Going with the flow

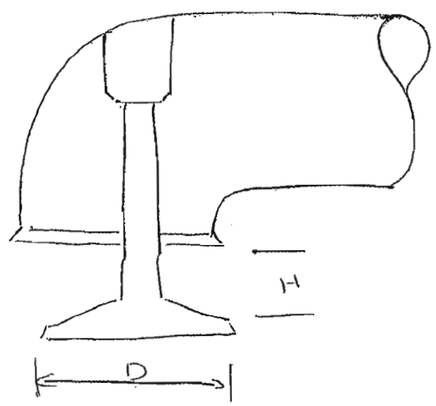
There used to be regular advert on TV for decongestion sweets, which reckoned they made you 'breathe more easily' and as such made you feel and hence go a bit better. The same could be said about engines, make them breathe easier and the better they'll go. **John Hutchings**, of Tollgate Classics, takes us through the procedure of giving a Bullet a clear head.

Photographs by Richard Goodwater
Illustrations by John Hutchings

Light shows a much improved flow.

Top: Selection of rotary burrs suitable for working with aluminium.

Many tuners believe that the inlet port should ideally be about 0.8 to 0.82 of valve diameter and the carburettor should be of similar size.



A valve flows gas not in proportion to its area but in proportion to its diameter and valve lift. The area the gas flows through is Pi DH, often called the curtain area. If a larger than standard valve is fitted in a standard port the effect is similar to using a cam with slightly faster acceleration and lift, although of course the timing stays the same. As a result a slightly wider power band may be achieved.

There are many reasons why someone might want to improve the performance of classic machinery. For sport, to keep up with modern traffic or just because they can. The changes can be dramatic. Such unlikely motorcycles as Norton's ES2, Matchless G80 and even BSA's C15 have been turned into competitive racers. The most dramatic transformation I've seen was a Lada Saloon. A few simple mods resulted in acceleration equal to a 2.5 BMW!

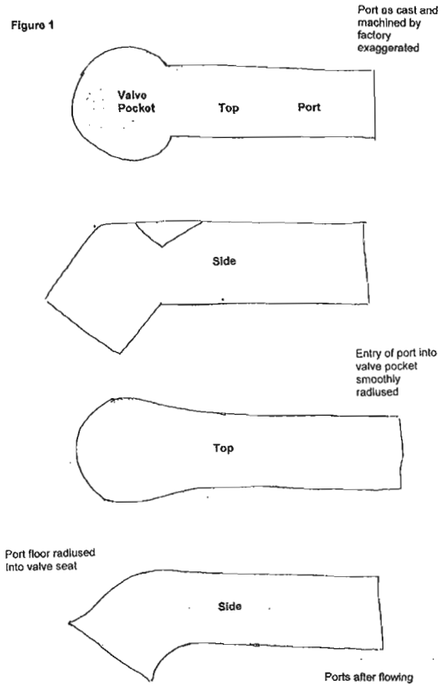
Decide what you want before you start on your engine. Mostly it won't be full race tune. A big single that is difficult to start, will not pull below 3000rpm and runs a four-speed box, is no pleasure and it will not be any quicker than a more tractable, moderately tuned bike. Often cleaning up the ports, tidying the valve seats and slightly increasing the compression ratio will produce a sufficiently satisfying performance increase.

Tractability

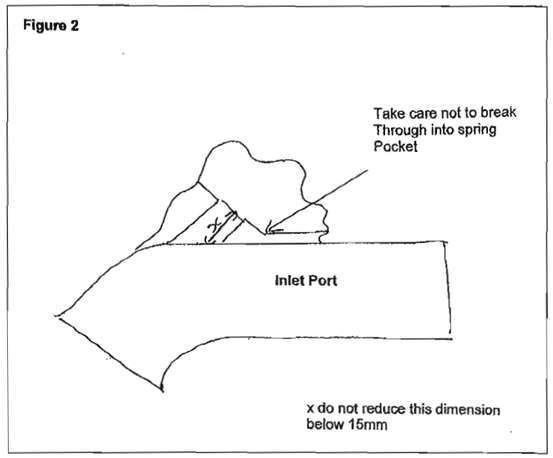
The valves found in most classic engines are of adequate size for road use, 1¾in is fine for 500 inlets, 1½in is plenty big enough in a 350 (or 650/750 twin) and most British engines have inlet valves around these sizes.

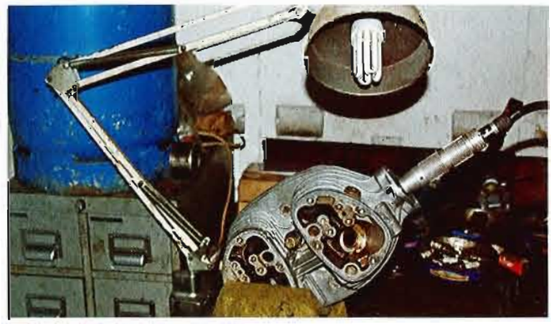
Engineers argue about the minimum size of exhaust valves. Some say 0.65 of inlet valve diameter, others 0.85. In most English engines the exhaust valve is 0.8 or more of the inlet diameter and is big enough. A big valve can quite easily be fitted to many models, such as a Gold Star inlet to a B33 but it won't make much difference. The greater curtain area may give a wider power band but that's all, unless you modify the port to suit, which is fine for racing but I would suggest a bit much for normal road use. (Figure 1A)

Many tuners believe that the inlet port should ideally be about 0.8 to 0.82 of valve diameter and the carburettor should be of similar size. The Clubman DBD conformed to this – 0.8 x 1.85in is 1.48in – the DBD has a 1½in carburettor. It is arguable that his formula gives the best possible performance from the engine but at the cost of tractability.



Many engines have ports which are cast and then have the valve pockets machined. This leaves the port rough and with many sharp edges. Simply smoothing these ports out will improve flow even if the basic size and shape remain the same. By contrast others are exquisitely smooth and well shaped but performance could be improved dramatically by increasing its size. I recently saw a head from a model 19 Norton that falls into this latter category. The head made by Wellworthy was a beautiful piece of work and any race shop would have been proud of the porting except that they were so small. The inlet was made to match an 1 1/16" carb, tiny for a 600cc single. The bike would certainly be quicker with say a 32mm carb and a port to match. The owner did not want to make his Norton faster though. No sense of fun with some people.





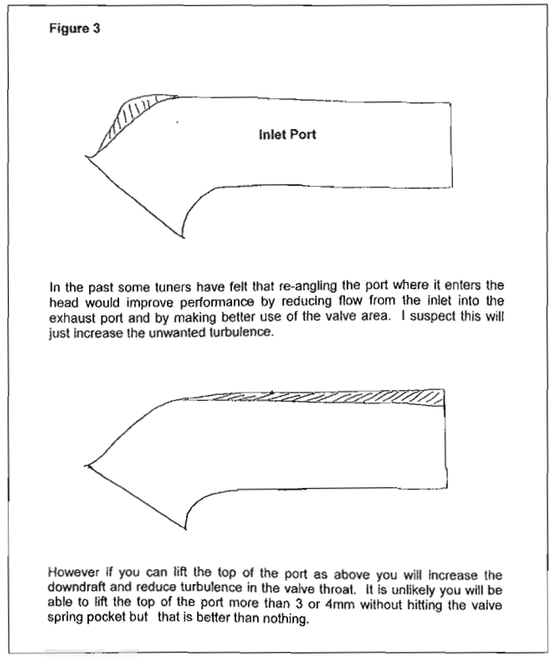
Hold the head in the vice and get plenty of light down that port.

Be careful not to cut into a stud hole as this would give a very weak mixture.

The tractability is lost because of low gas speed in the inlet port at the revs most road riders use. Gas speed is important for two reasons. Firstly, gas speed through the carburettor generates the vacuum to pick up and atomise the fuel. Doubling the area of the port halves the gas speed and if I remember Bernoulli's theorem correctly, because vacuum is proportional to the square of the speed, it's reduced to a quarter of the original figure, which naturally upsets carburation.

Second and perhaps more important, the inlet valve does not close on most classic engines until 60 to 80 degrees after BDC. The inertia of the gas in the inlet port pushes gas into the cylinder despite the piston rising on the compression stroke. If the gas speed is reduced the gas will have a tendency to be pushed back out of the inlet port at low revs and cylinder filling will be much reduced. This is why some engines have long inlet tracts, it is to enhance inertial or ram charging. Most English engines are long stroke with long con-rods. The geometry of this arrangement causes the piston to move slowly away from TDC on the induction stroke so that in effect the engine has a long slow pull at the inlet port. This favours smallish ports and carburettors (and also long duration cams). By contrast short stroke pistons move quickly and favour large carburettors.

So what does all this mean when applied to your cylinder head? For starters, be conservative. You can cut more metal out later if you want more revs. It's more difficult to put it back! For a road going 500 single I would recommend sticking with the standard valve and using a 30mm (1⅛in) carburettor. For a 350 use 26mm (1¼in) you can go to 32mm/28mm but you'll notice a drop in bottom end power. Cut the port as straight and parallel as possible from the carburettor to the valve guide. (You can put a slight taper in the carburettor and if you want to try different size carburettors.) The valve guide is an obstruction in the port. To compensate, flair the port out into the valve pocket to keep the port equal in cross section to the main part of the port, a little bigger if this can be done smoothly. Blend in and smooth any round edges, bumps and lumps in the casting. (Figures 1 & 2) If there are hollows left from the casting don't compromise the shape by



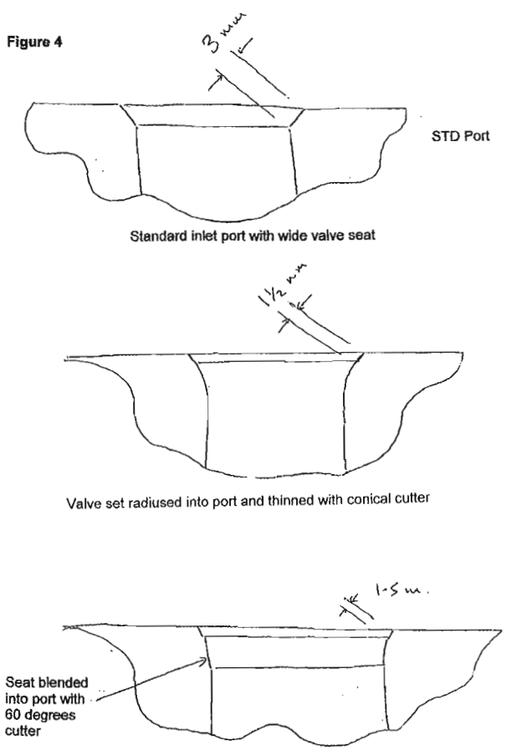
In the past some tuners have felt that re-angling the port where it enters the head would improve performance by reducing flow from the inlet into the exhaust port and by making better use of the valve area. I suspect this will just increase the unwanted turbulence.

However if you can lift the top of the port as above you will increase the downdraft and reduce turbulence in the valve throat. It is unlikely you will be able to lift the top of the port more than 3 or 4mm without hitting the valve spring pocket but that is better than nothing.

The Dremel professional is supported at high level to assist with the ergonomics of the flexible drive.

Inlet before porting.

Figure 4



For road purposes the machine cut port will work as well as the hand reduced item. For the ultimate racing item multi angle ports can be used. It is worth just breaking the edge of the 45 degrees seat with a 30 degrees cutter. 10 thou will do.

trying to cut them out. They will not usually cause any problems left as they are. You can cut away the support for the inlet guide so long as you leave a minimum of 15mm. Be careful not to cut into the valve spring pocket as this will result in a dramatic increase in oil consumption and a truly spectacular amount of smoke. Also be careful not to cut into a stud hole as this would give a very weak mixture. If you are making a large increase in port size try to tilt the port upward to improve down draught as this will increase the effective area of the valve. (Figure 3)

Speaking of down draughting, in the past, tuners such as Paul Dunstal and Phil Irving have recommended cutting back the valve pocket to give a down draught effect. I have the greatest doubts about this. Theoretically, at high revs the gas in the inlet port will be moving at 400-500mph at the middle of the induction stroke. In reality, it will be travelling slower than this because air is an elastic medium, but it will be moving pretty quickly. I can't see that gas molecules at that sort of speed will meekly follow such a shape. They are much more likely to bounce around like lottery balls causing lots of turbulence. So leave the shape as it is, just clean it up.

However, it's worth putting a gentle radius on the bottom of the port where it turns into the valve seat. It's also worth thinning the valve seat and reducing it into the port or have a machine shop cut a three angle seat for you. Many heads have inlet valve seats 3mm or 4mm wide. The seat can be cut to 1.5mm wide with the port reduced into the valve seat. Gas flow at low lifts will improve and at the same time the effective diameter of the valve increases by 3-5mm, improving flow at high lift. (Figure 4)

The inlet port requires careful attention to detail as atmospheric pressure pushes the air into the cylinder. A depression of a few PSI will mean having to coax the air to go where we want. By contrast the exhaust gases are under considerable pressure when the exhaust valve opens and so long as their progress is unimpeded they will make good their escape.

As already established, the valve is of adequate size and ideally the port should match the area of the valve throat. Remove any obvious obstruction and radius the exit from the valve pocket into the port, but in doing so do not undermine support for the seat or materially reduce the support for the guide. Both of these components have to transfer a lot of heat away from the port into the head casting and reducing their heat path can easily result in burnt or sticking valves. Likewise, don't reduce the width of the valve seat as it takes much of the heat from the head of the exhaust valve. (Figure 5). This component can run red hot and needs all the help it can to dump that heat. The port should not be cut to match the size of the exhaust pipe where it exits. A step here is useful. It does not impede gas flow into the exhaust but does help limit backflow of gas at low revs.

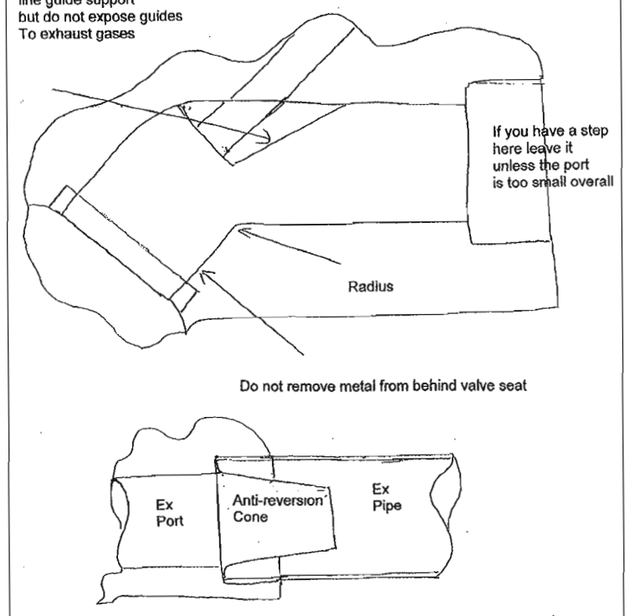
So much for theory, let's look at the practice. First the tools. You will need a slim grinder with a flexible drive capable of 20,000rpm plus, or a slim pneumatic die grinder, either capable of taking a 6mm/¼in shank. A standard Dremmel will not take big enough tools nor does it have enough power. A flexible drive in an electric drill is too slow; it will bounce over the work making an accurate job impossible. I use a Dremmel Professional with a foot control. Carbide cutters are best, they will cut aluminium, cast iron and even hardened valve seats. They are quite expensive at £20 to £30 each but they last. The flame and conical shapes are most useful and are available from any good engineering merchants.

Don't grind aluminium, it will simply clog the grind stone. Cast iron can be ground but make sure that the stones are rated for the speed of the tool. Cheap stones can shatter and a face full of Carborundum is not recommendable. Don't forget the safety glasses, ear defenders are a good idea too.

Paraffin

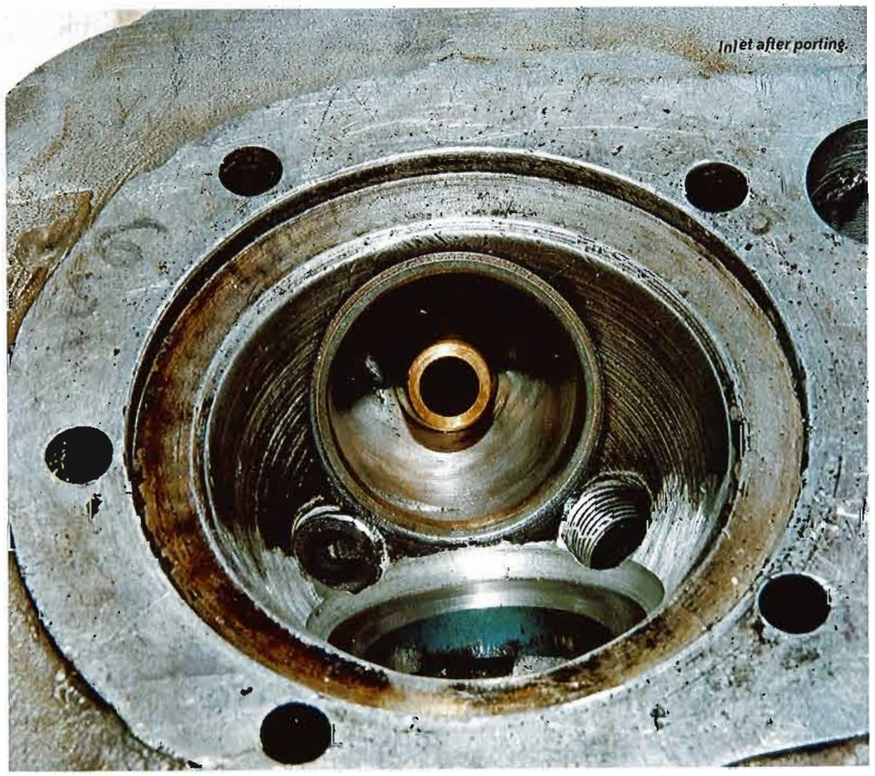
A vice is necessary to hold the work and a lamp to light the inside of the port. For some heads, like Imp and Indian 350 Bullet, an industrial radial arm drill is useful. It's unlikely you'll have one of these so woo someone in an engineering company if you want to work with one of these heads. The best cutting fluid for aluminium is paraffin. Cast iron doesn't require cutting fluid as it contains carbon, which acts as a lubricant. If you

Figure 5



At low revs, particularly on engines with a lot of overlap on the cams it is possible for exhaust gas to flow back into the engine contaminating the fresh charge. This will reduce power and may even cause the engine to misfire. At high revs the inertia of the exhaust gas prevents this from happening. Leaving a step here will help reduce backflow and hence help widen the power band. For some engines anti reversion cones are available to enhance this effect although I have to say that I've found they have little effect of big Bullets.

You will need a slim grinder with a flexible drive capable of 20,000rpm plus, or a slim pneumatic die grinder, either capable of taking a 6mm/¼in shank. A standard Dremmel will not take big enough tools nor does it have enough power.



Inlet after porting.

Above: Porting around the valve seat.

> ***Having dealt with the carburettor end, turn the head over and flair the port into the valve pocket with a smooth radius and radius the bottom of the port into the valve seat. Then smooth the valve pocket and blend it into the valve seat.***

are cutting a lot of cast iron be prepared to get very dirty. It is a good idea to wear a mask when grinding cast, because you'll end up as black on the inside as on the outside. Not very healthy.

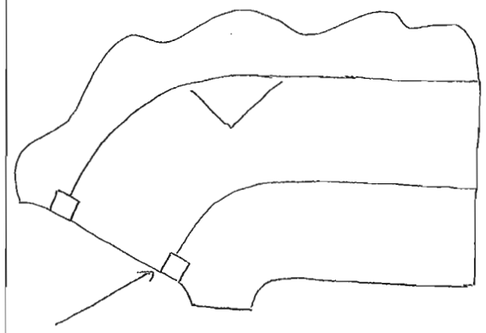
Since I am working on one at the moment, I'll use a 350 Indian Bullet head to show how it works in practice.

The Indian 350 head has a long, narrow inlet port, the work can be done with cutters but it's easier to remove the mass of metal by drilling out the port with a radial arm drill. For normal road use, a 28mm drill is ideal. For road racing or a 450cc conversion, it is possible to use 30mm. Once drilled, taper the carburettor end of the port slightly so that either a 26 or 28mm carburettor can be used without having to line them up on the studs.

This does produce a slight step, but this does not materially affect performance. If I were trying to exploit resonant tuning I would produce a seamless join but for road use resonance is a nuisance. It can boost power over a narrow range but will reduce it elsewhere. The mismatch will tend to disrupt the resonance if anything and help create a smooth torque curve. Road cams are not usually fierce enough for effective resonant tuning anyway.

Having dealt with the carburettor end, turn the head over and flair the port into the valve pocket with a smooth radius and radius the bottom of the port into the valve seat. Then smooth the valve pocket and blend it into the valve seat. (Figure 6) Quite often the valve seat is proud of the pocket and will disrupt the flow at a critical part of the port

Figure 6



Valve seat can sit proud of port and needs to be blended in or it will disrupt flow into the cylinders.

unless it is cut back. If the seat is good I will then narrow it to 1.5mm and radius it into the port with the taper cutter. If the seat needs refacing it is recut and subsequently narrowed with a 60-degrees cutter on a Serdi head machine. Finally for the inlet port is to smooth out all the cutter marks with a 25mm flap wheel. As with the cutter it is best to use a light circular motion with these as they are quite capable of producing a pronounced hollow in the work.

Ragged

The exhaust port is quite big but does have some obstructions that are best removed. The first is above the valve seat at the bottom of the port. There is usually a ragged ridge here that can usefully be cut back a little and radiused into the port.

There is a ridge on the left of the port where it meets the valve pocket. This can also be radiused into the port. The port can be cut away either side of the valve guide boss to give a sort of heart shape and the boss reduced in depth behind the guide. However, for reliability's sake, do not expose more of the guide. For the same reasons do not narrow the valve seat, on some Indian heads as it is a bit narrow anyway.

That's pretty much it for the exhaust port and for the head. You now have a gas flowed head that will perk up your Bullet no end when used with a few other mods. Most British heads are a variation on a theme and will respond to similar treatment although the big drill techniques should perhaps be used with caution.