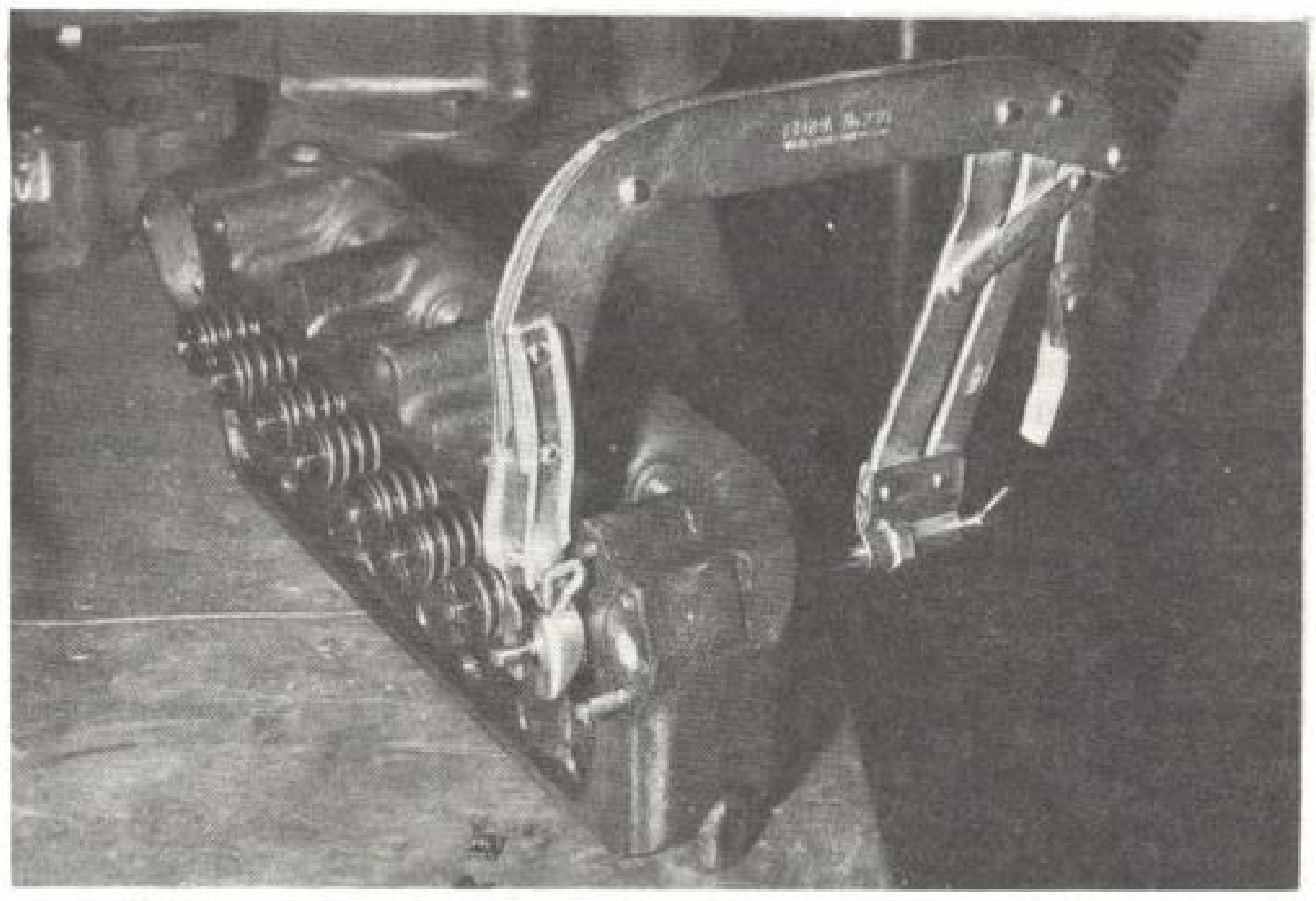
Carbon deposits should ideally be removed by the use of a wire brush mounted in an electric drill. However, small hand scrapers such as old blunt screwdrivers, kitchen knives, etc., together with a supply of emery cloth will eventually do the job just as well. One word however on wire brushes. In my experience there is only one sort that is usable, the "solid" round type (looks like a metal tar-brush) which can be purchased for about 40p and will give comparitively long service.

Do not let anyone try to persuade you that a wire brush is any good for anything other then the removal of carbon deposits. I have seen it in print from a supposed authority that wire brushes can be used to "polish" cylinder heads and remove rough metal protuberances from the casting. This is completely false.

The only tools for this job are rotary files and stones; however, more of this later. All a wire brush will do is to leave a lot of scratch marks, especially if the surface has previously been polished.

Two safety factors worth noting. Never try to remove valve springs without a proper valve-lifter, if a spring slips and flies out it can do very serious injury.

Always face the springs away from you when compressing them, preferably towards something soft from which they cannot bounce if they do happen to slip and fly. A spring on the rebound is even more dangerous since its direction of travel is unpredictable. I have seen a spring pass clean through a glass window and still travel about 15 feet beyond. So beware!! Secondly, if using a wire brush in an electric drill, always wear goggles, as the wire bristles have a nasty habit of breaking off and flying up into one's face. There is no need to enlarge on the dangers of wearing no goggles. I find that the best and most comfortable are those that are 100 per cent plastic and look like an ordinary pair of spectacles with side flaps. Most suppliers of industrial protective clothing stock these, and they only cost a few bob a pair.



An adjustable valve spring compressor such as this makes quick work of valve removal

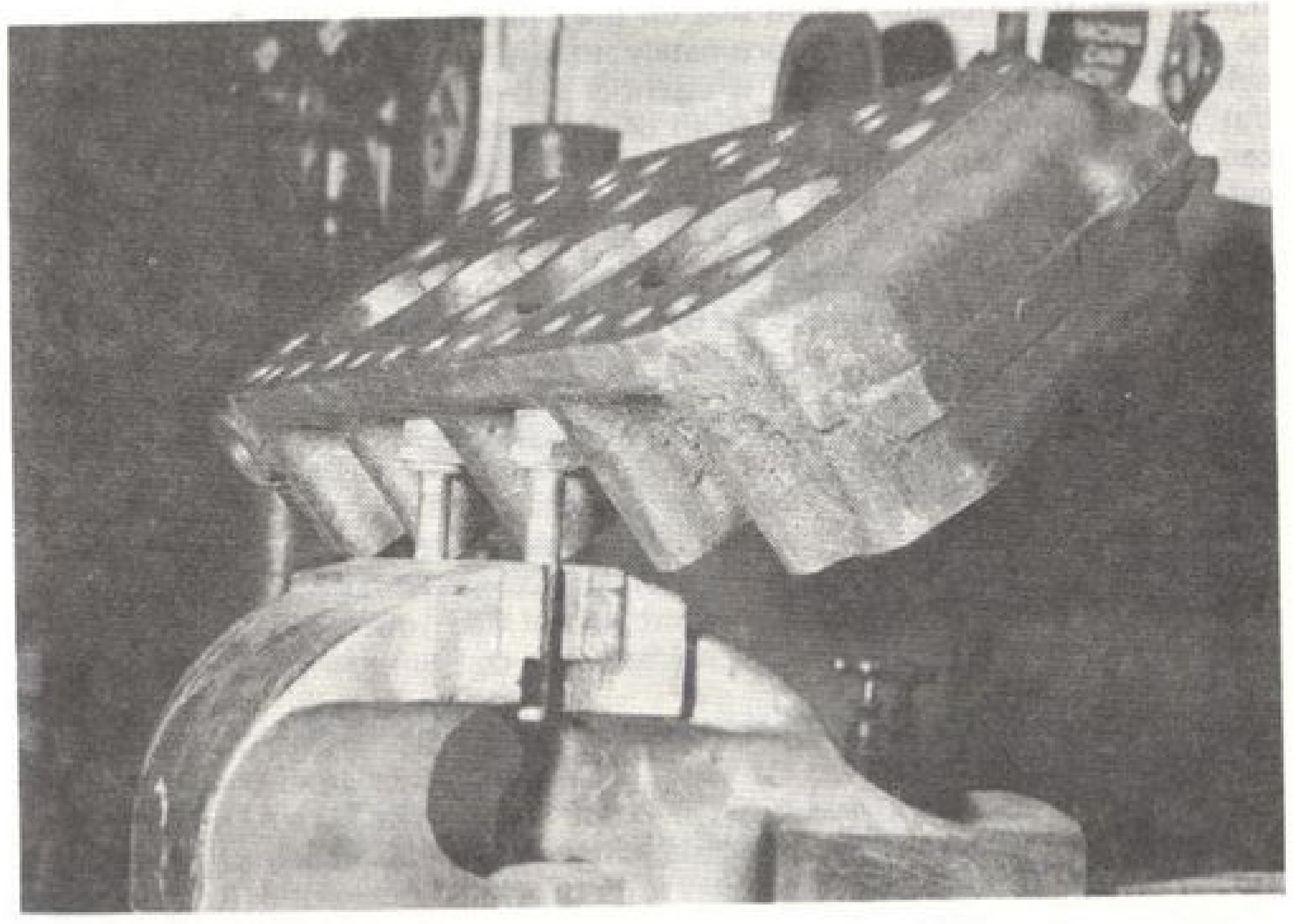
Grinding the Valves

The valve-grind sucker should be moistened (by obvious means) and pressed firmly onto the valve head. With a small amount of grinding paste on the seat, rotate the stem of the grinder in the palms of the hands with a rubbing motion. Lift the valve every few seconds and turn it around a few degrees and begin the rubbing motion again. As the valve beds in you should use a finer paste until you are satisfied that the valve is seating perfectly.

One small tip. I have found that valve grinding paste works far better if it is diluted with engine oil to thin it down. After grinding with fine paste clean both the valve and seat thoroughly. Then rotate the valve rapidly to and fro on the seat, using the same action as when "grinding" the valves in. At the point of contact between the valve and seat a dark shining line will be seen running around the seat. This line should be continuous and any breaks again indicate a failure to seat at that point. Do not worry if the line seems very narrow, as long as it is unbroken this will normally be O.K. since valves always hammer in after a few seconds use and this causes a quite considerable broadening of the seat.

A tin of "engineers blue" can be very useful when carrying out a final check that the valves are seating true after being ground in. Clean the valve and seat thoroughly in paraffin, dry off and put a **thin smear** of blue on the valve, then

A cylinder head with valves and springs removed



A useful head mounting device

rotate it once on the seat. This should leave blue dye round the **whole** circumference of the cylinder head seat. Any break in the blue line indicates that the valve is not seating at that point and further grinding is necessary. If further grinding does not remove the fault then new valves or guides are needed, or the cylinder head valve-seat needs recutting with the special tool for the job. This tool is expensive and since it is not often required I suggest that any seat cutting is carried out by a properly-equipped garage or engineering shop. If this is necessary try and find out what type of cutter has been used for the job, a rotary stone or a hand operated metal cutter. If the latter has been used then considerably more grinding-in will be necessary than if a stone has been used for although the metal cutters are quite efficient they to tend to leave "chatter marks" on the valve seat. These are a series of tiny ridges running across the valve seat and they must be completely removed by grinding with paste. These ridges can be clearly seen if one carries out a test with engineers blue after a brief period of grinding with paste.

Properly used, engineers blue is an extremely sensitive indicator but if any dust or grit contaminates it, it is worse than useless, therefore always keep the lid tight on the container unless one is actually taking blue from it and never use a dirty instrument (usually a finger) to do so.

One last word on the de-coke. You will notice that I do not mention re-facing valves. In my opinion, the end results are never completely satisfactory and it is cheaper in the long run to fit new valves even though they may cost about £2 each in some cases. Remember that a valve that is out of true, or which has worn hollow, can still indicate a good seat on the cylinder head, thus the valves must be carefully checked and unfortunately this is not as easy as checking the cylinder head seats. Experience is essential and this only comes with practice but the following will help. The truth of the valve itself (whether bent or not) can be checked using similar techniques to those employed for checking the cylinder head seat and merely taking ones readings from the valve and not the head. The only way I have found to check whether a "valve" is hollow or not is to clean it thoroughly and hold an accurate straight edge across the valve seat. Ideally one should not be able to see daylight between the valve seat face and the straight edge. Any pronounced daylight showing at the centre of the valve seat face indicates a hollow valve. If in doubt compare the "readings" obtained on the old valve with those obtained on a new valve. Do not try to correct these faults in a valve. Buy new ones!

chapter 2

REMOVING METAL

Dealing with operations involving the modification of the cylinder head/ manifolds/carburetter and valve gear in order to improve the gas-flow/ignition and valve bounce characteristics the picture is rather more complicated. A special amount of special though not always expensive equipment is needed. On the other hand the ardent "do-it-yourselfer" may already possess the basic essentials.

These essentials are an electric drill or motor capable of driving sundry rotary files, stones, and flexible shaft, and preferably fitted with a chuck of minimum ¼ inch capacity. The minimum r.p.m. rate should be 2,200. These requirements are easily met by most domestic handyman's drills costing between £5.50p each.

If however, one intends to undertake a continuous development programme involving continual gas-flowing then one must ensure that no matter what type of drill is used, the rotating parts must be mounted in ball or needle-roller bearings, not just simple bushes, the latter type tending to wear rapidly if used too often or too long for this purpose.

An ordinary 2000 r.p.m. plus ¼-horse electric motor, costing about £3 to £4 at government surplus stores, can be converted at small expense to drive a flexible shaft and will last indefinitely.

A point worth remembering is that the faster the motor, then the quicker will jobs be completed, though unfortunately some of the very high speed motors (6,000 plus) are not suitable for heavy grinding or close accurate detail work.

My own equipment consists of an old Black and Decker Vibro-Centric valve-seat grinder converted to drive a flexible shaft and purchased secondhand for £8. The conversion consisted of drilling out the ball end of the grinder and tapping a thread into it, into which is screwed the drive spindle of the flexible shaft similarly threaded. This set up has a free load r.p.m. rate of 12,500 but can be run for periods not exceeding 60 seconds when it must be stopped and left for 60 seconds to cool down. This is ideal however since the cooling time is merely used to inspect my work as I go along, which is essential anyway.

In addition to the above I also use a domestic drill for final polishing and working in the parts close to the valve seats. It has the advantage that it can be set-up in a wooden vice or special drill stand (£1.25p cost) and used as a lathe, or grinder for rough work such as initial shaping of valve guides and valves, or lightening of rocker gear. One further advantage is that this drill can of course be used for other work not connected with cars. Although slower it is capable of doing all that the faster motor can do and is far more universal.

Having a power unit we then need the cutting tools. I nearly always use stones instead of metal rotary files, they are quicker, don't chatter easily and tend to give a better finish for the amateur providing he finishes off with a finely textured type.

Do not think that stones will last forever. They will not. But providing one only buys the best, they have an acceptable life. Such stones cost about 25p each.

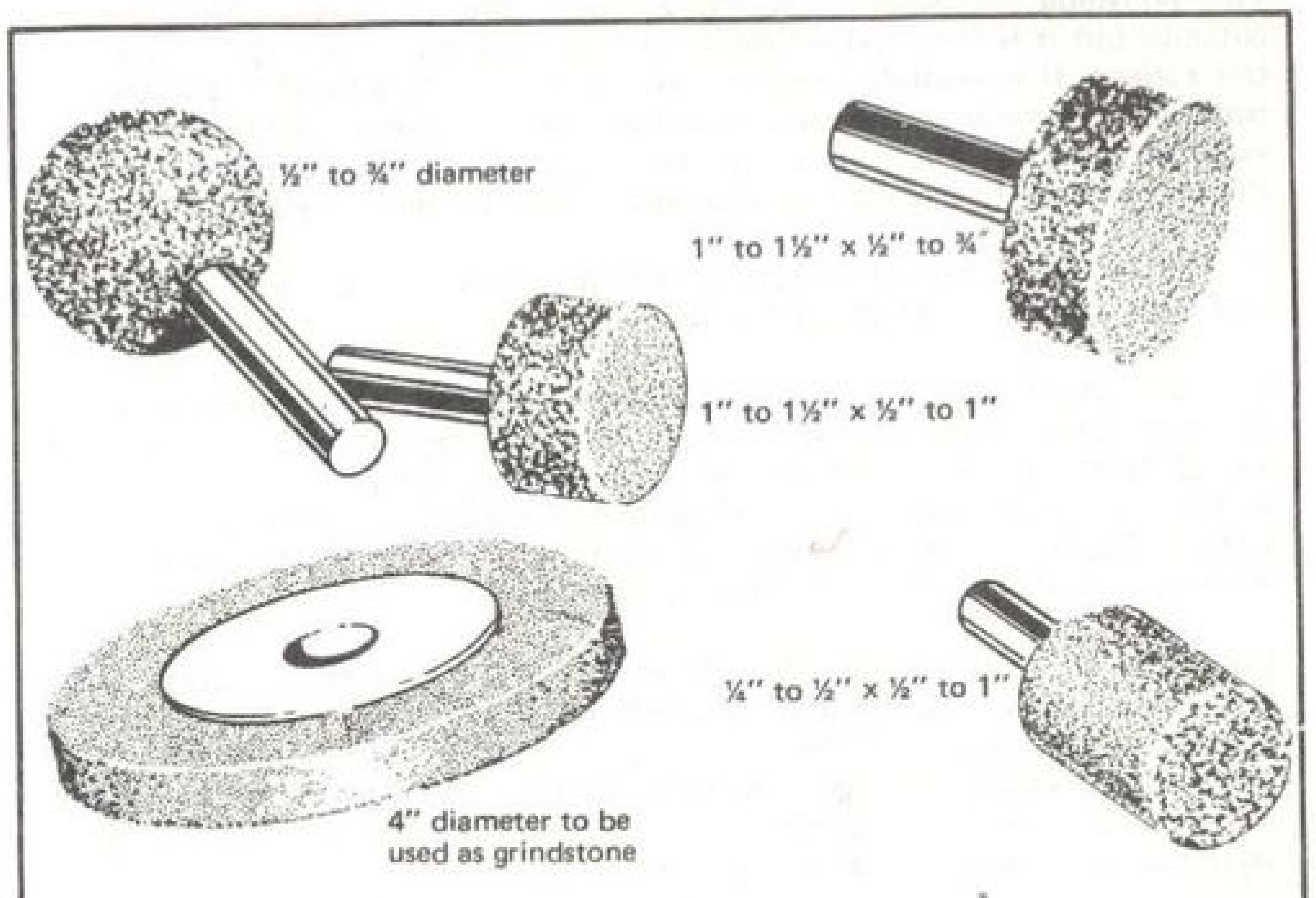
The "cheap" variety cost about 10p each and may only have a life of about five minutes continuous use, about 1/20th the life of a decent stone, depending how it is used.

Not only have cheap stones a short life but the axis of the cutting head is not always (usually NOT) the same as that of the shaft on which it is mounted, making it useless anyway since it will chatter excessively. This prompts me to mention an important point of safety. When a stone starts to chatter and this can happen even on expensive stones if held at an awkward angle, switch off the drill or take the stone away from the surface being ground. A chattering stone will often shatter and throw large lumps up in your face. So be careful.

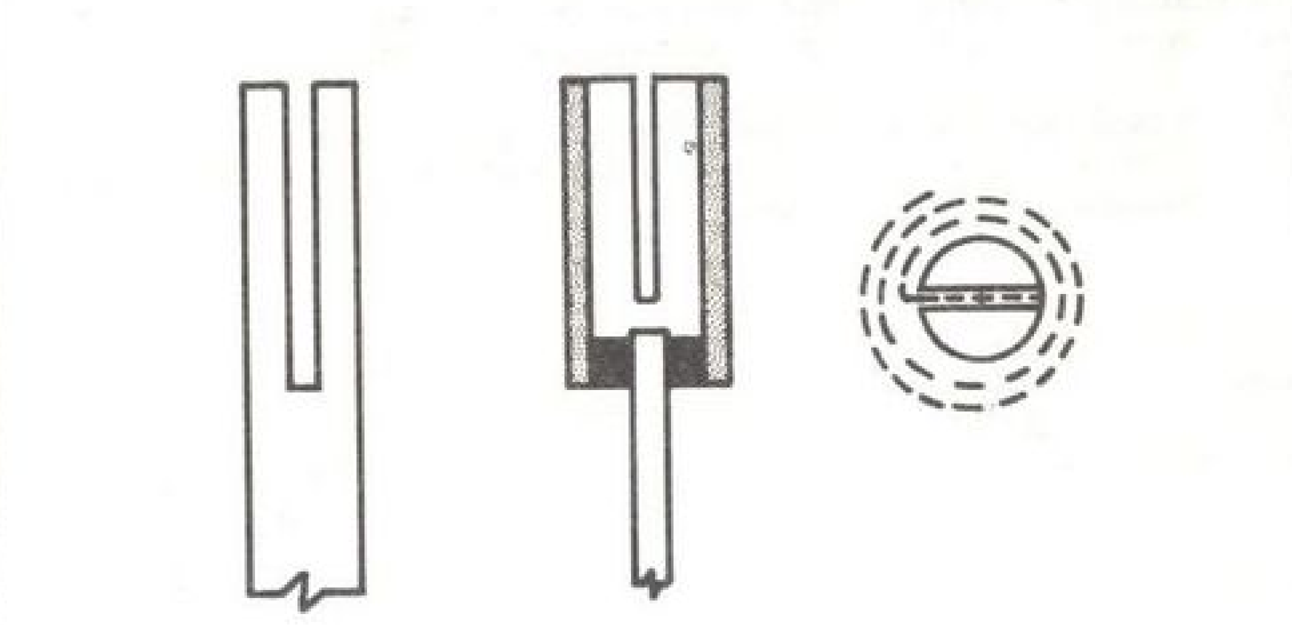
The shapes and sizes you will need are shown in diagram 1. If you can, get a coarse and fine stone of each type, but do not worry otherwise, it will merely mean that you need to spend longer polishing with emery cloth. As time passes you will find that you build a fairly comprehensive collection of stones and cutters (I have about three dozen different types) and during this time you will find that you develop your own preferences for certain sizes, shapes and grades.

All shaping should be carried out with these stones and a final "polish" obtained using emery cloth and or dry wet/dry paper. For polishing inside holes and vertical surfaces (ports and combustion chamber walls) the emery cloth should be mounted on a split rod or piece of split heater hose. Personally I prefer the former for use on chamber walls and the latter for inside the ports and valve throats.

A length of stiff heater hose (about six inches), of the type which incorporates "cloth fabric" in its construction, should have a split about three inches long cut in it with a hack-saw. This should then be mounted on a metal spindle and here I have found that the best way is to use an old cylindrical metal cutter which can be forced up inside the hose and providing it is a very tight fit the hose will not fall off it in use. The emery cloth should then be mounted on the hose exactly as with the metal rod. This latter should be about four inches in length, with a ½-inch slot cut in one end. For finishing off flat surfaces such as a combustion chamber roof one should again use emery cloth, but this time mounted on a flat rubber pad. The maximum diameter of this pad will depend upon the type of cylinder head being used and the minimum radius of the combustion space (e.g. on a Mini 850, this pad must not exceed 1¼ inches diameter or one cannot polish the chamber roof right in tight against the chamber wall). Unfortunately these pads are not easy to obtain (try an engineering stockist) though it is possible to reduce say a 3-inch diameter pad to the required diameter.



DIA. 1 Shapes and sizes of grindstones required.


DIA. 2 Left: Polisher from split rod.
Centre: Flexible polisher from heater hose.
Right: Method of attachment of emery cloth to both types.

This polishing procedure is somewhat fiddly and often very trying on one's patience but it is the most efficient method for the amateur. One last point on this subject. It is possible to buy ready cut abrasive discs for fitting to the above pads. They come in various grades but are hard to obtain, rather expensive and very, very vigorous in their action, so if you do use these remember, use only the fine or very fine grades, or you will remove far more metal than necessary.

As you will have realised the total cost of the above "home made" equipment is negligible, amounting to about 40p total.

It is an advantage to get a small engineering shop to accurately extend the shafts of some of one's grinding stones to enable one to reach awkward bends and corners in ports, though one must retain some standard short shafted stones as they are much easier to work with under normal conditions, tending to vibrate (chatter) much less, allowing one to apply much greater pressure when one has a lot of metal to remove from a small area.

One other very useful item of equipment is a 5-inch diameter rubber sanding disc, with provision for mounting a stiff abrasive disc on it, using a screw and washer. If one mounts a medium/fine aluminium oxide abrasive disc on it, it makes an extremely useful grinding wheel and due to its flexibility is often much more useful than a rigid grind stone. I always use such a set up for lightning valve gear and streamlining valve guides.

If by now you are rather dismayed at the seemingly large expense involved, bear this in mind. Once purchased you will "always" have your tools for future use and a decent kit of tools soon pays for itself over and over again, and can be accumulated gradually, many items can be borrowed at first or shared by two or three friends (e.g. electric drills, sockets, spanners etc.).

Having dealt with the general tools necessary and the basic de-coke let us now look at some of the more advanced tuning procedures, seeing what is involved and what special tools are needed.

chapter 3

GAS FLOWING

Having removed the head from the car as for the simple de-coke, remove all accessories such as manifolds, carburetters, thermostats, heater taps and all studs.

If you try working on a head with any of the above accessories still fitted you will soon learn why I say remove them before starting serious work. Do not remove the valves or springs at this stage. You may experience some difficulty in removing some of the studs but the following are three techniques I find suitable.

Screw two nuts onto the protruding part of the stud and lock them together by tightening one against the other. Then applying a spanner to the LOWER nut attempt to unscrew it. If the nuts are locked together tightly enough this should effect the removal of the stud without damage to it. Then unscrewing the TOP nut will unlock the nuts and enable them to be removed.

In the event of the stud being badly corroded into the head the above method may fail and this will necessitate the use of a mole grip or, more effective still a Stillson wrench. Unfortunately these latter two methods ruin the stud. Using the afore mentioned "solid" wire brush mounted in an electric drill, clean all loose carbon from within the combustion chambers and around and over the valves.

Then set the head up in a vice or on a suitable bench and using a spirit level as an indicator adjust the head positioning it so that the face is perfectly horizontal in all directions (i.e. across and along). Then using a 50 c.c. burette, which costs about £2.50p from a good chemist, measure the volume of each combustion chamber, taking the largest as one's guide.

Fill the burette with a mixture of 5 parts paraffin to 1 part CLEAN 20W engine oil, but do not fill above the zero mark at the top. Open the tap and allow about 1 c.c. to run from the burette into a "Slop tin". Then, holding a piece of clean white paper behind the burette, read off the level of the meniscus (which is the dark curved ring at the top of the fluid).

Then, carefully, completely fill a chamber with liquid from the burette, making sure the liquid is not allowed to overflow. Careful manipulation of the burette tap can vary the flow of liquid from a stream to single droplets. Having filled the chamber close the tap and again read the level at the meniscus. Subtract the first reading from this and you will obtain the volume of the chamber. Repeat for all other chambers. Then repeat all over again, having first completely dried out each chamber. This will give two sets of readings, or if one wishes to be fussy three sets. Take the average of each individual chamber's readings as being the actual volume for that chamber.

Take the volume of the largest chamber as being the one to which you work (i.e. all other chambers must be made equal to it when carrying out any final balancing).

One small point. On chambers with a large surface area it is often almost impossible to tell when the chamber has been completely filled. The easiest way to establish when the chamber is full is to clean the head face of carbon and excessive dirt, grit, etc.. Then put a fine smear of grease round the chamber, and place a piece of perspex with a quarter inch hole in it over the chamber. It is then a matter of simplicity to fill the chamber through the hole in the perspex until the level just starts to come up the hole in the perspex. At this early stage in the procedure, one's readings need not be more accurate than to the nearest 0.5 c.c. and one does not need to take more than one set of readings.

The importance of these readings, however, even at this stage, will be apparent when I tell you that it is from this information coupled to a knowledge of the maximum amount of metal it is possible to remove from the cylinder head face and the final compression ratio required, that one is able to assess just how much metal one can remove from the chambers in any gas-flowing operations. Influencing factors on the amount are also gasket thickness, annular groove size and piston crown profile, final calculations involving the use of the formula shown on the opposite page.

This operation, to determine the rough capacity of the chambers can often be avoided by consulting a workshop manual or R.A.C. Homologation sheet. The figures quoted can only be relied upon as being accurate to 0.5 c.c.

If you are now wondering about the maximum amount of metal it is possible to take from the cylinder head face, in the absence of an authority which you can consult there is a somewhat rough and ready guide which you can carry out yourself.

Carefully inspect the cylinder head face around the holes left for water and oil ways, try and identify which are which. Then using a depth gauge, or even a bent pin, measure as accurately as possible the thickness of metal at the thinnest point. If it is on a water jacket or anywhere near the combustion chambers, one must leave at least 25 to 30 thous. of metal after machining. On the other hand, in places one may be able to leave as little as 5 thous. or even break through into a gallery, then arcweld the break-through point and carefully remove any lumps of weld; this however is only for the very brave. (For example Mini heads are usually thinnest at the oil way behind number 4 chamber, right on the edge of the head. Here it is quite safe to leave a wafer of metal only, or even break through into the gallery. One must remember however to re-drill the oil way horizontally after arc-welding as this usually blocks the already narrow passage. I am afraid I cannot be more explicit than this as the maximum amount varies not only from model to model but also from one head to another comparing similar heads). There is however nearly always a safe maximum which covers all heads of a particular model (e.g. about 80 thous. on Minis) the absolute maximum normally only applying in extreme circumstances such as when one is race-tuning an engine.

D = Cylinder bore
S = Stroke
C.R. = Compression ratio
V = Swept volume of 1 cylinder
v.c. = Total engine capacity
n = Number of engine cylinders
H = Volume of **cylinder** head chamber
A = Volume given by gasket thickness, any dishing of pistons, annular groove, distance of piston from top of block, valve pockets etc.

Remember that pistons with raised crowns will have the effect of reducing volume A whereas dished pistons have the effect of increasing it. Also any valve pockets cut into the block or piston will increase A.

$$V = \frac{v.c.}{n} = \left(\frac{D^2}{4}\right) \times 3.14 \times S$$

$$C.R. = \frac{V + H + A}{H + A}$$

$$\text{and } H = \left(\frac{V}{CR\text{-}1}\right) - A$$

To show how these formula work, take 2 examples (i) if cylinder volume of 1 cylinder is 250 c.c., combustion head space is 21 c.c. and A = 6 c.c. and we want to find compression ratio.

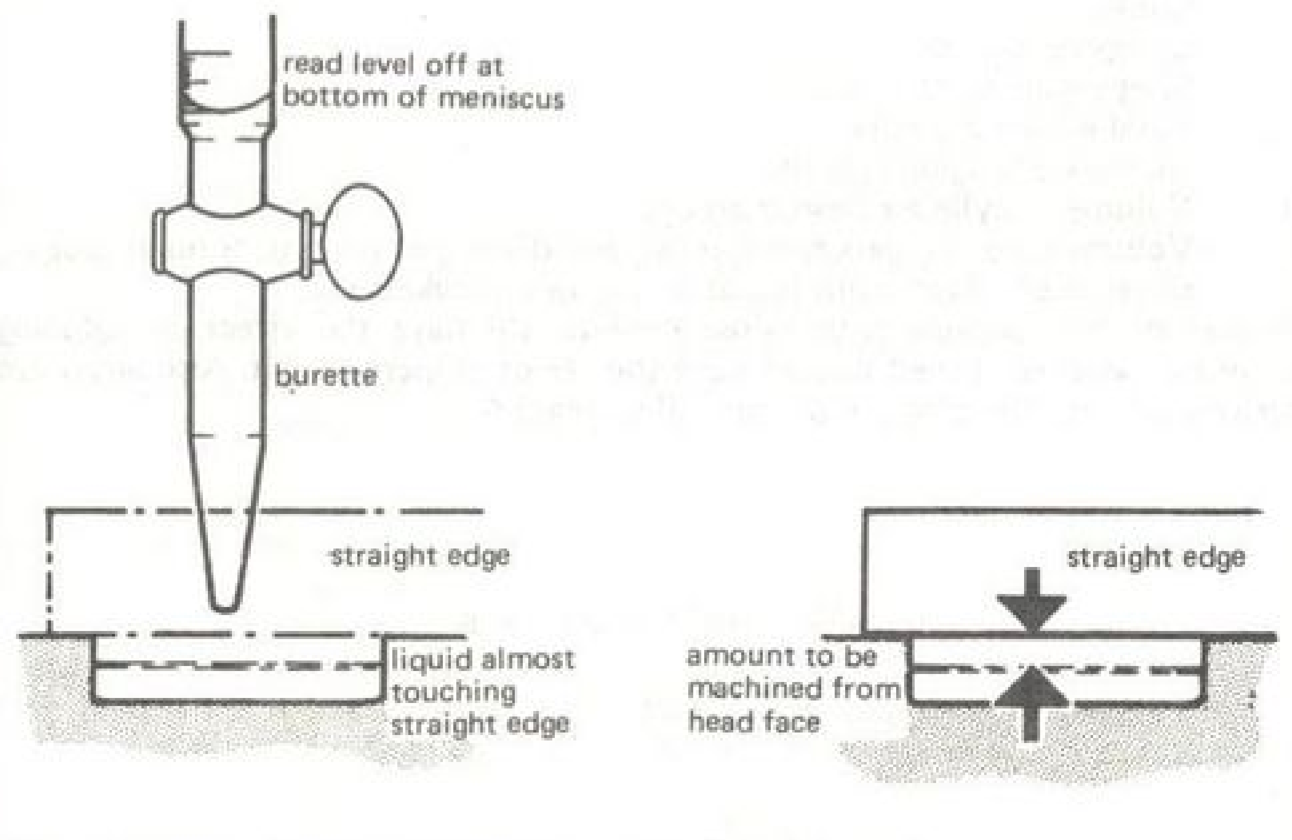
$$C.R. = \frac{V + H + A}{H + A} = \frac{250 + 21 + 6}{21 + 6} = \frac{277}{27}$$

$\therefore$ C.R. = 10.26

(ii) If we want a C.R. of 10:1, and V = 250 and **A is shown** to be 6 c.c. we need to find what **head** volume H is needed.

This can be done using the above formula namely $H = \left(\frac{V}{CR\text{-}1}\right)$ which in our case means that

$H = \left(\frac{250}{10\text{-}1}\right) - 6 = \left(\frac{250}{9}\right) - 6 = 27.77 - 6 = 21.77$ c.c. this is the head volume H required.



DIA. 3 Method of measuring combustion chamber.

However we are diverging too much. Having measured, roughly, the volume of the chambers one can then remove the valves using the aforementioned valve spring compressor and keeping in mind my earlier remarks on safety.

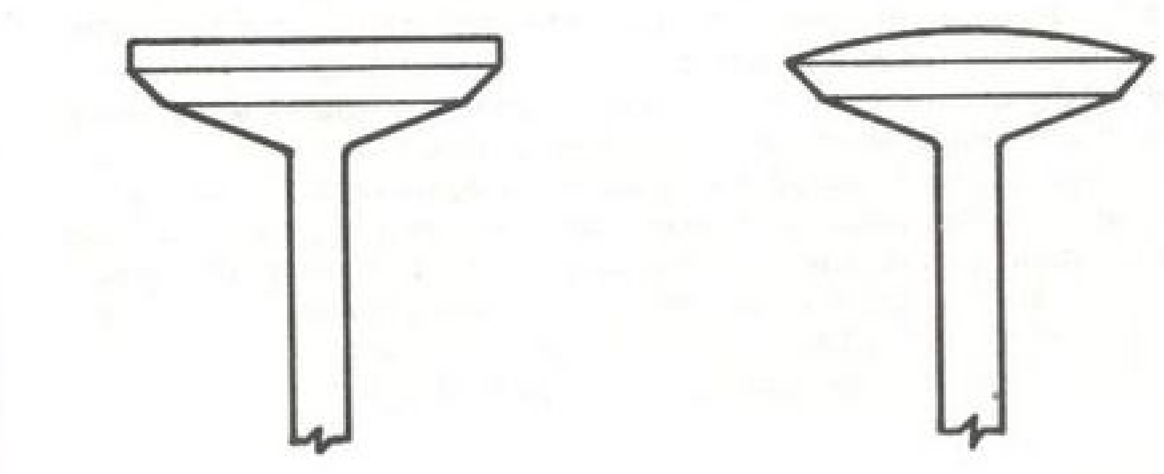
This brings us to the problem of marking which valve came out of which hole (unless one if fitting new valves) as most people prefer that valves are not mixed up and replaced on a "Strange" seat. Do not, I repeat do not punch dots or numbers onto the valves or scratch marks on them to identify them. These marks are nearly always difficult or more usually impossible to remove and they attract carbon deposits like magnets attract pins. Instead it takes about two minutes to make a disposable, no-cost valve-holding rack. Take a piece of tough cardboard and punch as many holes in it, in line about an inch apart, as there are valves in the head. Clearly mark them in pencil from 1 upwards. On removal of the valves put them in the appropriately numbered hole. If the holes are made a reasonably tight fit then such a rack can be easily moved about without much fear of the valves falling out and getting mixed up.

Some people use their old gaskets for this, but I do not, for two reasons. One the valves fall out too easily, and two, I always use my old gasket as a guide when modifying the combustion chambers as outlined in the next few paragraphs. Some people who are really fussy also keep the valve collars, collets, springs etc. carefully matched to the valves. Unfortunately I can offer no simple solution to their storage except small individually marked polythene bags or just plain simple undisturbed placement on a shelf out of harm's way. The valves are

the important thing however as they will be moved around and worked on in the course of carrying out modifications.

Do not remove the valve guides at this stage.

We now come to the modification of the combustion chambers.


DIA. 4 Standard valve left and right, valve with top turned down to act as seat blank.

Shaping the Chambers

It will be obvious that unless certain precautions are taken the valve seats can easily be irreparably damaged while modifying the chambers. The seats must thus be blanked off and the easiest and cheapest method is to use old valves as blanking pieces. These valves should have the upper faces of their heads ground off so that they only stand about 10 thous. proud of the surrounding chamber roof. It is for this reason that I suggested that one leaves the guides in place, for they enable one to obtain much better location of the blanking valves and will prevent the valve "chattering" when touched by the tool being used to remove metal from the chamber. If one is working with the head in a horizontal position with the chamber uppermost, there is no need to hold the valves in position, but otherwise they should be held in place using the ordinary valve springs in the normal manner. With the valves in place one can perform almost any grinding operation within the chamber, safe in the knowledge that the seats will not be harmed. When working on most chamber walls one should normally use a cylindrically-shaped stone though personal preference and experience must be the final deciding factor. All profiling should normally be carried out with a stone the final finish and polish being obtained using various grades of emery cloth attached to a convenient home made tool as mentioned earlier. It would be a good idea to point out at this stage, that polishing without emery, unless you spend ages at it, removes very little metal, so you need not polish the chambers until after they are balanced for volume. It is doubtful whether, by using normal means, the chamber volume can be measured closer than 0.2 cc, and this is about the amount a normal polish job will remove. This may sound like a lot, but if you consider even a small chamber at, say, 15 cc volume, 0.2 cc difference represents only 1.3% variation, and this is a negligable amount.

You may find it rather difficult to judge accurately whether or not you have taken similar amounts of metal from each chamber wall, and if you attempt to do so just with the naked eye without some form of guide you will invariably finish by having different profiles for each chamber. I usually overcome this by clamping an old, undamaged but well-compressed gasket onto the cylinder head. This gives one a line all round the chamber circumference, to which one can work. A better method still, is to make up a perspex template to the chamber shape you intend to use. Make sure that the gasket is clamped in exactly the same position as it would normally be on a fully-assembled engine. The gasket can be clamped on using four long bolts and nuts, each fitted with two large washers. These bolts can be located in the normal cylinder-head bolt or stud holes.

The alternative to this is even simpler, but will only apply if you have not already cleaned the carbon from the head face. Normally the old gasket will leave a clear pattern of its outline on the head face leaving a distinct outline all round the chamber circumference. Thus one can work to this outline exactly as if the gasket were clamped in position.

Stones are difficult to use on the chamber roof. The rubber pad shown with various grades of emery cloth stuck to it is quite suitable for any initial removal of roughness and final polishing. In most cases it is unnecessary and indeed undesirable to remove more than the minimum amount from the roof to give a good "polish". When using a rubber pad you will find that it is easier to work with it in a tilted position. If you attempt to work the whole face of the pad onto the metal surface you will find that any abrasive cloth or paper will not remain stuck to it for long.

Before removing the valve guides, re-assemble the springs and valves etc. into the chamber which, at the first measuring, came out largest, having first given it a rough polish and roughly ground the valves in. Set the head up again so that the face is horizontal. Calculate the final volume of each chamber required to give the necessary compression ratio. Then using the burette run into the chamber the same volume of paraffin/oil mixture. Measure the distance of the "High-water mark" from the head face in thousanths of an inch.

This gives us the amount of metal to be machined from the head face. I suggest adding 5-10 thous. to the reading to allow for any metal removed when finally

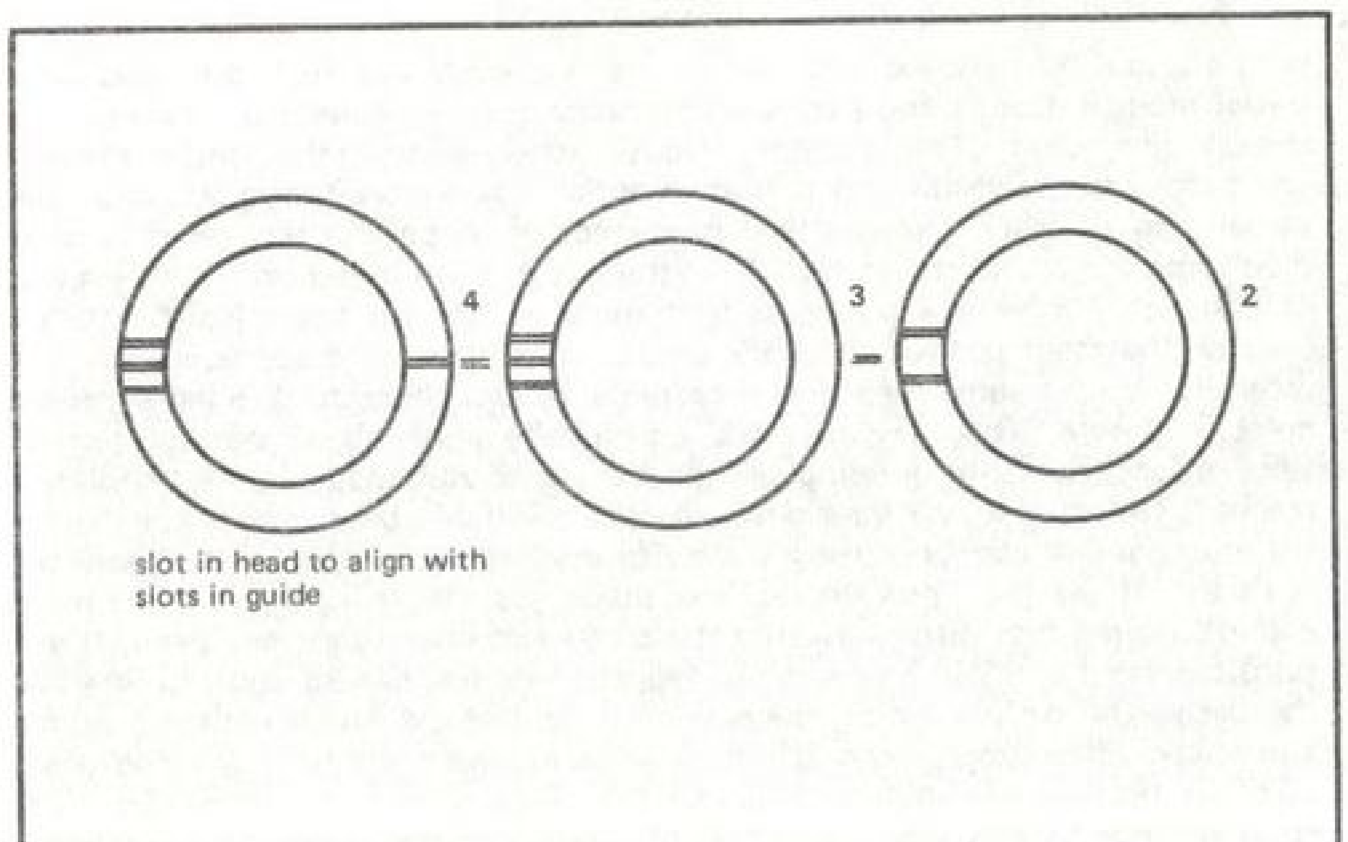
polishing, making final balancing or profile adjustments, and for metal removed from valves when grinding in or carrying out modifications to shape.

Remember that it is better to aim at a slightly higher compression ratio than you really want. You can nearly always lower the C.R. by removing a little more metal. You cannot stick metal back to raise it. Also machine shops charge less if all metal is removed at one go than if it is removed in two lots. They may charge say £3 to remove 85 thous., at one go, but will charge say £2.75p to remove 70 thous., plus about £2 to remove another 15 thous.

To measure the difference between the high water mark, use a simple depth gauge. When doing so, do not forget to allow for Miniscus effect which causes the fluid to come up and meet the end of the depth gauge. If 10 thous. are allowed for this, then things should be alright.

Removing Valve Guides

The next stage involves modifying the ports and valve throats, and to do this properly it is essential that the valve guides be removed. (Only the inlet valve guides if leaving the exhaust alone). This may pose the average tuner with limited equipment something of a problem because, (a) It is usually recommended that guides only be removed using specialist tools, otherwise they are liable to be damaged. (b) When replacing valve guides it is nearly always necessary to recut the valve seats, using special cutting tools made for the job, due to the fact that when replacing guides one usually causes the valve to centre in a different position, and hence fail to seat on the old seats.



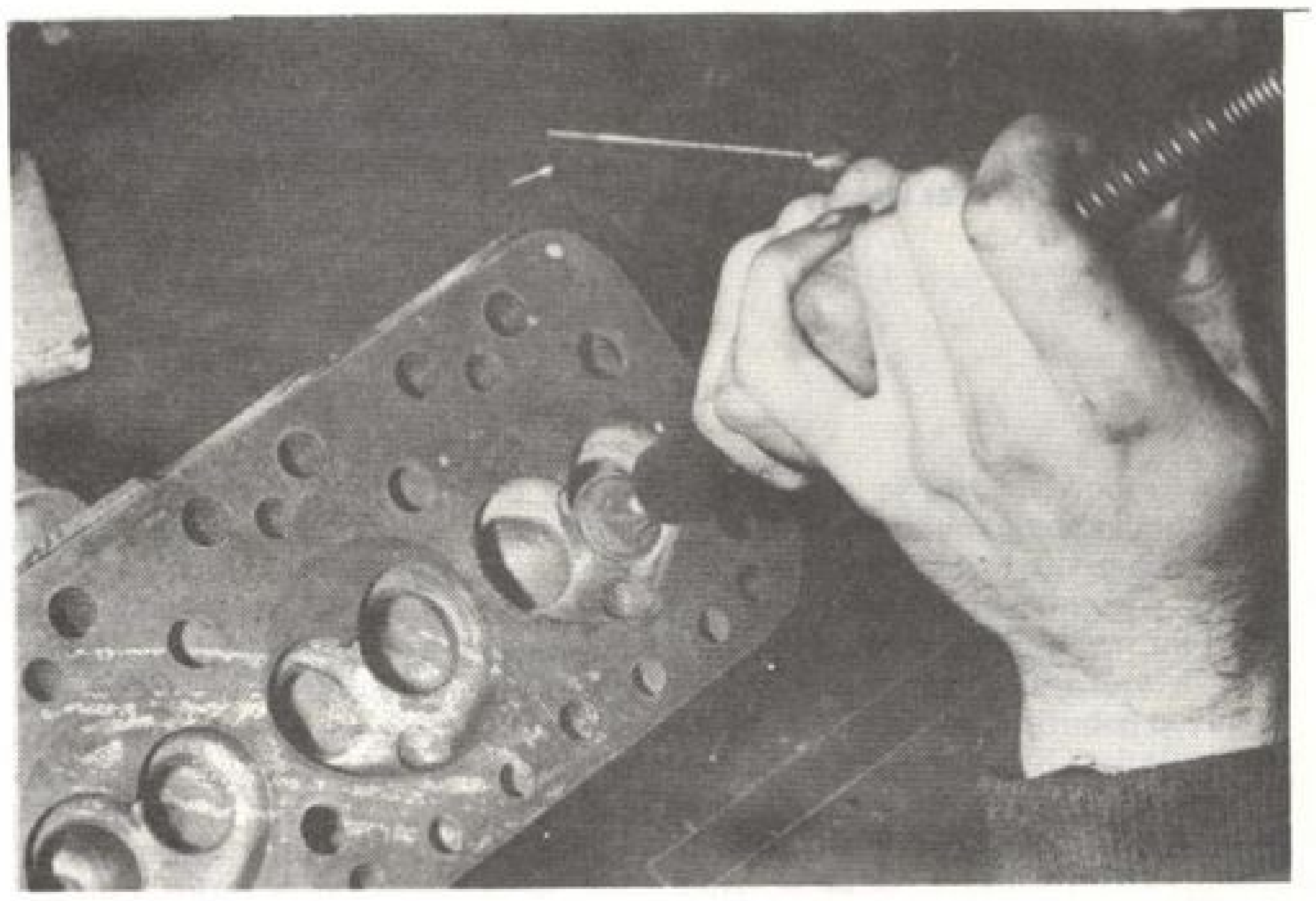
DIA. 5 Plan view of 3 valve guides showing position and markings.

I have developed an absolutely cost free method of overcoming both problems when replacing the ORIGINAL guides BUT NOT WHEN RENEWING GUIDES. When I do have cause to fit new guides I usually rely on scrounging the necessary seat cutters for a short while, though I still use the method, outlined below for removing and refitting. If the guides are marked properly they can be replaced in EXACTLY the same position as they were originally.

First make suitable marks on the cylinder head or choose suitable guide marks. Then using a very fine hack-saw cut slots in each guide at the valve spring end to line up with these marks, cutting one slot for number one guide, two for number two, etc. Try and cut all the slots in one side of the guide otherwise it is quite possible to relocate the guides at 180° to their correct position. This is best explained in the accompanying diagram. Do not cut the slots any deeper than is absolutely necessary. I cut mine about 1/64 in. deep. Thus by replacing the valve guides in exactly their original position one avoids the necessity to re-cut the valve seats.

Next one must make a drift for removing and refitting the guides. Take a 15/16 in. bolt (or such size as will fit snugly into the guide) and file the head to a few thous. less overall diameter than the valve guide. Fit a suitable washer under the bolt head, again with overall diameter reduced to that of the bolt head. This constitutes the drift, which should be put into the guide at the valve spring end. By hammering this drift one can then knock the guide out of the head. Carbon deposits at the valve throat end usually prevent the guide being drifted out the opposite way. When the bolt head is beneath the outer surface of the head a punch will be needed to continue driving the guide on through together with the drift, and I will offer one word of advice. DO NOT use a punch made of hard or brittle metal, and make its diameter as large as practical. A suitably modified old screw-driver blade is usually just right.

With the guides removed one can set to and carry out ALL port and valve throat modifications using a conveniently shaped stone, extended if necessary as already mentioned. (This is almost essential when profiling the bend in the port just before the valve throat.) It is as essential, when modifying ports and valve throats, to get each one identical in respect of shape and size, as it is when modifying the chambers, in fact if anything it is more important. The best way of doing this is by making up metal templates, one for the valve throat, and one for the main part of the port. Decide what size and shape you want, and carefully cut out some sheet metal patterns. Mount them on thin metal rods or bolts as shown. Then as you work, continually insert them into the port or valve throat, carefully grinding till the same size and shape as the template is reached. Unfortunately I have never devised a suitable template for the bend in the port, and I can only suggest careful application of the index finger and eye-sight. If using a finger to feel the shape, just run it lightly over the metal surface, having first made sure that the metal and your finger are clean. If you press too hard you will be unable to feel the true shape. Also you will find that the better the surface finish, the easier it is to feel the odd humps and bumps and shape differences. Then it's back to work, carefully with a stone. I say carefully because one should remember that shape differences discovered at this stage will not be very great, assuming of course that they were in fact undetectable before polishing.



A chamber roof being polished. Care must be taken to avoid damaging the valve seat

Chamber volume being measured. Note the perspex plate, with hole, covering the chamber. Use grease to seal the edges

However we have jumped the gun a little.

After profiling the chambers (don't polish them immediately) and ports with a stone, send the head to the machine shop having calculated how much metal you need to remove as already outlined.

chapter 4

MODIFYING VALVES AND GUIDES

Guides

Set the slow (2,000 r.p.m.) drill up in a bench stand or suitable wooden vice. Mount a 5 in. rubber pad into the drill and mount a medium grade aluminium Oxide abrasive disc on the pad. Switch on. Hold the end of the guide that protrudes into the valve throat against the disc, carefully rotating the guide between ones fingers, thus removing metal and thinning the end down till it is shaped like the end of a pencil. I usually remove metal down to the level of the carbon deposits on the guide or if the guide has not originally protruded beyond the guide - boss I remove metal so that my taper starts about 1/8 in. inside the point where it enters the valve throat. A final suitable finish can be obtained by rubbing down with fine emery cloth in the area of the taper. Most guides are relatively soft and power tools are not needed to obtain a suitably fine finish. I find that this method is far quicker and just as accurate as mounting the guide itself in a drill and holding a file or stone against it as it revolves.

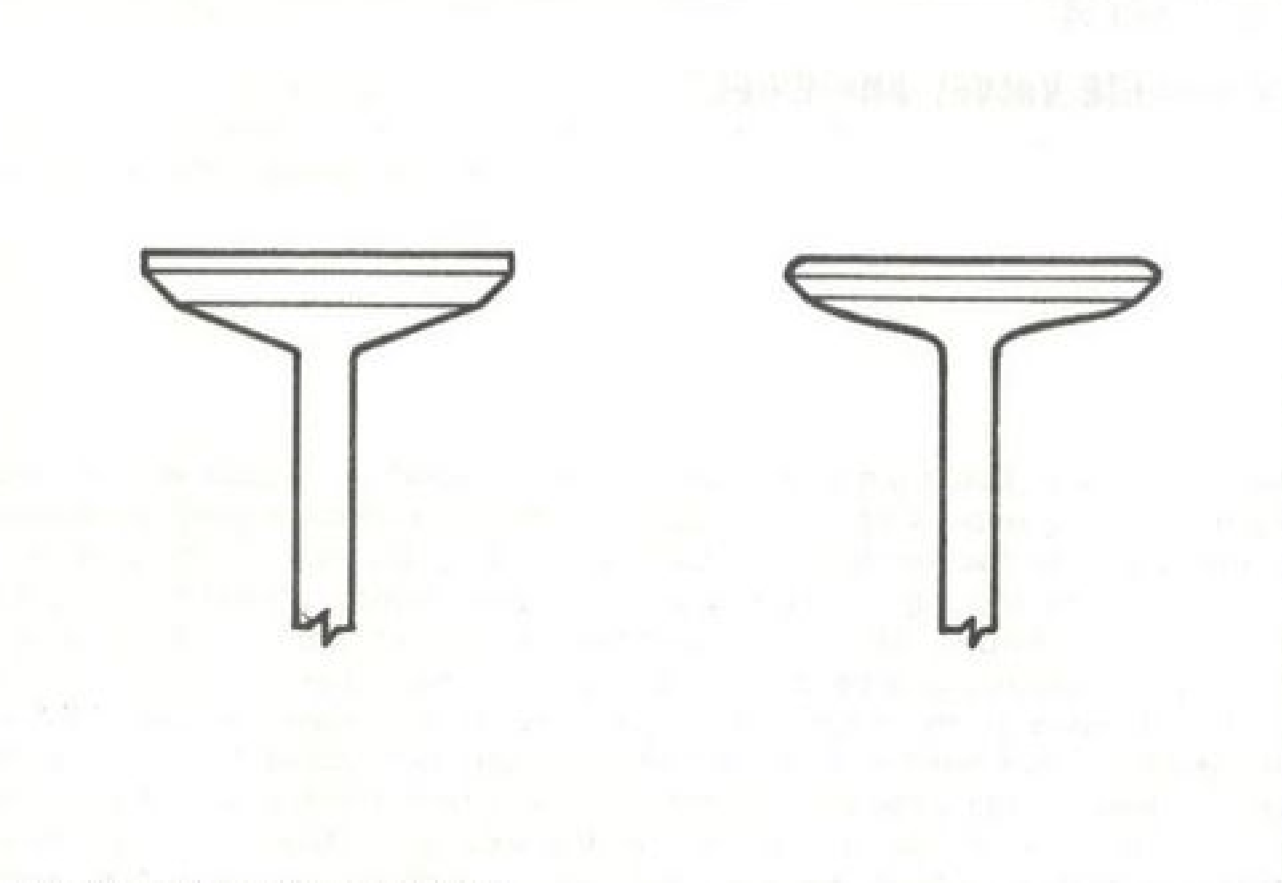
If your head is not fitted with guides and you intend having them fitted (e.g. Ford 105E) you should have the head suitably bored to take guides at the same time as you have it machined.

Valves

The easiest way to modify the valve profile is on an off-hand grinder. This is a common type of grinder and is sometimes known as a double-ended grinder. By holding the stem of the valve between the thumb and forefinger just under the head of the valve, and rotating the valve with the thumb and forefinger of the other hand, one can hold the underside of the valve head against the wheel and gently profile it in and around the seat area, as is depicted in the diagram. Failing the availability of an off-hand grinder, one can get the valves reprofiled at a motor machine shop on a valve seat facing machine. What they will, in effect, do is to grind a series of flats on the valve, which approximate the curve you require. It is then reasonably straightforward to emery the valve to bring it to it's final contours. Emerying can, of course, be done in an ordinary pistol drill suitably held in a vice.

Valve Seats

Modifying the cylinder head valve seats, is a job which, without the correct tools, is most difficult. There are several ways of obatining the required seat shape



DIA. 6 Left: Standard inlet valve.
Right: Modified inlet valve.

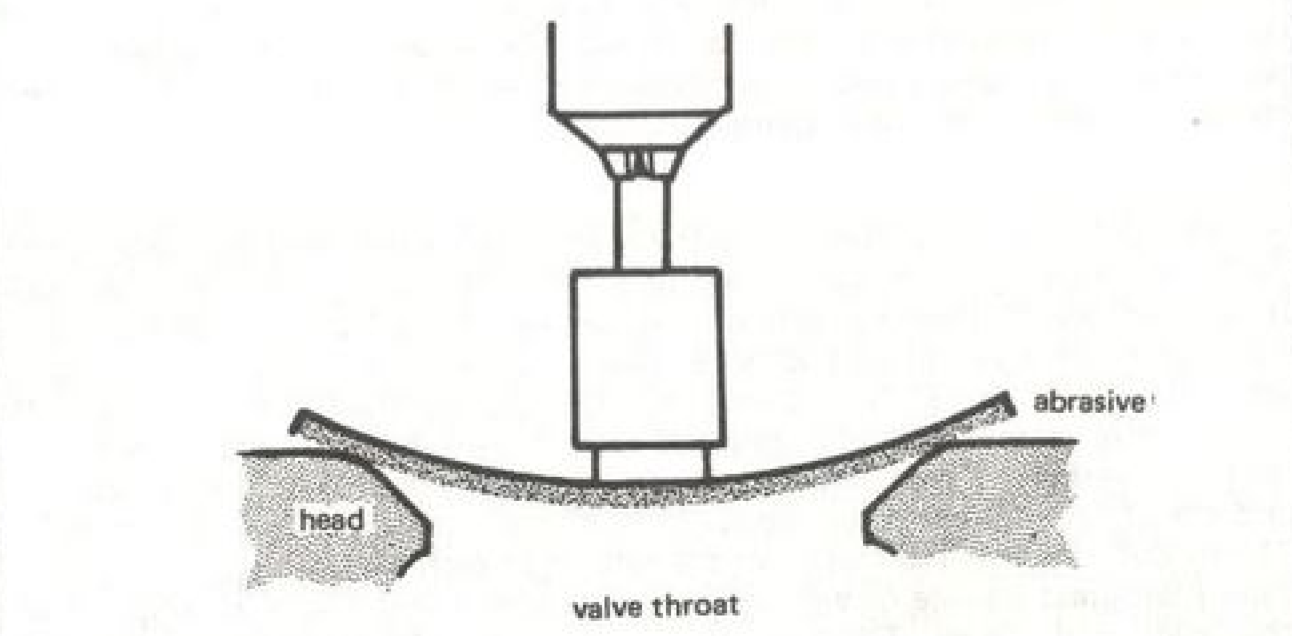
(i.e. a complete radius) and I think the best thing I can do is to list the methods I have used over the past few years in order of ascending merit, basing the merit not only on the end result but on the ease with which it is obtained. I am listing all the methods I have used, for you may find that, although I may not prefer that method it may be the most suitable for you, for any one of a number of reasons.

My first method was certainly extremely simple, but was far from efficient or accurate and entailed much slow tedious work.

Using first a small three-sided file, one should scrape the corner of the valve seat in the throat to give it a nice radius. Alternatively a three-sided bearing scraper can be substituted for the file, and this is in fact preferable.

Then the valve seat corner on the combustion chamber roof can be similarly scraped to a nice radius using a plate scraper. If you haven't got a scraper you can make one using a small flat file with the end suitably flattened and sharpened. Do not scrape the radius right across the valve seat. Leave at least 20 thous unscraped.

Then wrap a piece of fine emery cloth or paper around your finger and gently rub the valve seats to remove any file or chatter marks and complete the radius. Finish by lightly lapping the valves in and checking the seat accuracy.



DIA. 7 Radiusing valve seat using abrasive disc and tap washer.

The second method is exactly as the above excepting that one does not hand "polish" the seats with emery abrasive. Instead one uses the small tap washer buffing pad with an extra large disc of medium abrasive cloth mounted on it, the whole lot being set up in one's electric drill. Use a new abrasive disc every time the old one bends up around the tap washer. Doing this will quickly give a beautiful, polished, complete radius to the seats.

Unfortunately both the above methods tend to be somewhat inaccurate, especially in inexperienced hands. Often one can obtain what appears to be a perfect, highly polished radius, only to find that on lapping the valves in, one cannot get a complete seating of the valve. This will necessitate further seat cutting and of course means that one has to repeat the whole operation of radiusing the seats.

With practice the occurance of repeating these operations can be greatly reduced but not 100 per cent eliminated. Thus although with practice and perseverence coupled to very careful work one can arrive at a satisfactory conclusion, the above methods leave a lot to be desired, the inaccuracies stemming from the fact that all work is done free-hand and at no time is one able to accurately centralise one's cutting tools on the valve seat.

After a great deal of thought I have eventually developed a method which is pretty well fool-proof and inexpensive. I had considered purchasing a complete set of engineers' valve seat cutters complete with pilots and arbors, the cutters to be of 15°, 30°, 45° and 60°. Thus by the progressive light application of these cutters I could obtain an accurate "radiused" seat with the minimum of effort. The "radius" comprising a series of straight lines at varying angles to the valve axis, needing only the gentlest of rubs with abrasive to give a completely smooth radius. A slightly more sophisticated version of this method is in fact used by many conversion companies. Unfortunately these cutters are not only difficult to obtain but also extremely expensive. Thus this method was ruled out as being beyond my financial means. My answer was as follows. First I needed an arbor and a pilot that fitted into the valve guide, its diameter being the same as that of the valve stems.

A piece of 3/8 in. mild steel rod was obtained and a length of 9 in. was cut off. Then for 2½ in. the rod was turned to 5/16 in. diameter, the next ¾ in. had a thread cut on it. Then the rest of the rod was turned to the diameter of my valve stem. This would cost about £1.50p in an engineers shop. I thus had my arbor (the 2½ in. at 5/16 in. diameter) and my pilot (the 5¾ in. at the diameter of my valve stem). Onto the threaded section were screwed two suitably sized nuts and washers. I then took a piece of reasonably stiff ½ in. bore rubber tube and cut off a length that was about ½ in. greater than the diameter of my valve. Then I cut a hole in the middle of the tube right through both walls. Round this tube I wrapped a piece of emery cloth and made holes in it to correspond with the holes in the tube. This was then pushed onto the threaded section of my arbor/pilot and locked into position between the two nuts and washers.

This can be used exactly as an electrically-driven valve seat cutter, being pushed on down through the valve seat into the throat, allowing the tube/abrasive cloth to bend up alongside the arbor and thus pass down into the throat.

This gives a perfect, accurate radius, is cheap, and easily adaptable to any cylinder head by simply varying the sizes of one's pilot and rubber tube. One can obtain a really high polish by merely using finer grades of cloth. In my opinion the greater the polish in this area the better in order to minimise a carbon build up around the seats which destroys most of one's carefully prepared gas-flowing operation. I would think that the rubber tube could well be replaced by some other flexible material of suitable stiffness. I intend trying a strip of old tyre wall which as you know is canvas reinforced. The only trouble I have found with the above rubber tube is that it does not take long to tear and come off one's pilot/arbor. A strip of canvas reinforced tyre wall may solve this problem.

chapter 5

MANIFOLD MATCHING, FINAL FINISHING AND RE-ASSEMBLY

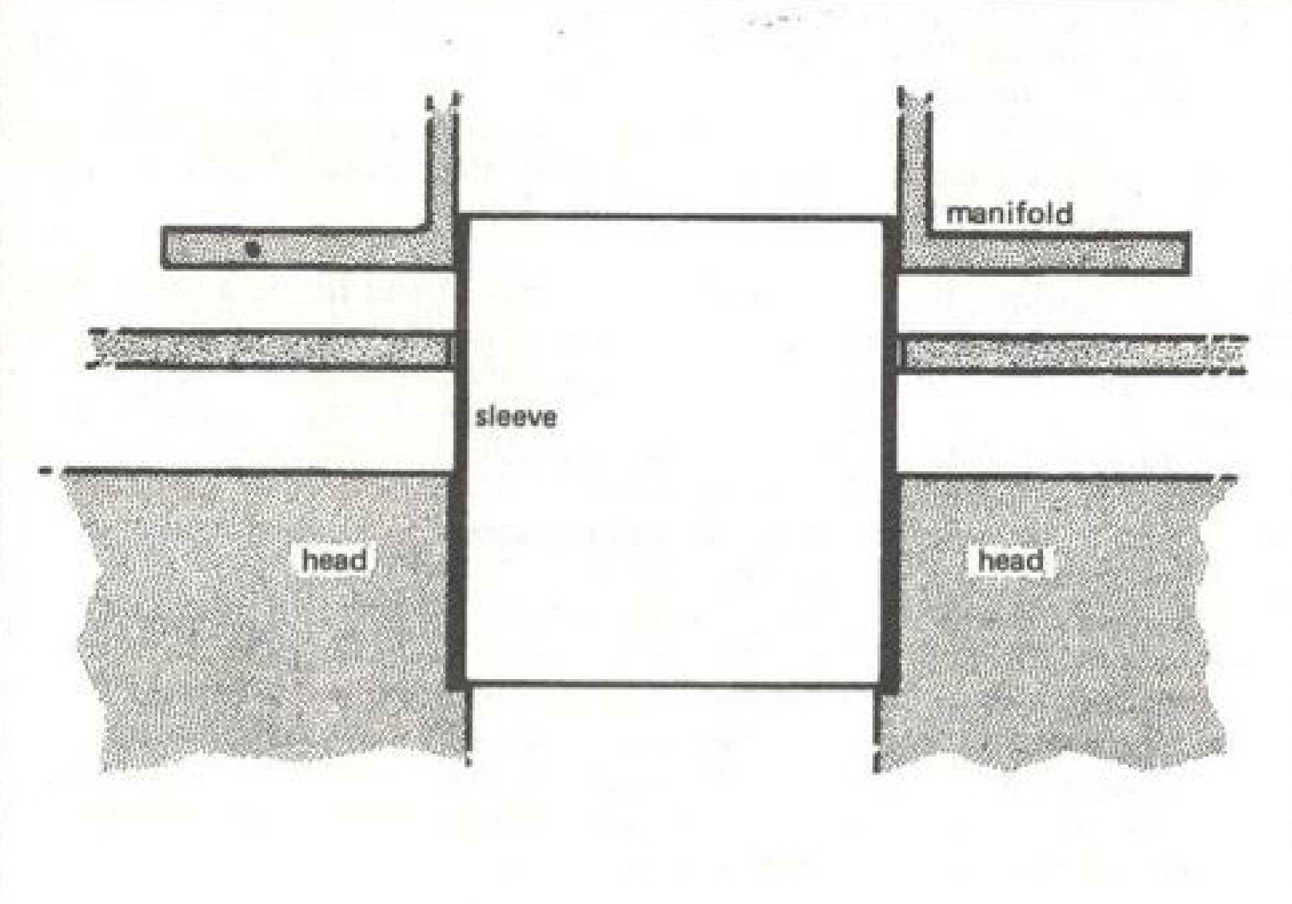
Before starting work on the actual head again, it will probably be better if one carries out the gas-flowing operations on the manifolds. Exactly the same techniques can be adopted here as for the cylinder head ports, and should present no problem. First machine to the required shape using an electric drill and conveniently sized and shaped stones. Then the surfaces should be polished using the described emery cloth and mounting rods etc.

One point regarding the inlet manifold. You may intend fitting a larger carburetter or moving the mounting position and studs in order to obtain a more efficient gas flow from the carburetter into the ports. When you come to relocate the studs they may come right on the edge of the manifold flange and leave insufficient metal to drill the necessary holes and tap threads. In this case the flange must be built out to leave 1/8 in. of metal around the stud hole. Unless one is an experienced welder and has access to welding equipment this job is best farmed out to those that can do it. There is little point in trying to weld on extra pieces of metal since the amount of build-up required is only usually about 1/8 in. A good welder would surely build the extra metal on with a welding torch. Remember however, having done this one must ensure that the flange face is perfectly true without any lumps or distortion. Any lumps can be carefully removed with a hand plate scraper or fine file. If however welding has caused the face to distort one must return to the people that machined the head face and get THEM to rectify the fault.

The next step is to match the manifolds to the cylinder head ports. Basically this simply entails bolting the manifolds to the head and checking that the trunk of the one runs smoothly into the trunk of the other. If it doesn't one must remove metal from the appropriate places until it does.

Unfortunately this is not as simple as it sounds because it is extremely difficult to see inside what amounts to two very thick bent metal tubes and see how they mate up. Even a long straight tube is difficult enough. Coupled to this we find that due to modern methods of mounting manifolds on cylinder heads, it is almost impossible to clamp it in exactly the same position twice running. Some cars utilise removable sleeves in the ports and manifolds to ensure that a nice even fit is obtained. These sleeves are mounted in grooves in the port and manifold. I personally do not like this system but must admit that it does give virtually perfect alignment.

If the ports between manifold and head are to be matched properly then the accuracy of location of the manifolds on the heads becomes of paramount importance. The easiest way to accurately locate a manifold on a head is to dowel it in position. This is done by mounting the manifold on the head with two or three gaskets between it and the head. One then drills through the manifold and the gaskets and into the head with, say, a drill of 1/8 in. or 3/16 in. in diameter. Now the drill needs to be properly sharpened such that it cuts a hole reasonably near size. Having done this, one can then acquire some 1/8 in. or 3/16 in. diameter steel rod from any good tool supplier or engineers suppliers stores, and from this rod, lengths can be sawn off to make dowels.



DIA. 8 Sleeve method of manifold location.

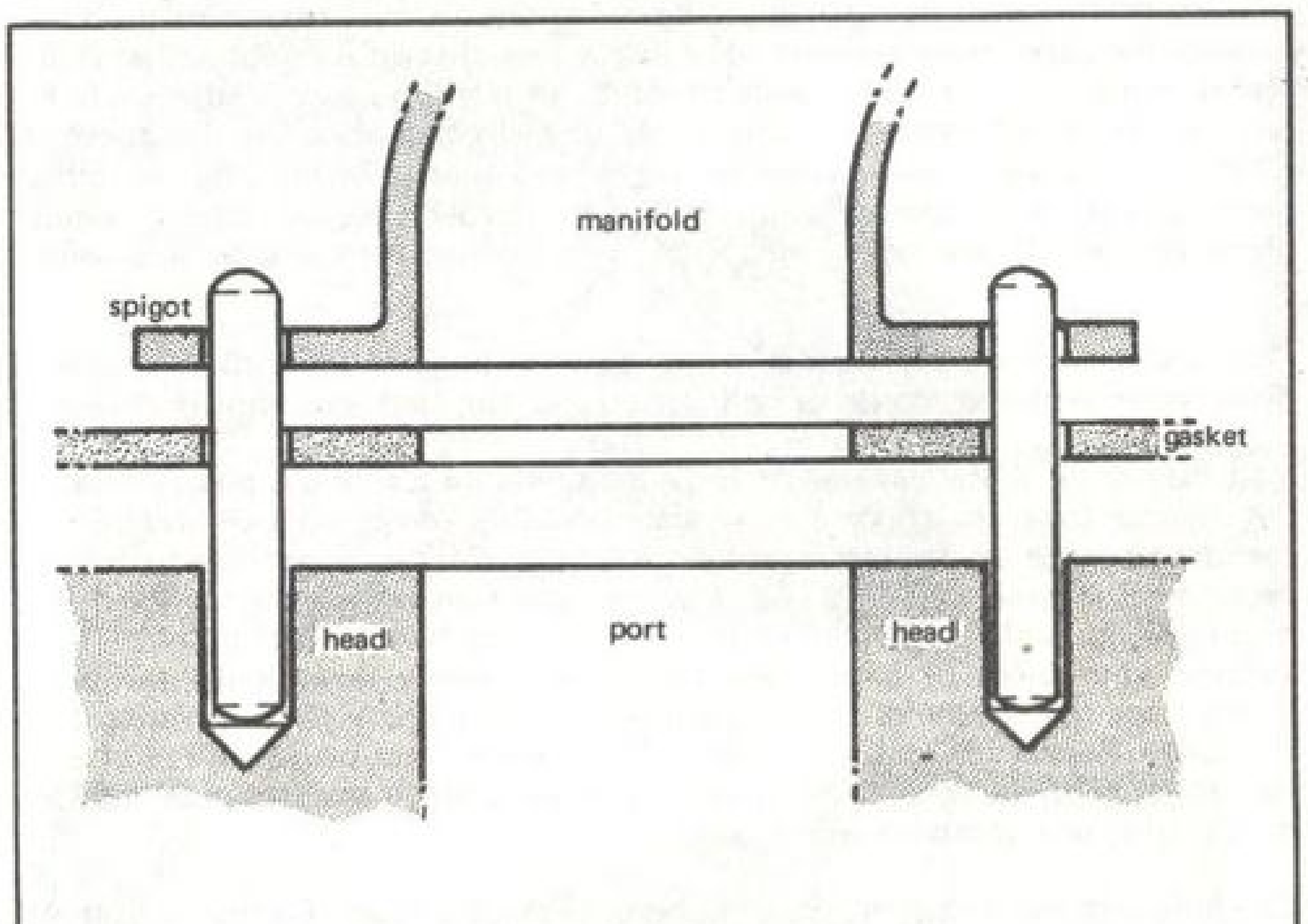
The reason for having two or three gaskets is so that you will be left with a couple of spares as it is difficult to reproduce a spare gasket after the dowels have been fitted to the head.

You will notice that I said in the first place, drill two holes right through the manifolds. This only applies of course to one piece inlet/exhaust units. If the inlet and exhaust are separate units one must of course drill two holes in each. Much better location is obtained if these holes are drilled as far apart as possible. (e.g. one alongside number one branch and one alongside number four branch.)

Make sure that the spigots give a nice snug (but not too tight) fit in the manifold. Remember, though a tight fit is useful, you have to remove the manifolds from time to time, and what's more difficult, get them back on.

Having fitted the spigots, clamp the manifolds into position on the head and see whether by reaching your finger down through the valve throat or in through

the manifold you can feel the point at which the manifold and head join. If you can, so much the easier, for you will obviously be able to feel any unevenness and decide where to remove metal. Such circumstances, unfortunately however, are rare, and we must devise some other method of determining the presence and degree of unevenness, and this is where the fun and games start.



DIA. 9 Spigot method of manifold location.

Many ways have been suggested by many people for overcoming this problem. Frankly I have tried them all but none has proved really 100 per cent simple. Most have been decidedly inaccurate and have varied from poking pieces of wire into the manifold/ports to feel for the unevenness, to smearing the mating faces of the head and manifold with Vaseline and blowing French Chalk through from the valve or manifold end, using a bicycle tyre pump!

At the risk of being wished into Hell's fires the following is the method I always use. Clean all dirt and grease from the head and manifold in the region where they mate. Clean all excess dirt and grease from your hands but make sure that they are reasonably grimy. (The type you wouldn't dare wipe on mother's or the missus' clean white towel.)

Take a piece of fairly stiff clean white or brown paper. Cut off a piece large enough to overlap the head mating face by about 3 in, all round. Carefully lay it on the head mating face, having first removed the manifold studs (assuming you had temporarily re-fitted them to the head in order to clamp the manifold on) stretch the paper as tight as you can over the head and using a very sharp fine bladed knife pierce the paper directly above the stud holes. This is best done by simply pressing the knife down onto the paper directly over the hole, twice, each piercing being at 90° to the other. Screw into the stud hole one of the studs. Repeat for each hole. At the finish all the studs should be in position, and the paper should still be in position, on the head without being unduly buckled. It is important that the holes for the studs in the paper are as tight a fit as is practical and this is why I suggest merely piercing the paper in the shape of a cross rather than trying to cut the proper holes to size. If these holes are too large or the paper tears you will have to start again for it is essential that if one makes a mark on the paper with the studs in position, then if the studs are removed it MUST remain a simple job to keep the mark on the paper in EXACTLY the same position relative to the head, merely by locating the various piercings over their appropriate studs holes with a couple of studs or similar diameter rods. If the holes are too big or torn then this will be impossible.

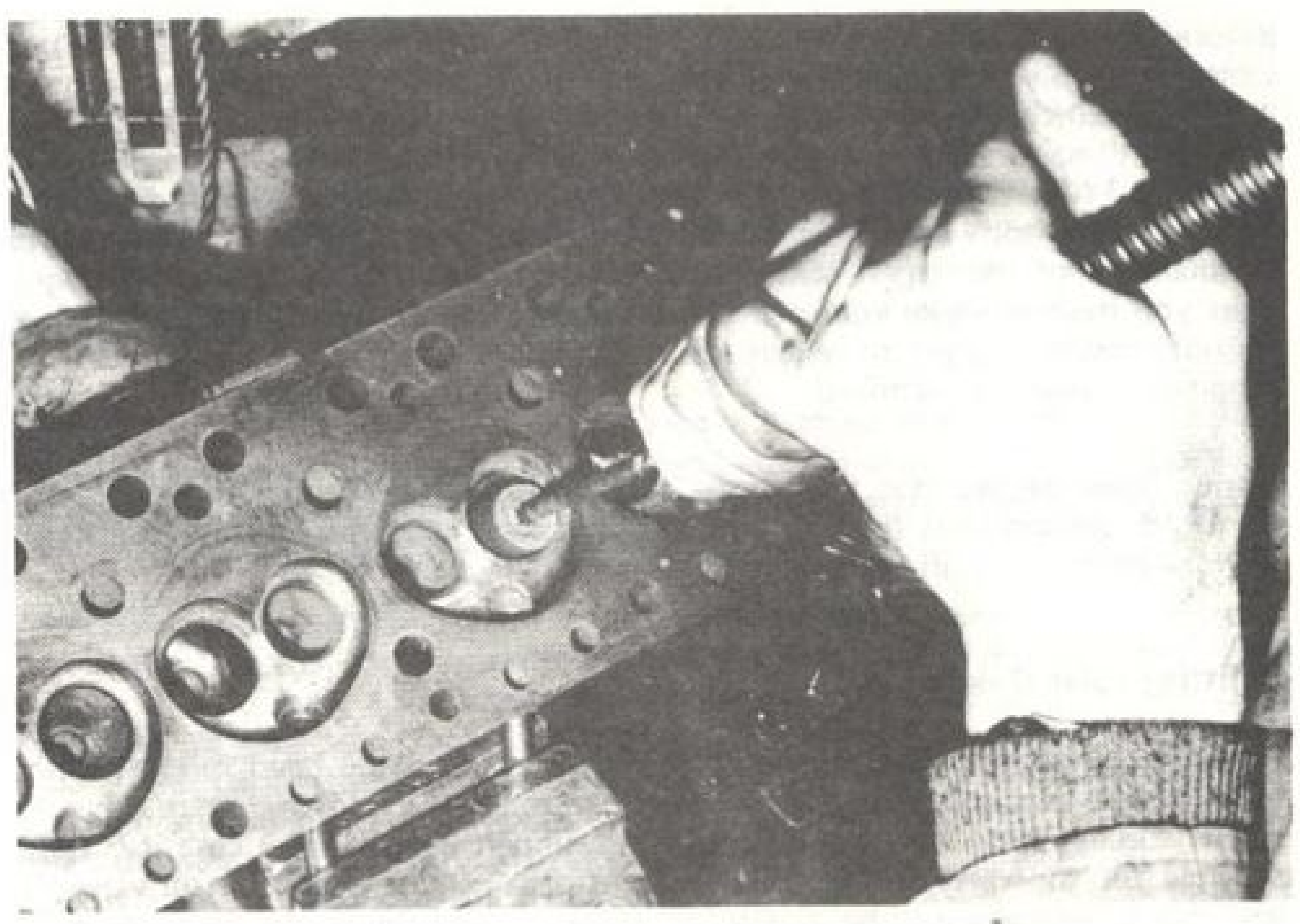
Similarly it will be obvious that if the paper is buckled up with the studs in place, when removed the paper will flatten and our mark will shift its position.

You may think that I have dwelt for a long time on a silly old piece of paper, but I cannot stress the importance enough. UNLESS you can GUARANTEE that any marks made on the paper at any one time can be repositioned with the paper on the head in EXACTLY the same position relative to the head you might just as well not bother to try matching the head and manifolds. Then keeping your piece of paper carefully pressed evenly down onto the head, gently trace the outline of the port entrance, with a grimy finger pressing onto the paper. Repeat for each port. This will leave a perfect black outline of each port entrance on the paper. The paper thus now becoming an exact picture of the head mating face complete with stud holes.

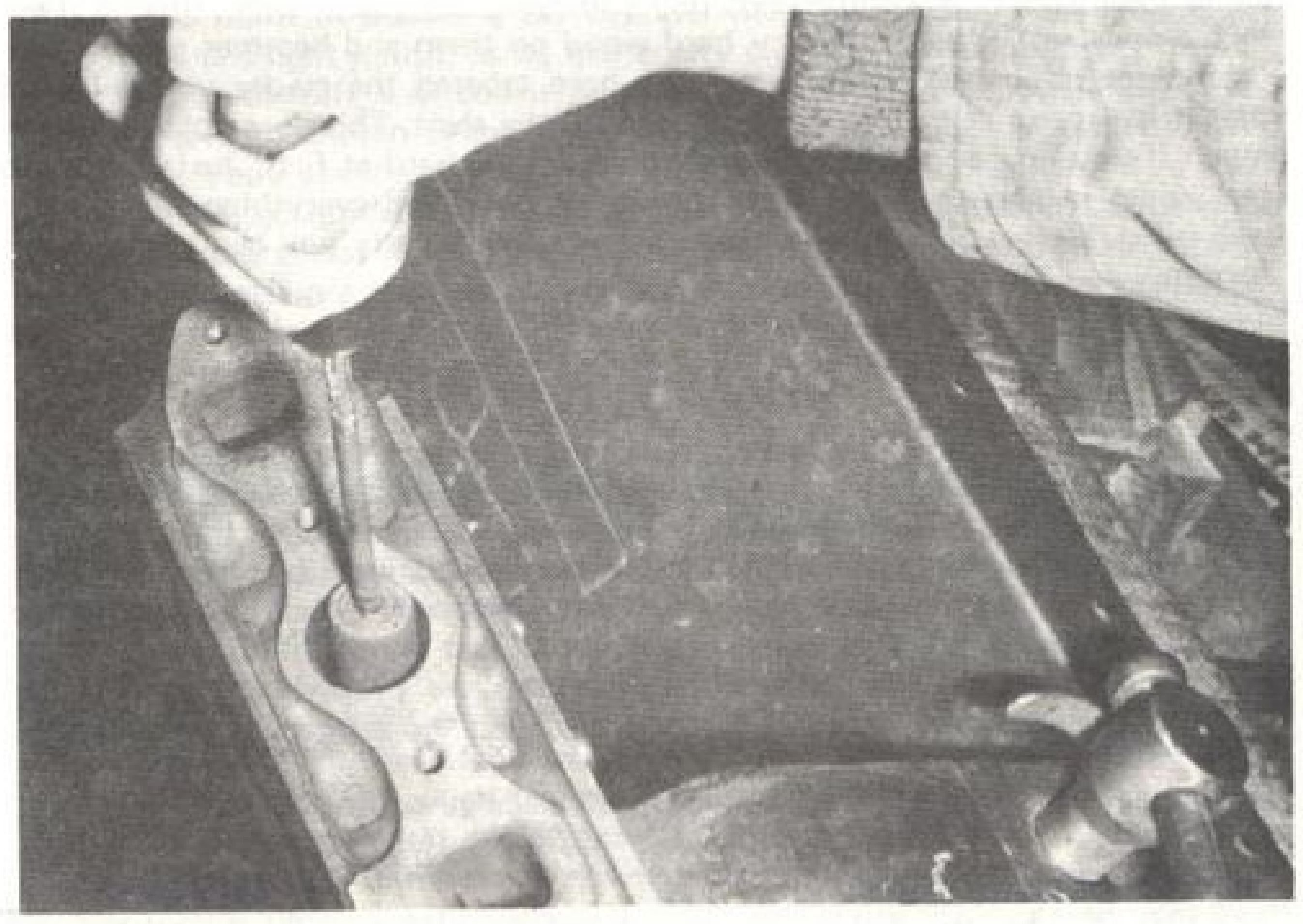
Carefully remove the paper from the head. (Take the studs out first or you will tear the paper). Using a pair of small, very sharp scissors, carefully cut out these holes following exactly the dark outline of the tracing of the port entrance. Then clamp the paper onto the manifold using suitable nuts, bolts and washers. Remember when doing this, that the paper must not be turned round, the manifold flange face should be adjacent to the opposite surface of the paper. Try and imagine the piece of paper in place of the manifold gasket. You should try and imagine that you were doing this with the whole lot bolted up together.

Usually you will find that in places the paper overhangs into the manifold hole, indicating that metal needs removing from the head in this region to open it out to the edge of the manifold. In other places you will see that the paper does not come to the edge of the manifold hole. Thus metal must be removed from the manifold in this region, till one reaches the edge of the paper.

Thus having removed metal in the appropriate places one should find that if the procedure of making up a paper template is repeated (often easier than re-cutting the old one) when the paper is clamped on the manifold the holes in the paper, line up with the holes in the manifold, and thus it will be obvious that on bolting the head and manifold together their trunks will form a smooth tube without any unevenness.



Polishing inlet valve throats



Polishing inlet ports

Before someone writes to shoot me down in flames by suggesting that one replaces the piece of paper with a normal manifold gasket, thereby saving the trouble of cutting the various holes—this is of course absolutely ideal but; these days many manufacturers use similar castings for different models (i.e. 850 Mini and M.G. 1100) which have ports on similar centres but on different diameters. Unfortunately both models usually use the same gasket, the holes being equal to the diameter of the largest M.G. 1100 but not so good if you have an 850 Mini. Thus you have to make your own template with holes the same size as the head. Do not however, forget to relieve the manifold gasket if it is found to be overhanging the ports or manifold.

Having thus carried out this most important job of aligning the ports and manifolds we can next finally polish the ports and valve throats, checking as we go for inaccuracies in our shaping and balancing of sizes as outlined earlier.

Refitting Valve Guides

Next fit the valve guides, carefully driving them into the head in exactly the right relative position and to the correct depth. It is, in fact, better to drive the guides too far into the head than not far enough. In the latter case it is quite possible for the valve spring collar to crush against the guide on full valve lift and this of course could be disastrous. Always insert the guides from the valve spring end. It is of course equally essential that the guides are driven into the head by equal amounts and this should be checked by laying a straight edge along their ends. To avoid excessively damaging the guides when driving them in I always rest a piece of very hard wood on them and hammer against this. One other important point. Since you have tapered the guides you will find that it is easy to put them into the head on the slant. This does not matter too much if you do not attempt to drive them in too hard at first. Just gently tap the guides in and they will align themselves providing everything is clean and well oiled. Having allowed a guide to align itself properly you can then drive it hard in.

Final Trimming

Next polish the combustion chambers. Then grind in the valves so as to make a good seat. Then assemble the valves into the head complete with springs. At this stage do not bevel off the upper edges of the chamber walls but do remove any frazes. It would of course be ideal if the corners were bevelled off before attempting to balance the chambers but I have found that this makes the accurate filling of the chambers with liquid almost impossible since the liquid merely tends to spill out before the chambers are properly filled, and this leads to even greater inaccuracies than bevelling the corners after balancing.

Also if at this stage you find that the seats need re-cutting now is the time to do so.

You may find to your alarm that the valves stick tight into the guides and will not slide through them. This is because our hammering operations have slightly

damaged the guide; belling the end over. Take a suitable round file, insert it into the guide at the valve spring end and turn it anti-clockwise several times, after every 3 or 4 times check to see whether the valve will slide freely. This may sound crude and rather brutal, but it is quite safe and your engine will suffer no ill effects. All you in fact do is reduce the valve to guide "bearing area" by about 1/64 to 1/32 in. When you find that the valve will slide in the guide reasonably freely give the inside of the guide, where you have filed, a few gentle rubs with fine wet and dry abrasive paper wrapped around a thin piece of rod.

Next after assembling the valves, balance the chambers as already detailed, removing any metal necessary from around the inlet valve or if necessary the exhaust valve. Do not take too much metal from the squish area or from around the spark plug. Work slowly and carefully.

After balancing the chambers and finally polishing you can bevel off the chamber wall corners at the junction with the cylinder head face. This bevelling is best done free hand using a small very fine file or metal scraper. Since you will only be removing very small amounts of metal it should be possible to get good accuracy in taking equal amounts from each chamber. Make sure when bevelling that you are not likely to cut back under the gasket. It is better not to bevel the edges than do this. Finish off with emery paper or cloth.

Polishing the Head Face

There is no point in polishing the cylinder head face, strictly speaking, but I always give it a light polish, using fine emery cloth on my rubber pad, mounted in the electric drill. It is of course quite easy to take too much metal off in one place and give an uneven cylinder head face which will cause the gasket to keep "blowing". Thus you must work carefully, do not try and polish just a small area at a time, go quickly all over the surface but at the same time buffing the whole surface and not missing any sections. Repeat several times and eventually the head will attain a fair polish. You will find it easier if you keep moving the drill itself as if it were a rag with which you were polishing. This will enable you to travel more freely over a large area at a time without missing large patches of metal.

You ask why I do this when it is not strictly necessary? Well, the squish area is effectively part of the combustion chamber, You polish the chambers to prevent excessive carbon deposits forming so you must polish the squish area which is part of the head face. The squish area is just as prone to coking up as the chamber itself!!

When working on the head face you may find that the holes which represent the water jackets have very rough frazes all around their circumference. These arise from the machining operations on the face and must be removed. The best way to remove them is to mount a countersink bit or small round stone in an ordinary carpenters' handbrace, and gently turning the stone or countersink in the hole. Do not remove more metal than is necessary to remove the frazes. This is why I suggest using a hand operated brace rather than an electric drill. If you take too much metal away the gasket will leak.

Re-assembling the Head

The assembly of the head should be perfectly straightforward and simple. However one most important point. **Clinical** cleanliness is absolutely essential and this ideally applies to any other engine assembly operations. I cannot stress this enough. One little bit of grit bedded under a valve can cause it to start to burn and destroy your carefully prepared seats. Dirt in the valve guides can cause a valve to seize, grit under the valve spring collar or collets can work on the stem and cause it to be cut into two, dropping the valve down into the engine. I could go on and on listing the disastrous results of a dirty assembly procedure, but space forbids.

How do we arrive at this cleanliness?

I always work on a steel-sheet-covered bench, swabbed down with paraffin and a clean cloth. This is then covered with clean newspapers which are renewed at frequent intervals as one goes. The head should be cleaned initially using paraffin and an old paint brush. This will remove or loosen grime, metal fillings, grease etc. Having removed or loosened the grease thus, one should then submerge the head in an old bath or bucket full of clean, hot, very soapy (use washing-up liquid) water and again worked on with the paint brush. You will probably find it necessary to renew the soapy water at least once. When the head seems reasonably clean hold it under a tap or hose and rinse, all the time rubbing the nooks and crannies of the head with one's paint brush to prevent grit particles lodging. Drain the water from the head, place on the clean newspapers and dry immediately with a perfectly clean dry cloth. Dry your polished areas quickly and thoroughly and immediately smear them with clean engine oil of the type used in **your** sump. Not only must you dry and grease the polished areas quickly but you must avoid putting the head in sunlight, otherwise before your very eyes a thin red coat of rust will form (you can actually watch it forming).

Clean all valves, springs, collars, collets etc. in clean paraffin, if necessary renewing the paraffin. Dry and smear with the same clean engine oil.

Throughout these operations your hands and finger nails must be spotlessly clean. It also helps to wear clean clothes. Dirt can easily rub off your overalls onto your nice clean head!

If you find that drying with a cloth leaves some fluff behind do not worry. When you apply the engine oil you will find that this can easily be wiped off with your bare fingers, In fact I always give a final clean up using engine oil and my fingers only.

Assemble the head, but do not yet fit the manifold. Store the head out of harm's way wrapped in **clean** newspapers or polythene sheet.

chapter 6

CARBURETTOR MODIFICATIONS

Having completed the cylinder head and gas flowed the manifolds, the next job is to carry out all carburetter modifications and matching with the manifold. When polishing the inside of a carburetter one can apply the same techniques as used with the cylinder head, but remember that most carbs are largely soft alloy and metal is very easily and quickly removed, so take care. If the intention is to enlarge the choke tube do not attempt this yourself. It must ideally be done by an experienced machinist using specialist tools; if you try hacking around free-hand you will probably finish up with one wrecked carburetter.

I suggest "knife edging" the butterfly and cutting off the retaining screws flush with the butterfly spindle. The knife edging is best carried out with a fine file and emery cloth. However I think that the best and safest method of cutting the screws so that they are flush with the spindles is as follows. You will usually find that these screws stick out beyond the spindle by about ¼ in. and this end is split and "belled out". This is to prevent the screws vibrating loose and falling into the choke tube and thence into the engine. Obviously if you simply cut these projections off you will remove the belling and this may cause disaster if a screw vibrates loose. The remedy? Do not cut the screws off. Use a screw driver and break them off by bending the split ends even further apart. This will leave a slight bell and prevent the screws dropping into the engine.

The carburetter and all gaskets and plates between it and the manifold flange can be matched to the manifold using simplified versions of the procedures outlined for the manifold head matching. If the carbs are fitted with trumpets or ducts on the air intake side do not forget to match these to the carburetter.

This brings us to the end of those operations likely to be carried out by the average enthusiast.

However, those people carrying out full race preparations or complete engine overhauls will probably carry out further modifications and improvements and for their information the following few observations may well be of use.

Lightening Valve Gear Pushrods

Needless to say if one is using special tubular pushrods their manufacture merely consists of fitting the necessary cups and balls into the required length of tube and either sweating them or brazing them into position. These cups and balls may be specialist machined or simply standard ends cut from standard push rods.

Most people however, merely lighten the standard push rods.

I find that the simplest method is to set my 2,000 r.p.m. drill up in the bench stand and mount my rubber disc/aluminium oxide abrasive in it. Then switch on and, rotating the push rod between one's fingers, hold it against the brasive disc. Finish off free-hand with emery cloth.

One word of warning. Do not remove metal from the necks of the push rods where the cups and balls merge into the main rod. If you do the rod may fracture at very high r.p.m. and cause untold damage. Personally I always buy several sets of rods at the local scrap yard for about 15p a set. Then if I do accidentally catch the necks on the push rods with the rotating disc I throw that rod away and use another. Do not be tempted to do otherwise. Even the lightest nick can cause breakage which can cause a completely wrecked engine. This is in fact a point well worth remembering. Unless you can quote a precedent which has proven reliable on any particular item **never** remove metal from a concave radius, though it is often quite safe to do so from a convex radius. On the other hand some concave radii are far too sharp and one should endeavour to increase the radius. Again the same statement is applicable in that one must not remove metal from the centre of the radius.

Remember one point however, when re-assembling the rocker gear (pedestals, shaft, etc.). There is a right and wrong way round, even though this may not appear to be so, usually there is a single oil feed hole in the cylinder head which lines up with a particular pedestal which in turn lines up with a hole in the rocker shaft. If these are not lined up there will be no oil flow and the valve gear will run dry. Under normal road conditions most standard or semi-standard engines will tolerate such conditions for about 10-15 minutes (if the rockers were assembled with oil painted on to them as they should be) and then seize up solid. So be careful!

Other Modifications

If one has fitted a more vigorous camshaft and or larger valves it may be necessary to cut slots in the piston crown or block face to give sufficient clearance to the valve on full lift. This can be awkward and though laborious work with small files and scrapers can cut the necessary slots there is a far simpler method though it does involve some expense.

One needs a flat cutter mounted on a rod of similar diameter to the valve stems. The rod should be inserted through the valve guide from the valve gear end. The cutter should be attached where the rod protrudes into the combustion chamber. Then mount the head on to the block. Put the piston at T.D.C. and then press the cutter down onto the block and piston and start turning. This will give a clean accurate valve pocket, though the pockets will have vertical sides and a sharp angle at their base. This angle should be increased and the sides carefully blended using fine hand files, scrapers and emery cloth, as shown in the diagram. I usually reckon that the cutter should make a pocket about 30 thous greater in diameter than the valve, my hand finishing operations being relied upon to give the final desired clearances around the valve. The bottom of the pocket can be blended into the sides using the small pad and emery disc previously mentioned

for use on combustion chamber roofs. Again I cut to a depth of about 20-30 thous greater than the point reached by the valve at full lift and again rely on my hand finishing to obtain the necessary 60-70 thous clearance. Remember to do all cutting with the head properly tightened down with the gasket in place, preferably an old, compressed, but similar gasket to the one you will be using.

You may ask just how can one measure the amount of metal which one needs to remove. Well several methods are commonly suggested including putting plasticine on top of the block and piston and then opening the valve to full lift by rotating the engine. My advice is to use the most laborious but in my opinion only really accurate method.

Careful measurement of the valve lift, and distance of valve from piston crown and block face when fully closed. Then applying addition and subtraction, calculating the amount of metal to be removed to give the necessary clearance. You will need a straight edge and a depth gauge to do this.

The final operation that I intend to enlarge upon involves countersinking all threaded holes in the block or cylinder head which are not already countersunk and which are situated where two flat metal faces join, usually with a gasket in between (e.g. cylinder head to block or sump to crank case). This is necessary since, the top thread often pulls up and creates a rough projection on the metal face, and this projection can cause inaccurate mating of the metal faces, blown gaskets, etc.

I therefore automatically countersink these holes, whether I can feel a rough edge or not since you can in fact pull a thread when carrying out final assembly and this is just as troublesome.

To do this I merely use a small ball shaped stone or metal cutter (preferably the latter) though of course a proper metal countersink is just as good (but why buy extra unnecessary equipment?). This cutter should be mounted in a simple carpenters brace and this set up applied to the hole.

I do not use an electric drill for this operation as I find that it is not always easy to hold steady and also it tends to cause the removal of too much metal which is just as dangerous as leaving a rough projection.

Summary

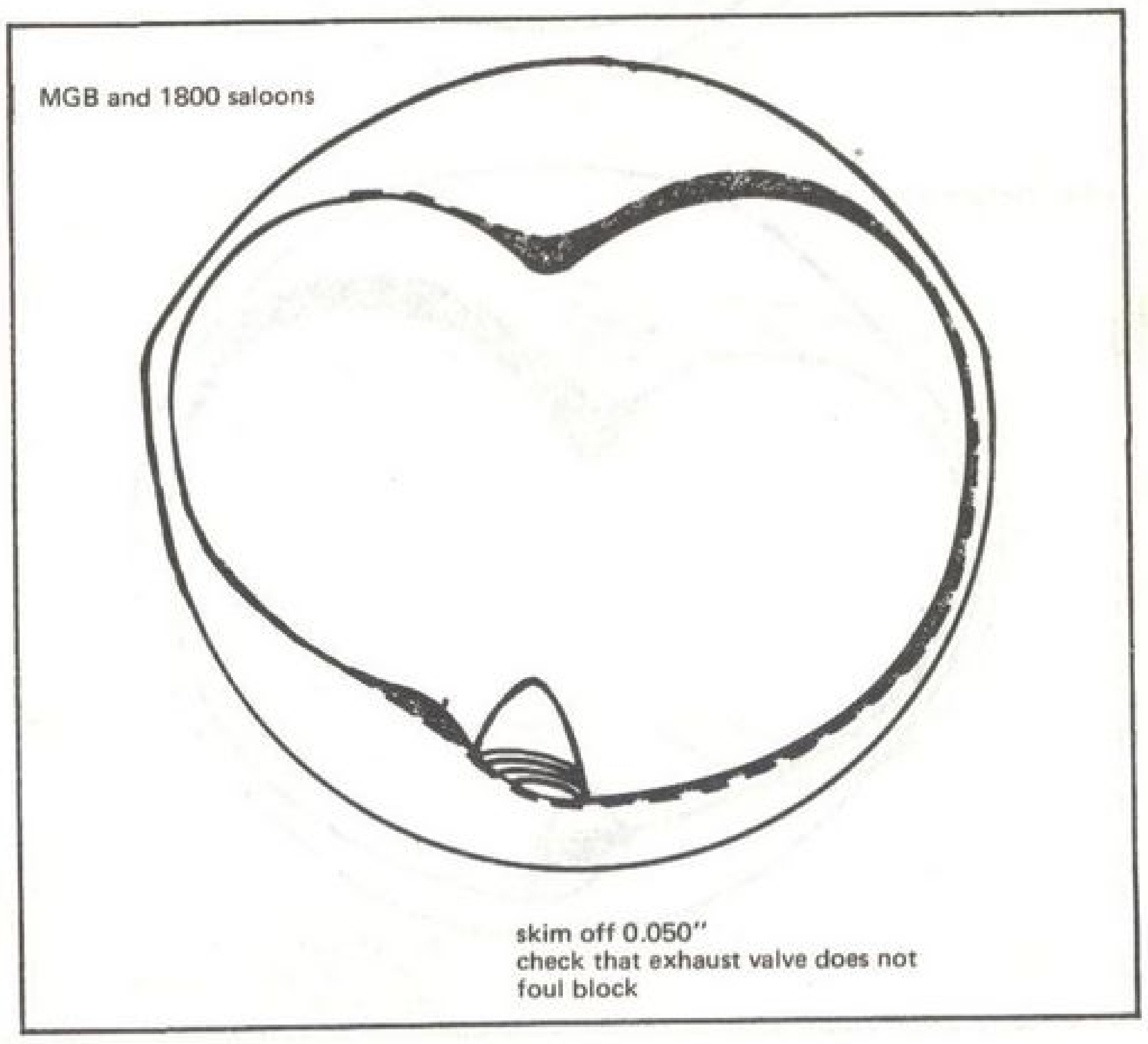
The techniques and principles mentioned in this book have been applied to specific operations and there are many other equally essential operations not mentioned.

On the other hand although the specific operations mentioned are of necessity somewhat limited numerically, the basic techniques and equipment necessary have been fully covered, excluding workshop practice as taught to your local garage mechanic and detailed in most workshop manuals, and other publications on Automobile Engineering.

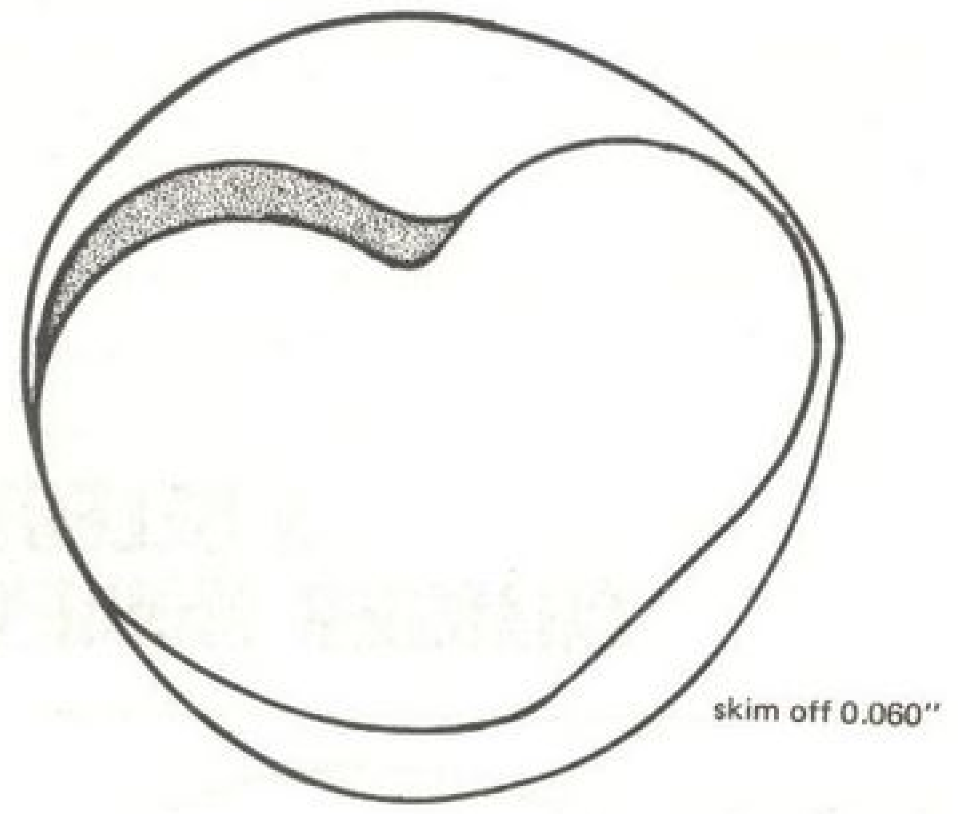
Commonsense should enable you to apply the methods set out by me to any other operations not covered. Do not think that my recommendations are Gospel. You may well and indeed probably will develop or discover far superior ways of doing things. I have merely attempted to put my own thoughts and observations on to paper in the hope that the rank newcomer to engine modifications may be able to gain some ideas and confidence in his own ability.

One final word of warning. Do not attempt to put this series into practice until you not only fully understand the workings of the internal combustion engine and all its components, but also fully appreciate the weaknesses, virtues and potentials of your own engine. The same way a scientist cannot carry out research "parrot fashion" from a textbook, nor can you hope to properly tune an engine without serious errors just following my suggestions. They are merely intended to direct and channel your thinking along the right lines.

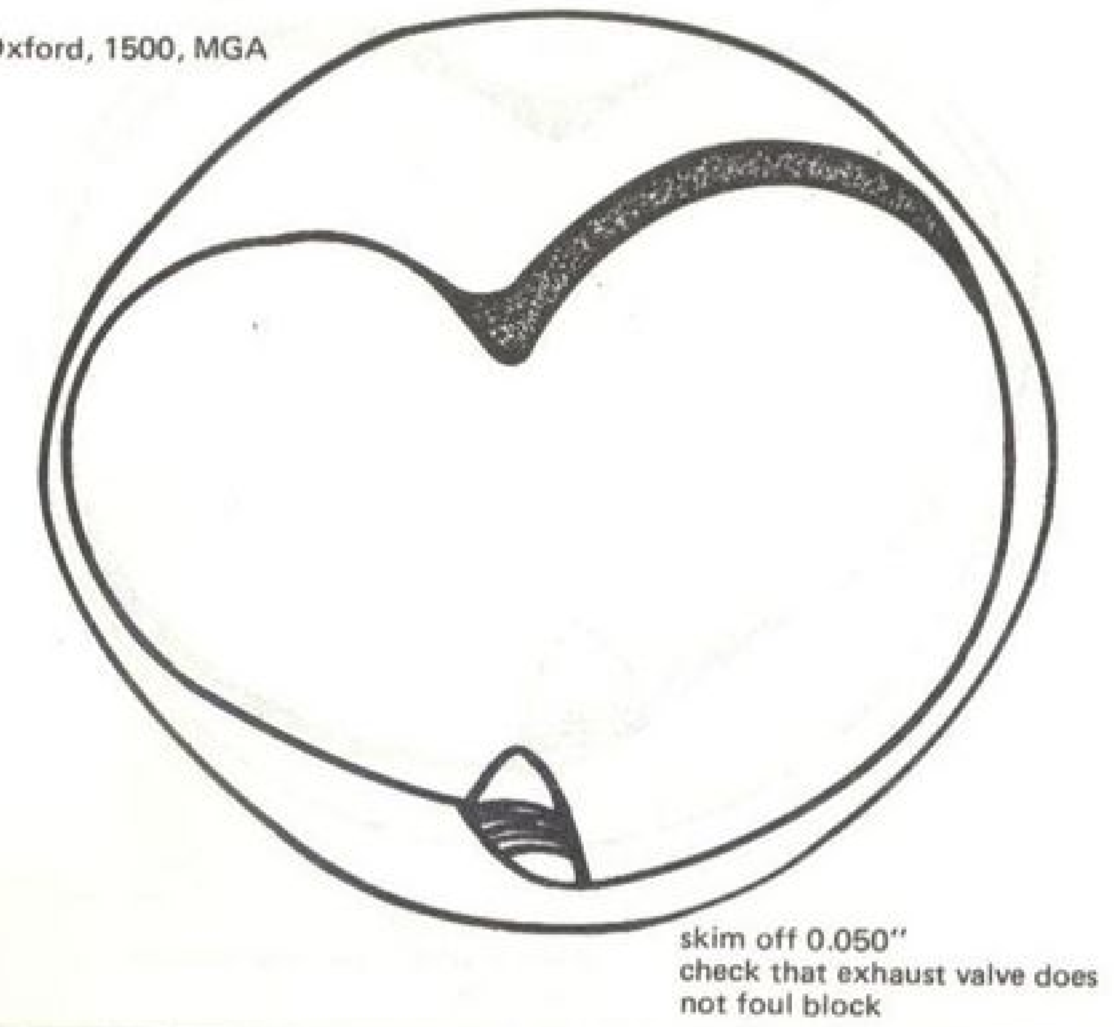
A SELECTION OF CHAMBER MODIFICATIONS



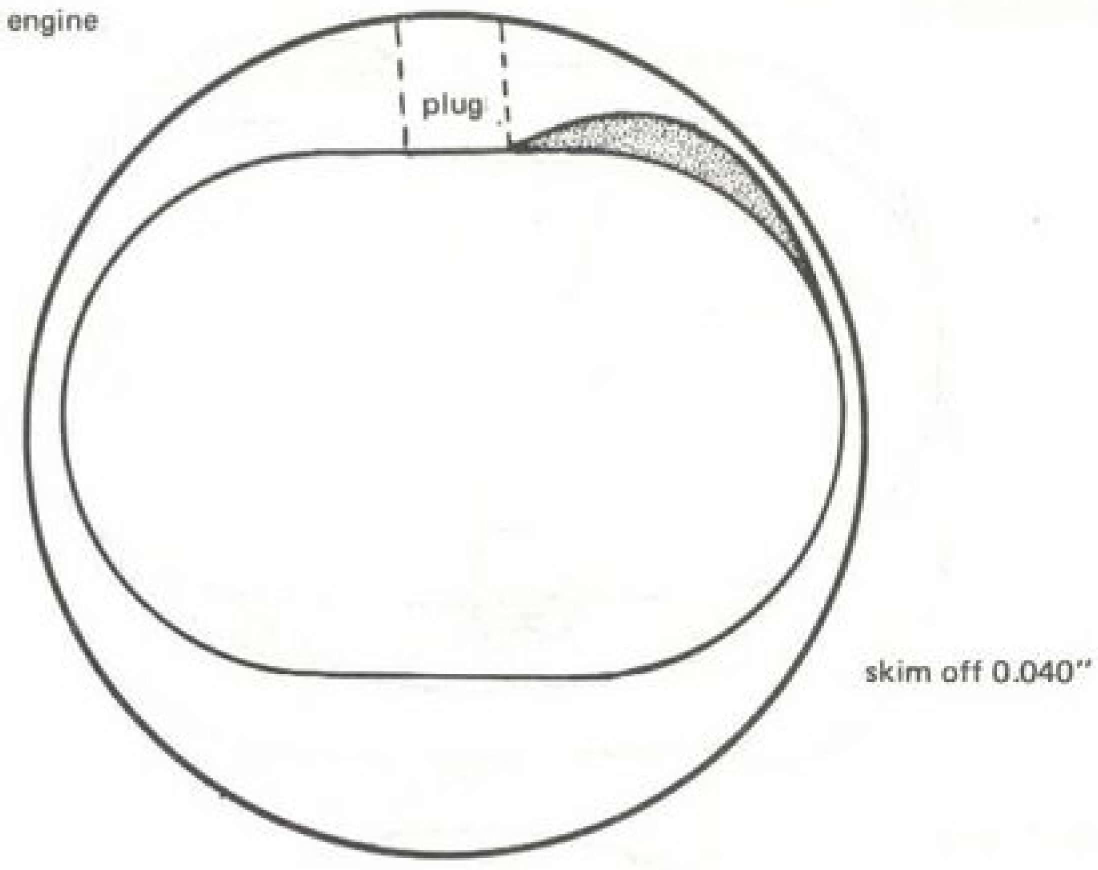
1100 Austin/Morris, A40 and Minor (1100 cc)



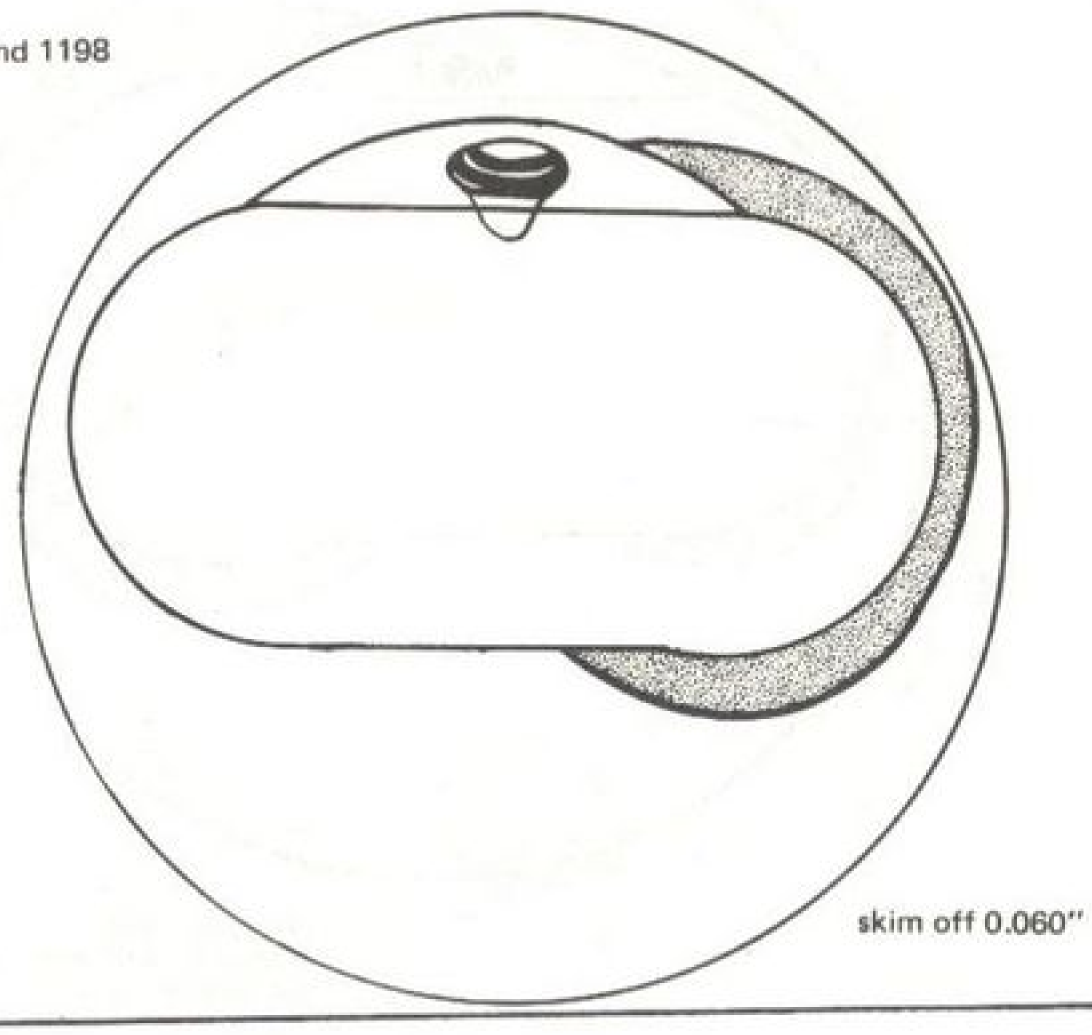
A55. Oxford, 1500, MGA



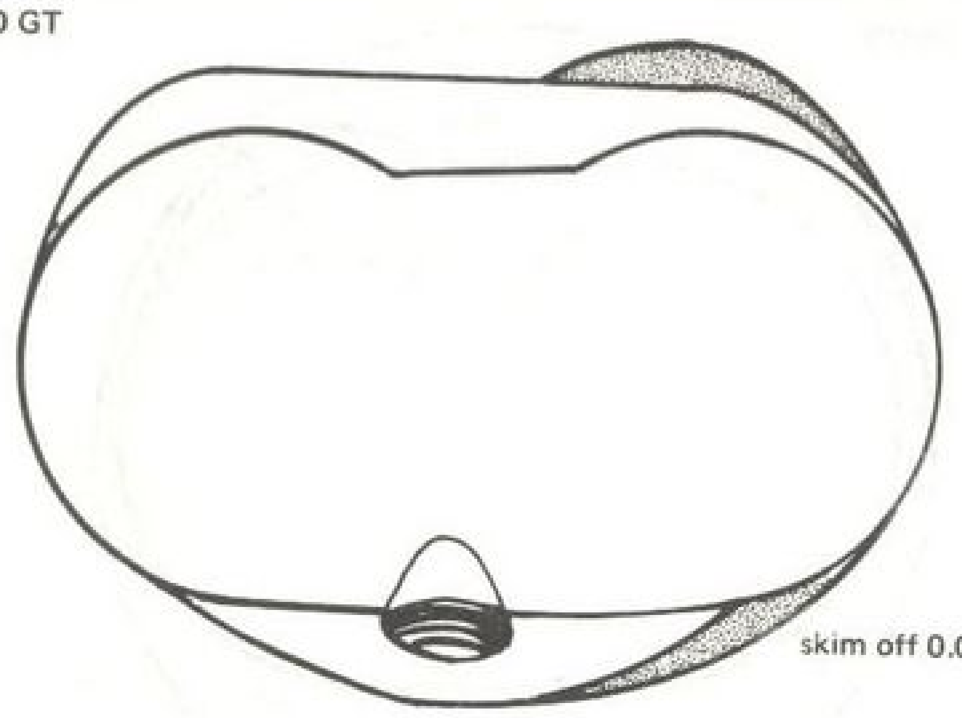
875cc Imp engine



Ford 997 and 1198

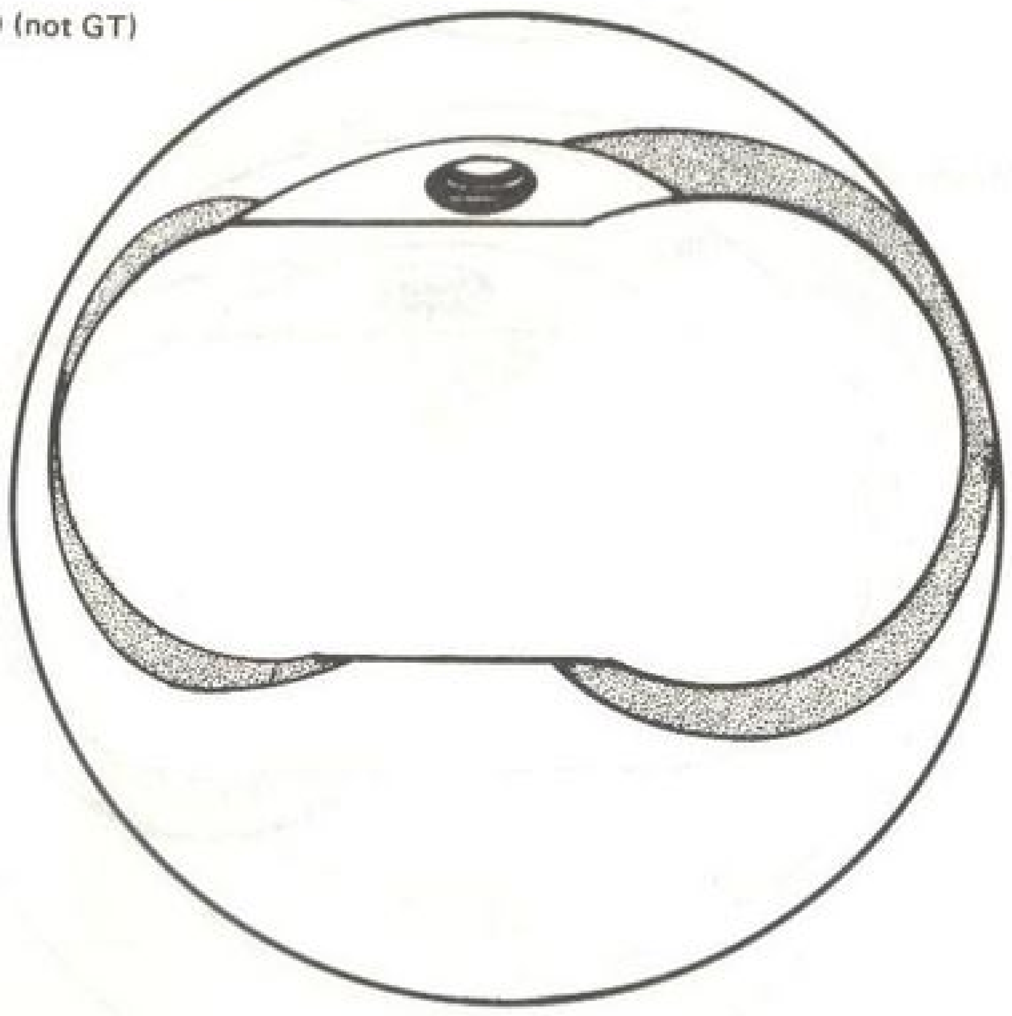


Ford 1500 GT



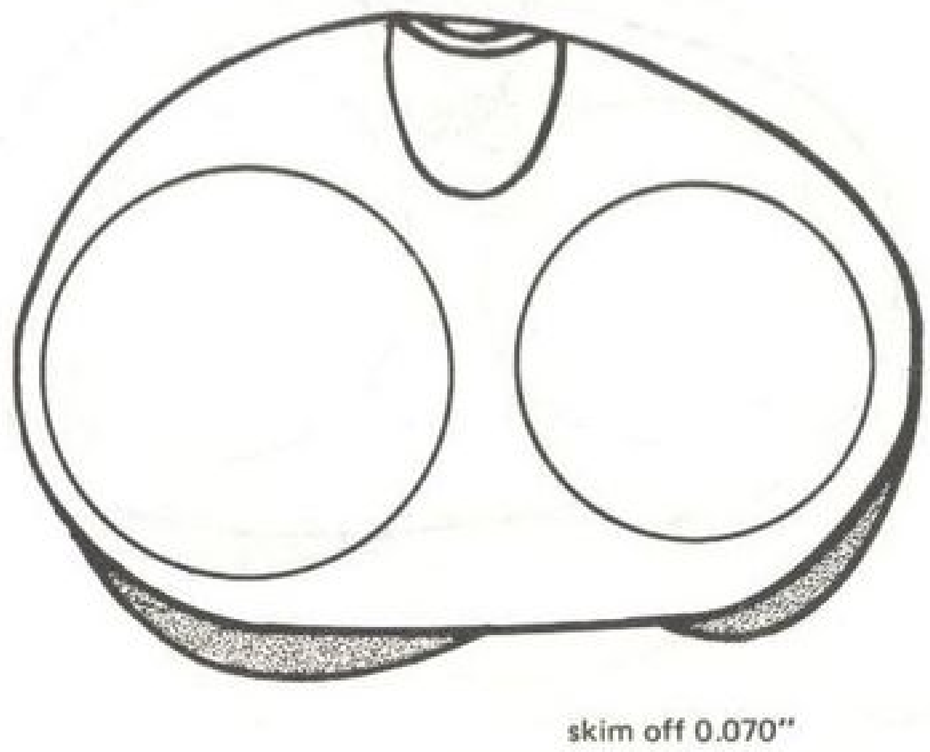
skim off 0.060"

Ford 1500 (not GT)



skim off 0.080"
similar to 105E only larger for
modified chamber

1300,1600 and 1500 Minx engine

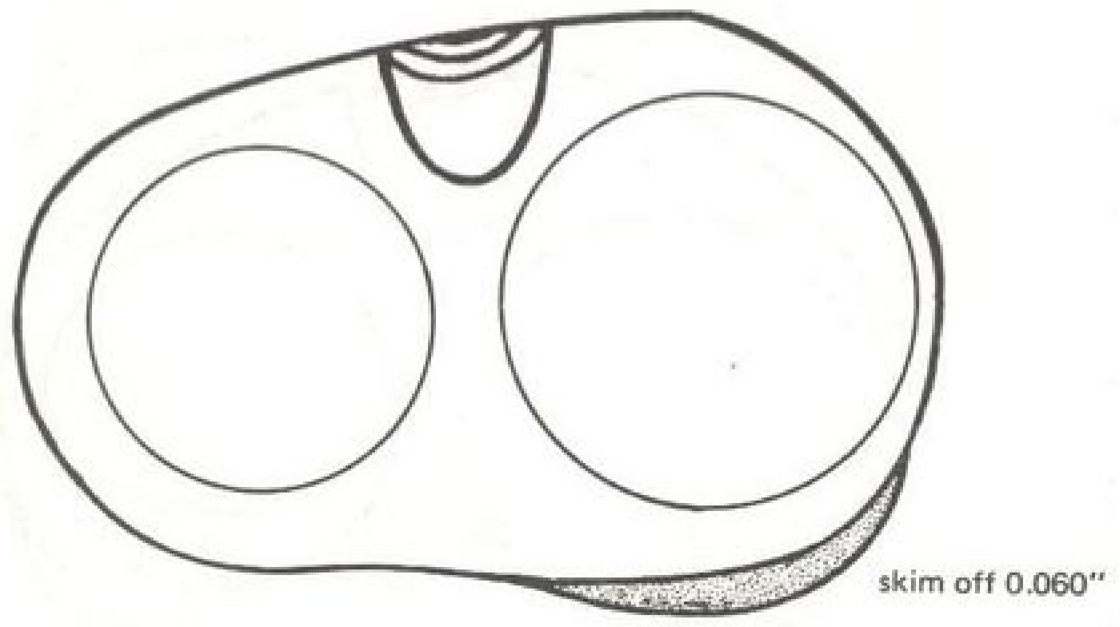


skim off 0.070"

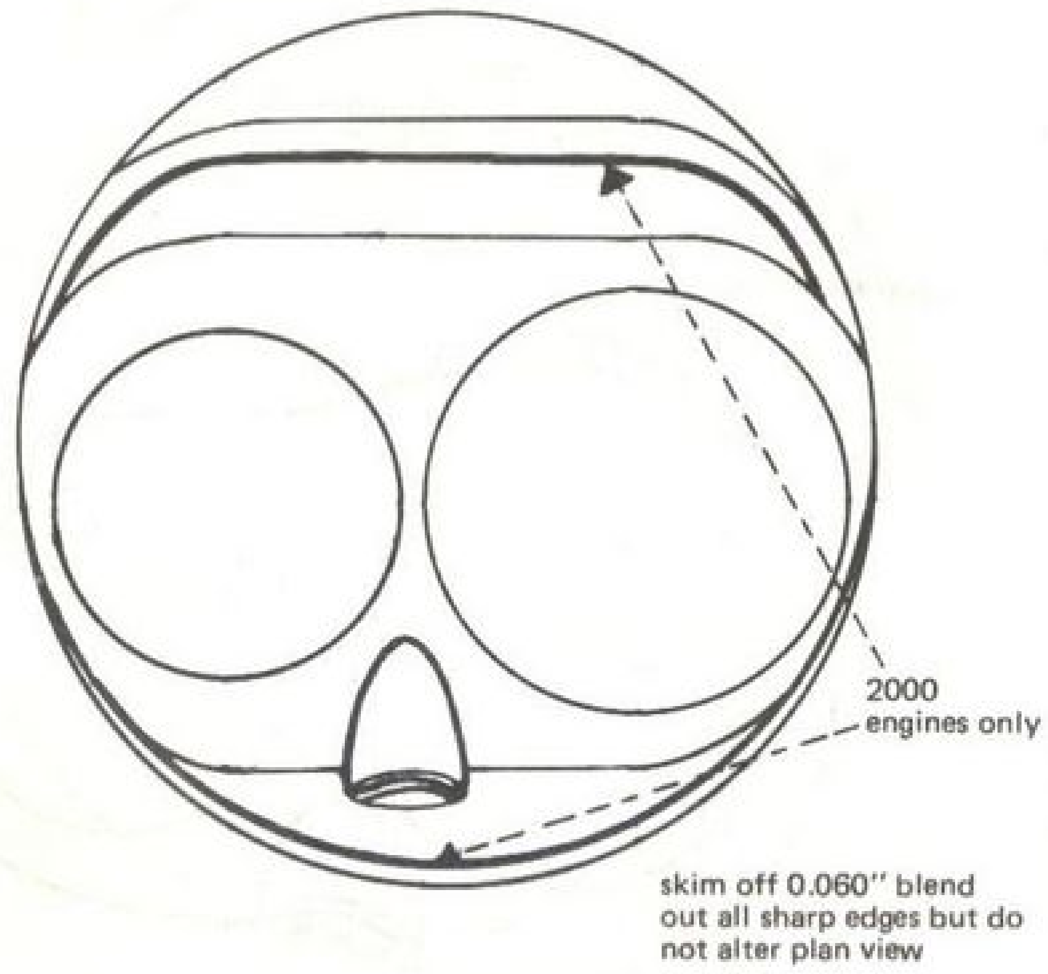
1500/1600 Rapier and Alpine

skim off 0.060"

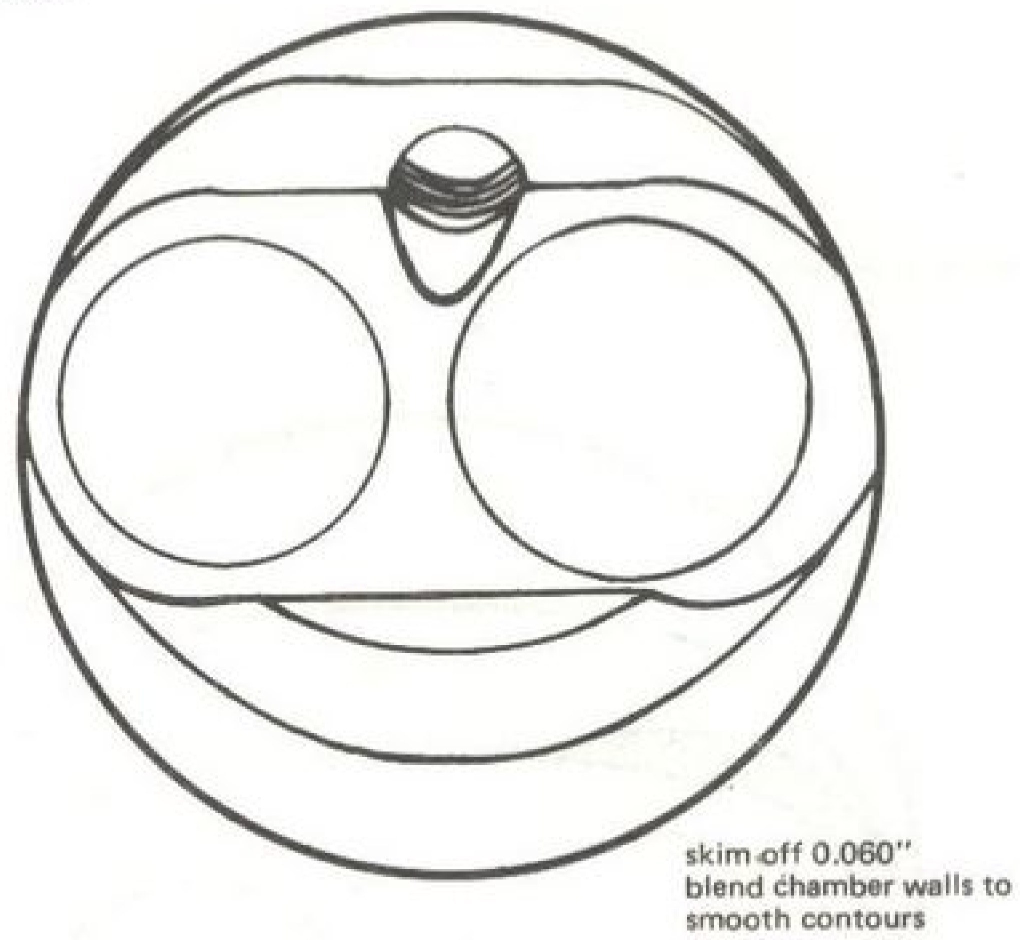
1725 Aluminium Rapier and Alpine



TR5, TR6, 2.5PI, and Mk 2 2 litre heads

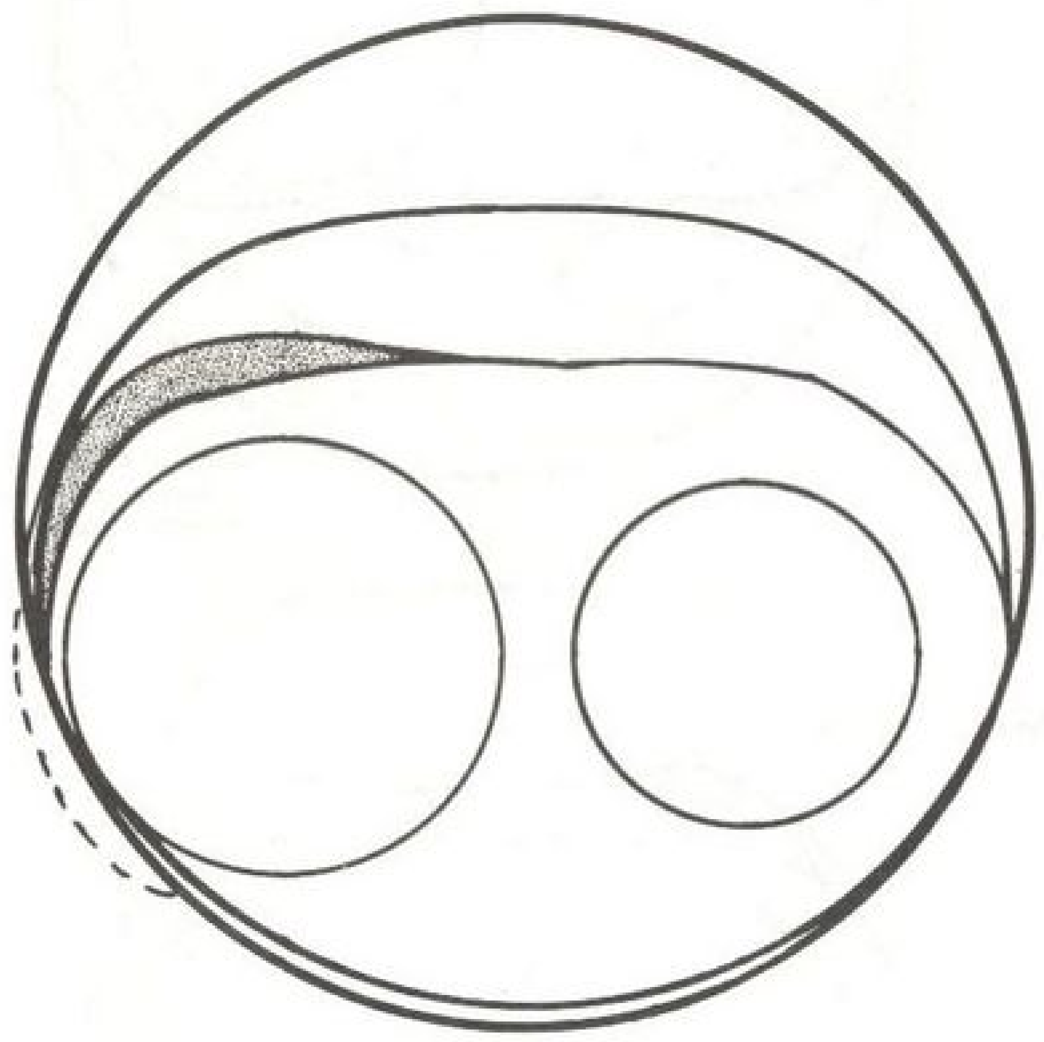


Triumph 2000 saloon



Herald, Spitfire 1200cc engines

TR2, 3, 4, and 4A engines



skim off 0.060"

Martyn Watkins formerly of the well known motoring enthusiast magazine 'Car & Car Conversions' really knows how to introduce the keen amateur to the fascinating subject of automobile tuning for road and track sports.

Together with the two companion books by the same author 'Tuning Engines and Transmissions' and 'Tuning Suspension and Brakes' this book is essential reading for anyone who wants to get more performance out of his motor car.

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