

# GENERAL ENGINE TUNING GUIDE

**By David Baker**

This guide is intended to give a broad idea of the sort of power increases one can realistically expect to get from normal tuning modifications. Of course there will always be engines which break the rules in some area or another but in the absence of a specific tuning article on a particular engine this guide will give you an idea of what to expect. It is applicable to road and fast road engines only. Race engines are too specialised a subject for a general guide like this to be of much use. The percentage power increase figures shown are the distilled results of feed back from hundreds of power curves reported back to me over the years from customers and colleagues. They represent what you see in the real world from different tuning mods as compared with the usually much higher claims from the firms trying to sell you the parts.

## CAMSHAFTS

The power claims from performance cam manufacturers pretty much beggar belief at times. I have a catalogue from one of them in front of me now which for the 1.9 Peugeot 205 Gti engine claims 20 bhp for the fast road cam and 30 bhp for the road/rally cam. The Peugeot engine already has one of the hottest cams of any standard engine which is partly how Peugeot achieved 128 bhp out of only a 1.9 litre 8 valve in the first place and to improve on the standard item to any great degree without losing all semblance of tractability is not easy. I find it hard to believe that even the most naive 205 Gti owner would credit 30 bhp (23%) just from changing the cam. Presumably this cam manufacturer thinks that car owners are considerably more naive than I do. Why these ridiculous power claims? Because in a small marketplace like the UK it's the company that shouts the loudest, claims the most power, spends the most on glossy adverts in the comics that will win sales. What the product actually does is almost irrelevant. How many people test the power increase under scientific conditions and then sue for misrepresentation? None of course. They just have a good moan about getting ripped off and don't go back - but by that time your money is in their bank and that's what counts. I remember the adverts claiming 25 bhp several years ago for a "brand new, state of the art" CVH RS turbo cam. One of the magazines tested it and got 7 bhp more at the wheels. Did the 25 bhp claims immediately stop? Of course not - that would have hurt sales. In fact the claims for the latest revision of this cam are even higher. I suspect that if you tried to pin a cam company down in writing before buying that you'd get your money back if you didn't achieve the claimed power they'd say something along the lines of "ah, you can get the power increases we mention but only in conjunction with other mods" - what like a big valve head and twin Webers maybe - hmmm.

So where is the line between fact and fiction really drawn? An average road car has a standard cam with usually around 255 to 265 degrees duration. It depends of course on whether it's a family runaround or a sporty model. To a fair extent you can grade performance cams by their duration although valve lift is also very important. The first grade of performance road cam is usually around the 270/275 degree duration mark with up to 10% more lift than standard. It should be worth about 4% to 7% extra power with some loss of tractability under 1500 rpm. It'll

be described as either a "mild road cam" or a "fast road cam" probably. The milder the standard cam the greater the potential increase of course. With a really good standard cam like the Peugeot above you are struggling to get even 4%. The Kent CVH22 for example is representative of a fast road type cam.

The next step up in road cams is those with durations in the high 270s to high 280s degrees region and should have up to 20% more lift than standard. Ideally these cams want to be used with cylinder heads modified to flow well at these higher valve lifts. Putting them into a standard engine is often a recipe for losing bottom end power without getting as much as you were hoping for at the top end of the rpm range. This high end of this duration band is about as hot as you want to go in a road engine or bottom end power will suffer too much. You'll see these described as either "fast road" or "road rally" type cams. Power increase is usually between 8% at the lower end of this duration band to perhaps 12% at the higher end with a fair loss of tractability under 2,000 to 2,500 rpm. If the increase in lift is much less than about 20% over standard then the power increase won't be so high. The Kent CVH33 is a good example of a road/rally type cam with decent lift.

Use a bit of common sense here ok. If the standard cam is really mild (like in a 1960's Mini engine or Rover V8) then you might see a bit more of an increase than the figures above. If the standard cam is fairly wild then of course you'll see less. You aren't going to see 20% plus from a road cam on a modern engine under any circumstances whatever the adverts say. If you get 10% from a cam at the high end of the road driveable duration band you've done well.

High lift cams work best with cylinder heads that flow well at high lift - hopefully that much should be obvious. If the head is standard and flow peaks at say 400 thou valve lift then using a cam with 450 thou lift isn't going to make the head flow any more air although you'll gain some power from the extra duration. If the head is modified to flow better at high lift then this same cam will work much better. So to put a single percentage power increase on a specific cam is not really possible. It depends on what has been done to the rest of the engine. A cam might only be worth say 4% extra power on a standard engine but give 6% increase if a well modified head and decent carburation has already been fitted.

People seem to agonize for ages about which cam to choose. Is company A's fast road cam better than company B's? If the lift and duration are similar then the performance will be similar too. There is no way of making a cam perform in a significantly different way than its lift and duration will indicate (ok the lobe centreline angle is important but beyond the scope of a simple introduction like this). Of course the "buzzword" changes every few years in an effort to make it appear as though some radical new breakthrough in design has been made. We've seen assymmetric cams, high torque grinds, high acceleration grinds and no doubt the marketing men are already working on the next bit of nonsense. It won't change the way the cams work though. In fact most of the profiles used on modern camshafts were actually developed over 30 years ago and just get copied from engine to engine - very little design work is done these days because it costs too much. It's easier and cheaper just to copy someone else's cam profile.

When trying to choose between cams go for the highest lift you can find without exceeding the duration that will give you the tractability you are after. The longer the cam duration the more

low end power you will sacrifice and choosing too hot a cam for road use can soon end up proving to be a mistake. For cars that need to be used every day or in heavy traffic then stick to profiles with less than about 275 degrees duration. Light cars, like kit cars and sevens, or purely fun cars can stand more duration and having mappable ignition and fueling will add low down torque which means you can get away with a hotter cam than might otherwise be the case. Finally, I find it very irritating that performance cams aren't usually properly ground so that they time in at the recommended setting on the standard pulleys. This is done quite deliberately to make you buy an adjustable pulley too. There is absolutely no reason why a cam ground on a new blank can't have the lobes in exactly the correct position with respect to the standard keyways to ensure perfect timing. I suggest that everyone write to the manufacturer before they buy a cam to ask if it is guaranteed to time in properly with the standard pulleys and if not then why not. Flood the buggers with letters and emails and maybe they'll decide it's easier to do it right than keep answering the queries. And don't get fobbed off with any excuses like the blanks don't have enough material in the right places or whatever - I design and make cams from time to time and there is no valid reason at all not to get it right. You don't expect standard cams to be ground at random so why should performance ones be.

## **EXHAUST SYSTEMS**

20 to 30 years ago the car manufacturers weren't particular concerned with engine efficiency or getting very high power per litre. The easy way to make an car faster was just to put a bigger engine in it. Fuel was cheap, company car tax was low and it cost less to make a bigger engine than to do a lot of development work on a smaller one. As fuel prices started to bite and car tax bands made it a good idea to buy cars with smaller engines the pressure grew to increase engine efficiency. People wanted 1800cc engines to stay in a low tax bracket but didn't want to lose performance over the 2 litre car they used to drive. One of the areas where these older engines lost power was in the exhaust system. They tended to have cast iron manifolds with only single outlets and small diameter systems. The easiest way to make a system quiet is just to use very small pipework inside the silencer that strangles the flow even if it kills the power and fuel economy too. Nowadays manufacturers can't afford to throw away any spare power or fuel economy and modern exhaust systems are highly efficient "straight through" systems that silence due to good design and exhaust boxes properly packed with sound absorbent materials. Manifolds are still usually cast iron for durability but with longer runners and twin outlets that then lead into a long twin tubular downpipe. In essence it's a productionised version of the tubular 4-2-1 performance manifold.

So with old cars like Capris and Minis it was quite easy to add a good few bhp with a better exhaust system. Single outlet cast iron exhaust manifolds could be swapped for welded tubular systems and strangulated exhaust boxes got thrown away in favour of noisier but better flowing straight through ones. Nowadays there is hardly any power to be gained so the performance exhaust system industry has changed into one primarily of fashion rather than power. Twin tailpipes, 5 inch tailpipes, chrome tailpipes - it's all about looks and image rather than power. If your car looks as though it can go fast that's as important it seems nowadays as if it really can go fast although what the point of all that is continues to escape me. I want my own car to look standard so it doesn't attract the attention of police or insurance companies and go like stink

when I nail the throttle. Having something that looks like a touring car and goes like a milk float seems awfully perverse or maybe I'm just getting old.

So that's pretty much the story with modern engines. Non standard exhaust systems on an otherwise standard engine generally do very little - a few percent extra bhp at most. Several years ago one of the comics did a group test on 8 or so performance systems for our old friend above, the Peugeot 205 Gti. Every system cost at least twice as much as the standard one and the BEST of them gave 1 bhp LESS than standard. By the time an engine is really highly modified with say a big valve head and long duration cam then the standard exhaust system might be getting a bit restrictive and a few percent power might be gained from changing it. On a standard engine though in most cases you're pretty much just a fashion victim if you change the standard pipework.

Beware also of magazine tests that don't use a brand new standard system in a back to back test with a performance system. Because that costs money they usually just test the car as it comes for the "before" power run. If the standard system is already 5 years old, nearly rusted away and with silencer boxes clogged full of carbon then of course the performance system shows a gain - but so would a brand new standard system.

Big bore systems can even hurt power quite a lot, especially at low rpm. I've fallen into that trap myself in my younger days. The OE manufacturers spend millions of pounds and several years in testing and development on their engines. The "performance" exhaust system manufacturers weld a few bits of tube together and spend a couple of grand on advertising. Who do you think has the best chance of getting it right?

## **AIR FILTERS**

Pretty much the same story as with exhaust systems these days. On older cars with carburetors the air filter box was usually a round plastic thing with a tiny snorkel tube for the engine to breathe through. This silenced induction noise very nicely but also strangled the engine. The filter itself wasn't the problem, it was the box it sat in that caused the restriction. Throw the box away and fit a K&N and a good few bhp was easily found. On modern fuel injection engines the induction systems are much better designed because the manufacturers can't afford to waste any available power. In my experience the filters themselves, which are usually flat square items, cause no restriction at all as long as they are new and clean. Replacing them with a "high performance" filter does absolutely nothing for power output. There is sometimes a bit of power to be found by enlarging the inlet tube in the bottom of the filter box or drilling a couple of extra 1" holes in the box. It's usually only a couple of percent at most though and hardly enough to even be felt in terms of extra performance.

The performance systems which replace the entire standard filter box with a tube and cone type filter achieve much the same thing as drilling a couple of holes in the standard box but for lots more money. You are unlikely to see more than a couple of percent extra power from these and very often they upset the standard fueling so much that power and economy in fact drop. To get any gain it's often necessary to spend even more money on a rolling road session to get the fuel mixture tinkered around with to restore it to optimum and often this is only partially successful

and you end up with poor starting, shunting and stalling in traffic and other irritating habits if it isn't done right.

Once again beware of magazine tests where the standard filter element isn't a brand new one in a back to back test or the results will be meaningless.

## **CYLINDER HEADS**

The items discussed above can be bought by quoting a part number and will be the same wherever you buy them from. All you really have to worry about is the price. When you buy a modified cylinder head you'll get a different item from each company you buy from. As far as flow gain and power gain you are in the lap of the gods, or more precisely that of the person who worked the head and how well he did it. It's perfectly possible to buy a modified head that loses you power and even more likely to buy one that gives some increase at high rpm but spoils low rpm tractability. The poor quality of most modified heads is what has made bolt on parts (air filters, exhausts and the like) so popular. You won't get much power increase from them but at least they are quick to fit and you know exactly what you are buying. So sadly, most people never get to experience just how much a really properly modified head can transform an engine. The important things to get right are valve seat profiles and port shapes - polishing ports and chambers does nothing for power and single angle valve seats are a disaster in flow terms. So what sort of power increases are possible with proper development work?

### **Standard valve heads**

Most heads are capable of being modified for a 15% power increase without increasing valve size. Some heads, like the CVH, have even more potential and 20% is not unusual. I've never had a head on the flowbench that couldn't be worked to achieve at least a 10% gain on the standard valve sizes. It makes little difference whether the head is 2 valve or 4 valve, modern or old, motorbike or car. The constraints of production line engineering mean that port shapes, valve seats and valve shapes can never be totally optimized for flow without some human intervention and hand porting. Castings come out slightly different each time and in any case engine designers have many other factors to consider than just power. They need to consider ease of manufacturing, emissions, fuel economy, cost and a variety of other constraints that work against maximising flow and power potential.

Properly done with due consideration for port sizes and valve seat profiles, a modified head will increase power throughout the rpm range. Low and mid range torque increase significantly as well as peak power.

### **Big valve heads**

A ported big valve head should show a further power increase over a modified standard valve head as a consequence of the increase in valve area. It is the inlet valve that we are really concerned with here - fitting larger exhaust valves only leads to a very small increase in power. It is not always possible to get a flow increase that's exactly in proportion to the increase in valve area but it is normal to get at least 75% of that with development work. So fitting inlet valves

with 10% more area should enable at least 7% or 8% more flow and power. Most types of cylinder head have room for 10% bigger valves although a few engines, like the Peugeot 205, are tight for space and you can't quite get the 10% extra valve area in. In contrast, the 8 valve Golf Gti head has room for bigger valves than standard but you can't open up the ports to enable these to work properly without breaking into a waterway. But many heads can have even bigger valves fitted. The CVH for example, on selected castings, can usefully run 45mm inlet valves instead of the standard 42mm items - a 15% increase in valve area. The Ford Pinto can go larger still. 46mm valves in place of the standard 42mm ones can be fitted without difficulty and some race engines use even larger valves than that. Most 4 valve heads can run 2mm larger valves than standard for an increase in area of 12% or so.

So if we add the power gain from extra valve area to that obtainable from porting modifications we see that a properly modified big valve head can easily show power gains of 20% to 35% over standard with 25% being a good average. To work properly and make full use of their extra flow it is best to use big valve heads with high lift cams although they still work fine with standard cams or normal fast road ones. A good engine builder will choose items that work well together as a package.

### **Fun on the rollers**

A friend, Garry, phoned me up last week (May 2001) to relate a story of a recent trip to a rolling road which illustrates nicely the benefits of a properly modified cylinder head. He lives near Aberdeen where up till now there have only been two local rolling roads to choose from. One about 30 miles west of the city and one about 15 miles south. A new one has just started up in business closer to the city centre and coincided with Garry needing a tuning session having just fitted DCOEs in place of the standard single carb. He also wanted to see how the power figures on these rollers compared with the other two for which he has plenty of data. In the end it turned out that the new rollers read about a fair bit lower than the other two local ones but that isn't really relevant to the story. Someone else also wanted a tune up and in the end three cars went along. All three cars were Fiestas with seemingly identical 1600 CVH engines with standard bottom ends, performance exhausts, ported standard valve heads, Kent CVH33 cams on double valve springs and DCOEs. Two of the cars had my own flow bench developed ported heads and the third person had ported the head himself as best he could to save money. The two cars with flow bench developed heads showed flywheel bhp of 130 and 131 respectively. The one with the home ported head made 112 which is about what you'd expect from just the cam and carbs anyway so I suspect the home porting had achieved very little if anything in the way of extra power. If you rate a standard engine at about 94 bhp then this last engine showed 18 bhp increase and the other two about 36 to 37 bhp - exactly twice as much (or looked at another way a further 17% increase over a home ported head). In other words the properly ported heads were worth as much horsepower as all the other mods put together. In terms of power per pound spent that might give you some food for thought.

## INDUCTION SYSTEMS

There are so many designs of standard carburetor or injection system that it is impossible to list all the permutations of power gain that are possible from replacing one type with another. We'll look at two representative examples which give an idea of the power gains available.

### Twin DCOE Webers

These are usually used to replace a standard twin choke downdraft carb such as those fitted to Pinto, CVH and many other types of engine. Expect about 10% increase in power.

### 4 butterfly throttle body systems

The fuel injection equivalent of the DCOE, these are usually used to replace a standard single or twin butterfly plenum injection system. Expect at least 10% increase in power as an average with up to 15% or even a tad more on some engines. It all depends on how restrictive the standard system is of course. The Vauxhall 2 litre XE engine for example is particularly responsive to having throttle bodies fitted and you can expect to see about 180 bhp instead of the standard 150 bhp (20% extra power) with just these and a decent exhaust system in a Westfield or similar. Claims of well over 200 bhp with just throttle bodies on this engine abound though and you can make your own minds up about those now.

I'm often asked how much extra power a 4 butterfly TB system gives over DCOEs. Usually around 5% in terms of peak power but there are more benefits than just this. Using really big carbs, or big chokes, to get the best peak power leads to poor low rpm operation and high fuel consumption. TBs can be sized for best power and still give excellent economy and good low rpm torque.

## SUMMARY

This is a general guide so of course there will be engines that don't fit into the above rules. In most cases though it'll give you a realistic guide to what is possible on a modern engine and what isn't. The table below summarizes the information above.

TUNING ITEM	EXPECTED POWER GAIN
MILD ROAD/FAST ROAD CAM	4% TO 7%
ROAD/RALLY CAM	8% TO 12%
EXHAUST SYSTEM	0% TO 5%
AIR FILTER	NIL
CONE FILTER TYPE INDUCTION SYSTEM	0% TO 3%
FLOW BENCH DEVELOPED STANDARD VALVE HEAD	10% TO 20%
FLOW BENCH DEVELOPED BIG VALVE HEAD	20% TO 35%
DCOEs REPLACING SINGLE CARB	10%
THROTTLE BODIES REPLACING PLENUM INJECTION	10% TO 15%